Item No. 540
Cathodic Protection

Notes to Specifier:

Delete these notes and parts that are not applicable.

Where options are given, make appropriate selection and delete the other option, fill in all blanks.

Verify all references to paragraphs within this specification and to any applicable Sections, standards or other specified sources of information.

540.1 Description

Section includes:

A. Requirements for cathodic protection systems on steel, ductile iron and concrete cylinder pipe. The cathodic protection systems can be either sacrificial, impressed current or both.

B. Electrical isolation of the pipelines from adjacent metallic structures, steel reinforced concrete structures, structures with dissimilar metal or coatings, conduits and all other metallic components that may impact the operation of the cathodic protection system.

C. Electrical bonding of non-insulated, non-welded pipe joints and mechanical joints.

D. Installation of rectifiers, anode wells, and all other Work described herein and on the Drawings.

E. Removal and disposal of existing rectifiers, anode junction boxes, vent pipe risers and associated items described herein and on the Drawings.

F. Provision of electrical power for rectifiers including any permits, trenching, conduits, services meters and other items required. Not all required items are shown on the Drawings.

G. Installation of galvanic (sacrificial) anodes.

H. Testing of system during installation.

I. Cleanup and restoration of work site.

J. Testing of system after installation and backfill (Final System Checkout).

Related Specification: Item No. 530 High-Performance Coatings

540.2 Performance Requirements

A. If the products installed as part of this Section are found to be defective, damaged or not in conformance with the Specifications then the products and Work shall be corrected at the Contractor’s expense.

B. Any retesting required due to inadequate installation or defective materials shall be paid for by the Contractor.

C. The Work requires coordination of assembly, installation and testing between the Contractor and Owner’s representative.

540.3 Submittals

A. Shop Drawings: Catalog cuts, data sheets and other information for all products proposed.

B. Certification that the equipment and materials proposed meet the Specifications.

C. Certification of experience required for installation and testing of cathodic protection systems.

D. Schedule including the expected start date and planned completion date.

E. Copy of well drilling permits (if applicable).

F. The following procedures and collected data shall be submitted after the completion of the Work:

1. Wire connection testing.
2. Insulating flange testing, before and after backfill.
3. Casing insulator testing (if applicable).
4. Joint bond testing before and after backfill.
5. The following will be submitted for deep well installations only:
    a. Well completion report.
    b. Electrical log with anode-to-earth resistances.
6. System check-out report.
7. Record drawings shall be submitted to and approved before the Work is considered complete.
8. An owner's manual is required and will be submitted for and impressed current system only. It will include the following:
    a. Operations and maintenance instructions.
    b. List of spare parts recommended for 2 years of successful operation.

540.4 Quality Assurance

A. Installation of the cathodic protection system shall be performed by individuals having a minimum of 5 years of experience in the installation of cathodic protection equipment described in this Section.

B. All well drilling shall be performed by a state licensed well drilling contractor.

C. All deep well installations shall be installed in accordance with the State deep well standards and the applicable sections on wells from Local regulations.

D. All testing required shall be performed by a NACE Level 2 CP Technician (or higher) under the direct supervision of a NACE Level 4 Cathodic Protection Specialist.

540.5 Standards

The applicable provisions of the following standards shall apply as if written here in their entirety:

A. ASTM International (ASTM):

ASTM A518	Standard Specification for Corrosion-Resistant High-Silicon Iron Castings

ASTM B3	Standard Specification for Soft or Annealed Copper Wire
ASTM B8	Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM B80	Magnesium-Alloy Sand Castings
ASTM B348	Titanium Substrate Grade I/II
ASTM B418	Cast and Wrought Galvanic Zinc Anodes
ASTM B843	Magnesium-Alloy Anodes for Cathodic Protection
ASTM C94	Standard Specification for Ready-Mixed Concrete
ASTM D1248	Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
ASTM D1785	Standard Specification for Polyvinyl Chloride (PVC) Plastic Pipe, Schedules 40, 80, and 120
ASTM D2220	Standard Specification for Polyvinyl Chloride (PVC) Insulation for Cable and Wire

B. Association for Materials Protection and Performance (AMPP):

NACE SP0109	Application of Tape Coatings for External Corrosion Protection of Buried Metal Pipelines
NACE SP0169	Standard Practice, Control of External Corrosion on Underground or Submerged Metallic Piping Systems
NACE SP0200	Steel Cased Pipeline Practices
NACE SP0286	Electrical Insulation of Cathodically Protected Pipelines
NACE SP0375	Field-Applied Underground Wax Coating Systems for Underground Metallic Pipes
NACE SP0572	Design Installation Operation and Maintenance of Impressed Current Deep Anode Beds
NACE TM0497	Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems

C. National Electrical Manufactures Association (NEMA):

NEMA 250	Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA TC2	Electrical Polyvinyl Chloride (PVC) Tubing and Conduit
NEMA TC3	PVC Fittings for Use with Rigid PVC Conduit and Tubing

D. National Fire Protection Association (NFPA):

NFPA 70	National Electrical Code (NEC)

E. Underwriter Laboratories (UL) Standards:

UL 6	Rigid Metal Conduits
UL 514B	Fittings for Cable and Conduit

F. Whenever the Drawings or the Specifications require a higher degree of workmanship or higher quality material than indicated in the standards, the Drawings and Specifications shall prevail.

540.6 Permits and Job Access

A. Prior to the start of construction, the Contractor shall apply to the required authorities for permits required for installation of the cathodic protection system.

B. The Contractor shall contact Underground Service Alert prior to commencing construction to locate existing utilities in the area of construction. Existing utilities include, but are not limited to, water lines, gas lines, telephone, streetlights, sewer and storm drains and overhead and underground electric utilities.

C. The Contractor shall be responsible for reviewing the rectifier locations to determine if there are any conflicts with obtaining power from the indicated locations. The Contractor shall report any conflicts to the Engineer prior to proceeding with the Work.

D. The Contractor shall submit an application to the local power company for AC power to the new rectifiers. Contractor shall be responsible for all fees and expenses associated with providing power to the rectifiers.

E. Traffic control shall satisfy the requirements of the governing locality.

540.7 Interference and Exact Locations

A. The locations of cathodic protection equipment, test stations, devices, outlets and appurtenances as indicated are approximate only. Exact locations shall be determined by the Contractor in the field subject to the approval of the Engineer.

B. The Contractor shall field verify all data and final locations of Work done under other Sections of the Specifications required for placing of the electrical Work.

C. In case of interference with other Work or erroneous locations with respect to equipment or structures, the Contractor shall furnish all labor and materials necessary to complete the Work in an acceptable manner.

540.8 Delivery, Storage, and Handling

A. All materials and equipment to be used in construction shall be stored in such a manner to be protected from detrimental effects from the elements. If warehouse storage cannot be provided, materials and equipment shall be stacked well above ground level and protected from the elements with plastic sheeting or other appropriate methods.

540.9 Materials

Rectifiers

A. Rectifiers shall be air cooled, single or three phase AC input and DC output rectifiers as manufactured by Universal Rectifiers, Inc., Corrpower Rectifiers, Inc., or approved equivalent. DC output is to be calculated and called out on the Drawings.

B. Rectifiers shall be designed to operate continuously at an ambient temperature of 50 C without damage to the rectifier components.

C. Rectifiers shall be capable of operating continuously at the rated output current at any voltage from zero to 100 percent without damaging any rectifier components. Full rated DC output voltage shall be adjustable by not less than 25 equal steps from approximately 4 percent of rated voltage to full rated output voltage. This adjustment shall be accomplished with silver plated or stainless-steel connectors and adjustment link bars.

D. Transformer shall have separate primary and secondary insulated copper windings that meet NEMA and UL requirements.

E. Rectifier stack (rectifying elements) shall be a full-wave bridge high current density selenium cell or silicon diode stack with efficiency filter, metal oxide thyristors, and current-limiting devices for overvoltage and overcurrent protection of stack. Ratings shall be within the manufacture's recommended current rating for continuous operation at with a 50 C ambient temperature.

F. Rectifiers shall have overload and lightning protection for both AC and DC circuits.

G. Rectifiers will be equipped with a voltmeter and ammeter (digital or analog). Voltmeter and ammeter shall be calibrated and adjusted at the factory and will be delivered with the calibration certification.

H. Rectifier cabinet shall be a NEMA 250 Type 3R enclosure.

I. Rectifier cabinet shall have a single door with a full-length hinge and lockage hatch.

J. Rectifier cabinet shall be constructed of 10-gauge steel and coated with a baked enamel finish.

K. Rectifier and cabinet shall both be equipped with a permanent identification tag affixed. The tags will list the manufacturer, model number, AC and DC voltage and amperage, serial number, manufacture date and manufacturer name.

L. The following electrical tests will be performed by the manufacturer:

1. AC Voltage Input.
2. DC Amperes Input.
3. Apparent Watt Input.
4. True Watts Input.
5. Power Factor.
6. DC Voltage Output.
7. DC Amperes Output.
8. DC Watts Output.
9. Conversion Efficiency.
10. Dielectric Strength.
11. Transformer Primary to Ground.
12. Transformer Primary to Secondary.
13. Stack AC to Ground.

14. Stack DC to Ground.
15. Ripple Voltage at Full Output.

M. The following shall be provided for each rectifier in a waterproof bag or container:
   1. Operations and Maintenance Manual.
   2. Circuit Diagram.
   3. Electrical Test Report.

AC Power Service

A. All AC power components must meet local power company requirements.
B. Meter base to be 120/240-volt, single-phase, 20-ampere.
C. Provide fused disconnect switch in NEMA 1 enclosure. Mount in cathodic protection cabinet with rectifier.
D. Ground rod must conform to the requirements of the utility company having jurisdiction.
E. Ground wire to be bare, No. 6 AWG solid copper wire. Use a bronze, bolt-on ground rod clamp.

High Silicon Cast Iron Anodes

A. Cast iron anodes shall be corrosion resistant high silicon iron castings in accordance with ASTM A518, Grade 3.
B. High silicon cast iron anodes shall be tubular type anodes with a minimum wall thickness of 13/32 of an inch, length of 84 inches, and shall be furnished with the wire attached to the interior of the anode and sealed using manufacturer's standard connection.
C. Anode shall have a 2.65 inch outside diameter, minimum weight of 63 pounds (TA-3) and minimum surface area of 4.9 square feet.
D. The wire attached to the anodes shall be stranded copper wire and insulated for 600 volts. Wire size shall be minimum AWG No. 8. Wire insulation shall be a dual extrusion type. The outer insulation jacket shall be HMWPE and the inner insulation shall be fluorinated polymer. The wire shall be Halar cathodic protection wire or equivalent and shall conform to the requirements of ASTM D1248 Type 1, Class C, Grade 5. Anode wire connection shall have a pulling strength exceeding the wire's tensile strength. Any damage to the wire insulation or anode prior to installation shall require a complete replacement of the wire and anode.
E. The resistance of each anode wire connection shall not exceed 0.004 ohms. Each anode wire connection should be tested for conformance with the Specifications. A record of tests shall be submitted to the Engineer. The records shall include the following information:
   1. Anode numbering system to identify anode under test.
   2. Anode wire length.
   3. Resistance value as indicated by test.
   4. Test equipment.
   5. Test method.
F. Anodes shall be individually labeled with the length of lead wire and anode number. Anodes shall be consecutively numbered with the deepest anode being Number 1.

G. Anode wires shall be one continuous length without splices from the anode connection to the junction box. Anode wires with the attached anodes shall be shipped to the Site with the wire coiled and secure. The minimum coil diameter shall be 6 inches. The anode wire insulation shall be free of surface damages such as nicks, abrasions, scratches, etc., in all respects throughout the entire length of the wire. Precaution shall be taken during fabrication, transportation and installation of the anodes to see that the wire is not kinked or sharply bent.

Mixed Metal Oxide Anodes

A. Anodes shall be 1 inch in outside diameter and a minimum 40 inches in length, mixed metal oxide coated tubes as manufactured by De Nora.

B. Steel canisters (if used) for the anodes shall measure a minimum 3 inches in diameter by 60 inches in length and shall be constructed of thin wall galvanized steel conduit. The ends of the canister shall be sealed with epoxy resin. The anode shall be centered in the canister and the canister filled with calcined petroleum coke breeze. The canister shall be vibrated during filling to ensure the coke breeze is compacted around the anode and the canister is completely filled.

C. Anode wire connection shall have a pulling strength exceeding the wire's tensile strength. Any damage to the wire insulation or anode shall require complete replacement of the wire and anode.

D. The wire attached to the anodes shall be stranded copper wire and insulated for 600 volts. Wire size shall be minimum AWG No. 8. Wire insulation shall be a dual extrusion type. The inner insulation jacket shall be chlorine resistant 20-mil thick chlorofluorethylene (E-CTFE) primary insulation with an outer jacket of 80-mil thick HMWPE. The wire's insulation shall be rated at 600 volts.

E. Anode shall be furnished with a cable attached to the center of the anode using a mechanical wedge connection. The connection shall be sealed by filling the tube with epoxy and the ends of the anode shall then be covered with heat shrink tubing for a watertight seal. The pulling strength of the connection shall exceed the tensile strength of the wire.

F. Anode wires shall be one continuous length without splices from the anode connection to the junction box. Anode wires with the attached anodes shall be shipped to the Site with the wire coiled and secure. The minimum coil diameter shall be 6-inches. The anode wire insulation shall be free of surface damages such as nicks, abrasions, scratches, etc., in all respects throughout the entire length of the wire. Precaution shall be taken during fabrication, transportation and installation of the anodes to see that the wire is not kinked or sharply bent.

Anode Groundbed Casing

A. Solid, Schedule 80, ASTM D1785 PVC casing above anode column. Length and diameter found on the Drawings.

B. Slotted PVC Casing for Anode Column (only if necessary to install deep anode system): Perforated casing for active anode area of deep anode, fabricated of Schedule 40 PVC following ASTM D1785.

   1. Casing:

      a. Diameter: 10 inches nominal.

      b. Length: 20-foot sections, to make up total length of active anode column.

c. Slots: 224 slots per 20-foot length (each slot 0.75 inches, min. wide x 5.5 inches long), to permit normal current output of at least 0.35 ampere/linear foot in 10-inch diameter well.

d. Metallic membrane: 26-gauge sheet metal membrane covering exterior of perforated pipe.

e. Manufacturers: Loresco International or equal.

Calcined Coke Breeze

A. Backfill material for impressed current anodes shall be calcined coke breeze with a resistivity of 25 ohm cm or less when tested with an applied pressure of 2 psi and a bulk density of 64 to 72 pounds per cubic foot. The backfill material shall have a particle size of 200 to 20 mesh.

B. The calcined coke breeze backfill shall have the following chemical properties:

1. Fixed Carbon: 98 percent minimum.
2. Ash: 0.5 percent maximum.
3. Sulfur: 5.8 percent maximum.
4. Volatile Matter: 1 percent maximum.
5. Moisture: 1 percent maximum.

C. Coke breeze backfill shall be Loresco SC-2, Asbury 251 or approved equivalent.

Anode Vent Piping

A. Plastic conduit for the impressed current anode vent piping shall be 2-inch diameter PVC, Schedule 80, conforming to ASTM D1785, Type 1 Grade 1, NEMA TC2 for conduit and TC3 for fittings.

Anode Centralizers

A. Steel centering device: Capable of maintaining each anode in concentric position within the hole.

B. Approved Manufacturers: Ventralizer Model as manufactured by Elgard Corporation or equal.

Galvanic Anodes

A. High Potential Magnesium anodes shall be cast magnesium anodes in accordance with ASTM B843 Type M1C.

1. Ingot Weight: 17 pounds, Packaged Length: 29 to 30 inches.
2. Ingot Weight: 20 pounds, Packaged Length: 62.5 to 66 inches.
3. Ingot Weight: 32 pounds, Packaged Length: 28 to 30 inches.
4. Ingot Weight: 40 pounds, Packaged Length: 64 to 66 inches.
5. Ingot Weight: 48 pounds, Packaged Length: 34 to 38 inches.
6. Ingot Weight: 60 pounds, Packaged Length: 64 inches.
7. Chemical composition as percent of weight shall be as follows:
   a. Aluminum: 0.01 maximum.
   b. Manganese: 0.50 to 1.3.
   c. Copper: 0.02 maximum.

d. Nickel: 0.001 maximum.
e. Iron: 0.03 maximum.
f. Other Impurities: 0.05 percent each; 0.3 percent maximum total.
g. Magnesium: Remainder.

B. H 1 Alloy Magnesium anodes shall be H 1 Alloy, Grade B cast magnesium anodes, in accordance with ASTM B80.
1. Ingot Weight: 17 pounds, Packaged Length: 17 inches.
2. Ingot Weight: 17 pounds, Packaged Length: 29 inches.
3. Ingot Weight: 20 pounds, Packaged Length: 62 inches.
4. Ingot Weight: 32 pounds, Packaged Length: 28 to 30 inches.
5. Ingot Weight: 48 pounds, Packaged Length: 38 inches.
6. Ingot Weight: 50 pounds, Packaged Length: 110 inches.
7. Ingot Weight: 60 pounds, Packaged Length: 64 inches.
8. Chemical composition as percent of weight shall be as follows:
a. Aluminum: 5.3 to 6.7.
b. Manganese: 0.15 to 1.3.
c. Zinc: 2.5 to 3.5.
d. Silicon: 0.30 maximum.
e. Copper: 0.05 maximum.
f. Nickel: 0.003 maximum.
g. Iron: 0.003 maximum.
h. Other Impurities: 0.05 percent each; 0.3 percent maximum total.
i. Magnesium: Remainder.

C. Zinc anodes shall be “High Purity” cast zinc anodes in accordance with ASTM B418, Type II.
1. Ingot Weight: 30 pounds, Packaged Length: 36 inches.
2. Ingot Weight: 30 pounds, Packaged Length: 66 inches.
3. Ingot Weight: 45 pounds, Packaged Length: 51 inches.
4. Ingot Weight: 60 pounds, Packaged Length: 60 inches.
5. Chemical composition as percent of weight shall be as follows:
a. Aluminum: 0.005 maximum.
b. Cadmium: 0.003 maximum.
c. Iron: 0.0014 maximum.
d. Zinc: Remainder.

D. Ribbon anodes shall be 5/8-inch by 5/8-inch zinc ribbon anodes, 1.2 pounds per foot, with a 0.135-inch diameter steel wire core as manufactured by Plattline. Zinc Anode shall meet ASTM B418-88 Type II.

E. Galvanic anodes shall be prepackaged in a cloth bag containing backfill of the following composition; 75 percent gypsum, 20 percent bentonite and 5 percent sodium sulfate. The anodes shall be of the size indicated and placed where indicated.

F. The wire attached to the anodes shall be (AWG) stranded, single conductor, copper and insulated for 600 volts. Wire size shall be minimum No. 10 AWG THHN and shall conform to the requirements of ASTM D1248, D2220 and NEMA WC70. Connection of wire to the anode shall have a pulling strength that exceeds the wire's tensile strength.

G. Anode wires shall be of one continuous length without splices from the anode connection to the test station.

Permanent Reference Electrode

A. Provide a copper/copper sulfate, double membrane, ceramic cell in a geomembrane package, such as a Permacell Plus or approved equal. Equip with No. 14 AWG stranded copper wire with blue HMWPE insulation of suitable length to extend from the pipeline to the rectifier without splicing.

Anode Junction and Test Station Panel Boards

A. Panel boards shall be made of 1/4 inch thick phenolic plastic sized as indicated on the Drawings.
B. Connection hardware shall be brass or bronze. All connections shall be double nutted bolts with lock washers.
C. Copper bus bar shall be 1/8 inch thick and sized to fit. The copper bus bar shall be per ASTM B187, 98 percent conductivity.

Concrete Traffic Valve Boxes

A. Traffic valve boxes shall be rated to withstand AASHTO H-20 traffic loading. The traffic valve boxes shall be G5 Utility Boxes as manufactured by Christy Concrete Products, Inc., No. 3RT Utility Box as manufactured by Brooks Products or approved equivalent. Traffic box covers for test stations shall be cast iron with welded bead legend and labeled "CP TEST" or "ANODE" as required.

Junction Boxes

A. Junction boxes shall be NEMA 250, Type 4, fiberglass construction. Junction boxes shall be sized as indicated on the Drawings. Hinges shall be stainless steel and a neoprene gasket shall be furnished with the box to ensure a watertight seal. Junction boxes shall have a latch with a 1/4 inch diameter hole for installation of a pad-lock.

Solderless Lug Connectors

A. Solderless lug connector shall be made of brass or copper with a brass screw. The lug shall be designed for direct burial and shall be appropriately sized for the connection wire. The lug shall be ILSCO Type XT 6DB or approved equivalent

Shunts for Impressed Current Anodes

A. Shunts for impressed anodes for the impressed current anode systems shall be 0.001-ohm and 25-ampere capacity. Shunts shall be Type SS as manufactured by Holloway or equivalent.

Shunts for Galvanic Anodes

A. Shunts shall be 0.01-ohm, 6-ampere, manganin wire type, or as indicated on the Drawings. Shunts shall be Type RS as manufactured by Holloway or equivalent.

Post Mounted Test Stations

A. Weatherproof Enclosure: Cast aluminum, galvanized steel, or high impact plastic, Lexan, Gyrlyn or equal.
B. Terminal Block: Phenolic resin, plastic, micarta, Lexan, or Bakelite high dielectric material, with eight terminals unless otherwise shown on the Drawings.
C. Terminals: Nickel plated brass 1/4-inch threaded studs, nuts, and washers.

Ready-Mix Concrete

A. Ready-mixed concrete shall be in accordance with ASTM C94.

Conduit and Fittings

A. The minimum conduit size shall be 1 inch unless otherwise indicated. Refer to NFPA 70 (NEC) for additional conduit size requirements.
B. Conduit and fittings placed below grade shall be PVC, Schedule 80.
C. Conduit and fittings placed above grade shall be rigid steel. Rigid Steel conduit shall be galvanized conforming to UL 6.
D. Conduit Straps shall be a two-hole galvanized steel conduit strap.
E. Fittings for use with rigid steel conduit shall be galvanized cast ferrous metal, with gasketed covers, Crouse Hinds Condulets, Appleton Unilets, or equivalent. Rigid metallic conduit fittings shall be galvanized conforming to NEMA FB 1, UL 514B listed.
F. Union couplings for conduits shall be the Erickson or Appleton type EC or O-Z/Gedney three-piece Series 4, or equivalent.

Dielectric Insulating Flange Kits

A. Insulating flange gaskets shall include full faced gaskets, insulating sleeves and washers and steel bolts, nuts and washers. The complete assembly shall have a pressure rating equal to or greater than the flanges between which it is installed. Insulating Gasket shall be neoprene faced phenolic, 1/8 inch thick. Insulating sleeves shall be Mylar, 1/32 inch thick. Insulating washers shall be two sets of 1/8 inch thick phenolic. Sleeves, gaskets and insulating washers shall have a dielectric constant of 300 volts per mil, minimum. Steel washers shall fit well within the bolt facing on the flange. Insulating washers shall fit within the bolt facing the flange over the outside diameter of the sleeve.

Monolithic Insulating Joints

A. Monolithic insulating joints shall be designed to provide for the permanent electrical isolation of piping sections. They shall be completely factory assembled and designed to be welded into the piping section.

Petrolatum Tape

A. Petrolatum tape system shall be Trenton Primer and #1 Wax-tape, as manufactured by Trenton Corp., or Denso Paste and Densyl Tape by Denso North America, Inc., or approved equivalent.

Utility Warning and Identification Tape

A. The warning and identification tape shall be an inert plastic film designed for prolonged underground use. The tape shall be a minimum of 3 inches wide and a minimum of 4 mils thick. The tape shall be continuously printed over the entire length with the wording "CAUTION: CATHODIC PROTECTION CABLE BURIED BELOW". The wording shall be printed using bold black letters. The color of the tape shall be red.

Wire and Cable

A. Direct-Burial Cable: Single-conductor Type HMWPE, insulated cable specifically designed for DC service in cathodic protection installations.
   1. Conductor: Stranded, annealed, uncoated copper, complying with ASTM B3 and B8.
   2. Insulation: High-molecular-weight polyethylene, complying with NEMA WC 70.
   3. Minimum Average Thickness of Insulation: 110 mils (2.8 mm) for No. 8 through 2 AWG, and 125 mils (3.2 mm) for No. 1 through 4/0 AWG; rated at 600 volts.
   4. Connectors: Copper compression type or exothermic welds.

B. Negative cables shall be size #4 AWG, single conductor, seven-strand, copper with medium density, HMW/PE insulation for the rectifier negative cables. The polyethylene to conform to ASTM D1248, Type I, Class C, Grade 5.

C. Test leads shall be No. 12 AWG, solid copper wire with white, TW or THW insulation and of sufficient length to extend from the protected structure to the rectifier without splicing.

D. Cables for Installation in Conduit: Type THWN copper conductors as specified on the Drawings.

E. Joint Bonds:
   1. General: Single-conductor, stranded copper wire with 600-volt HMWPE insulation. Supply joint bonds complete with formed copper sleeve on each end of wire. Bond cable gauge shall be based on the diameter and thickness of the pipe cylinder. Two bond cables shall be used for each non-welded, non-insulating pipe joint.
   2. Push-On, Mechanical, or Flanged Joints: 18 inches long, minimum.
   3. Flexible Coupling Joints: 24 inches long, with two 12-inch long THHN insulated No. 10 AWG wire pigtails, as manufactured by Erico Products Inc. (Cadweld), Cleveland, OH.

F. Concrete Cylinder Pipe: A minimum of two pipe bonding jumpers for each joint. Bond jumpers shall use 12-inch long stranded copper cable with the steel rods welded to the ends of the wire.

Exothermic Welds

A. Exothermic Weld Molds, Weld Powder and Weld Metal Cartridges: Use proper mold and proper size and amounts for wire size, pipe size, pipe material, and weld position. Utilize adapter sleeves as recommended by exothermic weld manufacturer.

B. Approved Manufacturers:

1. Exothermic weld material:

   a. ERICO International – CADWELD products.

   b. Continental Industries – thermOweld products.

   c. Or approved equal.

1. Weld powder: As recommended by each exothermic weld manufacturer for specific wire size and pipe material.

2. Exothermic Weld Caps:

   a. Royston Handy Cap – use Royston Roybond 747 primer.

   b. Royston Handy Cap IP – no primer needed (has integrated primer).

   c. Ci thermOcap – use thermOprimer primer.

   d. Ci thermOcap PC – no primer needed (pre primed cap).

Cable-to-Pipe Coating Materials

A. Coating material for exothermic weld connections to the pipelines shall be two part ProPoxy 20 epoxy putty manufactured by the Hercules Chemical Company, or approved equivalent. The epoxy putty shall be non-conductive and have compression strength of 18,000 psi when cured.

540.10 Construction Methods

Storage of Materials

A. All materials and equipment to be used in construction shall be stored in such a manner to be protected from detrimental effects from the elements. If warehouse storage cannot be provided, materials and equipment shall be stacked well above ground level and protected from the elements with plastic sheeting or other method as appropriate.

Rectifier Installation

A. Approximate locations of rectifiers and associated equipment are shown on the Drawings. Rectifier installation includes provision of AC power to the rectifier by the Contractor. The Contractor shall furnish and install all required wiring, conduits, cables, meters, splice boxes, and equipment as necessary for operation of the rectifier and as required by the local power agency.

B. The Contractor may propose an alternative rectifier location to the Owner for review and approval. The reinforced concrete pad shall be constructed such that water will not collect against the rectifier cabinet. The vent pipe riser shall be cast into the concrete pad.

C. The installation is not considered complete until the AC and DC wiring is installed and the rectifier is capable of operating at full rated load. Install AC power such that the rectifier can be activated for test purposes.

Impressed Current Anode Installation

A. Impressed current anode beds shall be installed in accordance with NACE SP0572, state and local well standards, and the Specifications.

B. Well Drilling:

1. The Contractor shall obtain and pay for all fees and permits required for well drilling.
2. Fresh water shall be circulated from the bottom of the hole to clear the well of drilling mud and cuttings after the well is drilled.
3. The Contractor shall protect the well bore from the intrusion of contaminants into the hole at all times. The Contractor is responsible for the cost of all clean up associated with contamination of the well and/or Site resulting from the Contractor's Work.
4. The well shall be covered with a steel trench plate or other heavy device that blocks access and that cannot be removed by hand whenever the well is left unattended.
5. Loading of anodes and other equipment in the well shall be done in the presence of the Owner's representative. A minimum of 48 hours' notice shall be given by the Contractor to the Owner prior to loading anodes. Loading of the anodes into the well shall begin early enough in the day to ensure completion of all loading, including backfilling, during regular working hours.

C. Well Casing: The Contractor may elect to install the well with or without a casing. If the well collapses, for any reason, including the elimination of the casing, the well shall be relocated, redrilled and the original hole abandoned at the Contractor's expense. Only a metallic casing may be used in the coke breeze column.

D. Vent Pipe: Install the vent pipe in the hole with the first anode. Cap the bottom of the vent pipe. Cap the top of the vent pipe throughout the anode and coke breeze backfill installation procedure to prevent intrusion of foreign material. Do not allow drilling mud to enter in the vent pipe.

E. Anodes:

1. The Engineer shall visually inspect the insulation on the anode lead wire for abrasion or other damage to the insulation and wire as the anode is lowered into place. Anodes with damaged insulation or wire are not acceptable and shall not be installed. Splices are not allowed on the anode wire.
2. Record an electric log of the hole using one of the anodes. Previously mark the anode lead wire in 5-foot increments. Mark the anode lead wire for a distance equaling or exceeding the maximum anticipated depth of the hole. As the anode is lowered into the hole, perform a resistance log by impressing a minimum 12-VDC current between the anode and a very well-grounded structure such as the local AC power neutral network. Do not use Nilsson type soil resistance meters to perform this test. A recommended 12-VDC power source is a heavy duty lead acid automobile battery. Lower the anode into the hole at ten foot increments, hold in place, and measure the voltage and current output of the DC current source.
3. Attach the centering devices to the anodes using the adjustable stainless steel bands. The terminal end of the anode cables shall be identified with permanent cable markers.

Anode No. 1 shall be attached to the bottom section of the anode vent pipe with adjustable stainless steel bands and lowered into the hole. A digital soil resistance meter, furnished and operated by the Engineer, shall be connected between the anode cable for Anode No. 1 and the drain cable. The drain cable must be installed and be accessible to the Engineer during time of testing. The Contractor shall stop lowering the anode at 10-foot intervals to tape the anode lead to the vent pipe and to allow the Engineer to measure the resistance profile of the anode well. This shall continue to the bottom of the hole and the vent pipe shall be secured in place.

4. Continuing with Anode No. 2, with centralizers attached, the anodes shall be lowered into the hole supported by the attached lead wires. The Contractor shall fabricate an apparatus that allows the anodes to be lowered by the lead wire but does not bend the wire into a radius less than 2.5 inches. All sharp edges on the centering device assembly shall be taped with vinyl electrical tape to preclude damaging any wires while lowering anodes into place. The vent pipe shall not be attached to Anodes No. 2 to No. 10. The Engineer may adjust the depths of the individual anodes to avoid high resistance soil layers. When an anode has been placed at the final depth it shall be securely fixed in that position prior to coke breeze backfill. Anodes shall not be backfilled until the Engineer has inspected the placement of the anodes and given permission to backfill.

F. Coke Breeze Backfill:

1. Slurry the coke backfill above-grade and then pump into the hole after the anodes are installed. Pump the coke from the bottom of the hole up using a pipe that is the length of the anode hole. Do not use the vent pipe to pump the coke. Raise the pipe as the anode column is filled with coke. Remove the pipe from the hole after the coke installation operation is completed. Use a enough backfill so that the coke breeze column extends a minimum of 5 feet above the top of the uppermost anode. Install the coke backfill uniformly with no voids around the anodes.
2. Take all necessary precautions to avoid entrance of foreign matter into the hole, movement of soil strata, or collapsing of the hole during the progress of the Work. Should movement of soil strata or collapse of the drilled hole interfere with proper completion of the anode groundbed, recover the wires, anodes and vent pipe and ream or redrill the hole at no cost to the Owner.

G. Well Seal:

1. Backfilling operations above the coke breeze column shall begin no sooner than 24 hours after installation of the coke breeze to allow for settling. Backfilling shall be done continuously, without interruption, until the hole is sealed.
2. Collapse of the hole prior to the introduction of the seal material shall be cause for abandonment of the well at the Contractor's expense.
3. If well casing materials are used in the construction of the well, then the annular space between the well bore and the casing shall also be sealed with a conductive grout.
4. Sealing material shall not enter the vent pipe.
5. The Contractor shall record the volume of sealing material installed in the hole.

Wire and Cable Installation

A. Install all underground wires and cables at a minimum of 36 inches below final grade with a minimum separation of 6 inches from other underground structures.

B. Buried wires shall be laid straight without kinks. Each wire run shall be continuous in length and free of joints or splices, unless otherwise indicated. Care shall be taken during installation to avoid punctures, cuts or other damage to the wire insulation. Damage to insulation shall require replacement of the entire length of wire at the Contractor's expense.

C. Enclose all positive and negative cables, and anode lead wires in rigid galvanized steel conduit when above-grade.

Anode Junction Panel Installation

A. Install anode lead panel inside the cathodic protection cabinet, immediately adjacent to the rectifier with the bottom of the panel at a minimum height of 1 foot above grade.

Negative Cable and Test Lead Attachment

A. Install wires, without splices, as shown on the Drawings.

B. Attach negative cables and test leads to the pipe (for the dielectrically coated steel and ductile iron pipe options) or to the "L" bracket (for the concrete cylinder pipe option) by thermite welding.

C. Clean and dry the pipe to which the negative cables and test lead are to be attached.

D. Use a grinding wheel to remove all coating, mill scale, oxide, grease, and dirt from the pipe over an area approximately 3 inches square. Clean the surface to bright metal.

E. Remove approximately 1 inch of insulation from each end of the wires to be thermite welded to the pipe, exposing clean, oxide-free copper for welding.

F. Using the proper size thermite weld mold as recommended by the manufacturer.

G. If the weld is secure, coat all bare metal and weld metal with Kop-Coat. Cover the coated weld with a plastic weld cap.

Permanent Reference Cell

A. When not shown on the Drawings, locate the permanent reference cell near the negative structure connection.

B. Remove the permanent reference cell from the shipping package and place below the 1 foot away from the pipeline. Make certain that the reference electrode is completely surrounded by the special backfill material in the geomembrane package.

C. Run continuous lengths of the blue reference cell wiring, and the white test lead to the rectifier unit in the same trench as the negative cable. Do not nick or otherwise damage the wire insulation.

Galvanic Anode Installation

A. Install prepackaged anodes in a dry condition after plastic or waterproof protective covering has been completely removed from water-permeable, permanent container housing the anode metal. Do not use anode connecting wire for lowering anode into hole. Backfill annular space around anode with fine earth in 6-inch layers; compact each layer using hand tools. Do not strike anode or connecting wire during compacting. After backfilling and compacting to within 6 inches of finished grade, pour approximately 5 to 10 gallons of water into each filled hole. After water has been absorbed by earth, complete backfilling to finished level.

B. Use clean fill, free from tree roots, wood scraps, vegetable matter, and refuse. Place cable warning tape within 18 inches of finished grade, above cable and conduit.

C. If rock strata is encountered before achieving specified augured hole depth, install anodes horizontally at depth at least as deep as bottom of pipe to be protected.

D. Install anodes spaced as indicated, to the pipeline, allowing adequate slack in connecting wire to compensate for movement during backfill operation.

E. At least 18 inches of slack (coiled) shall be left for each wire at each flush-to-grade test station. Wire slack shall be sufficient to allow removal of wire extension for testing. Wire shall not be bent into a radius of less than 2 inches.

Test Station Installation

A. Test stations are to be located as indicated on the Drawings.

B. Test stations are to be placed directly over the pipe except in areas that would place the test station in a roadway.

C. If test stations cannot be placed as indicated on the Drawings, they are to be placed just off the edge of the road or curb.

D. Identify the test station with the number associated with it on the Drawings.

   1. Paint the number legibly inside the test box lid or cover.

   2. Use a permanent or weatherproof paint for metal or plastic surfaces.

E. The Contractor shall provide global positioning system (GPS) coordinates of each test station location with a minimum accuracy of 1 meter or 3 feet. The Contractor shall submit the GPS coordinates of the test stations to the Owner after installation.

F. Flush mounted test stations shall be installed with a 4 inch diameter, Schedule 40 PVC pipe as shown on the Drawings. The PVC pipe shall be 24 inches long and extend 4 inches above the bottom of the test box as shown on the Drawings. PVC pipe shall be filled with native soil.

Exothermic Weld Connection

A. Exothermic weld connections shall be installed in the manner and at the locations indicated. Coating materials shall be removed from the surface over an area of sufficient size to make the connection. The surface shall be cleaned to bare metal by grinding or filing prior to welding the conductor. The use of resin impregnated grinding wheels will not be allowed. A copper sleeve shall be fitted over the conductor. Only enough insulation shall be removed such that the copper conductor can be placed in the welding mold.

B. After the weld has cooled, all slag shall be removed and the metallurgical bond shall be tested for adherence by the Contractor. A 22 ounce hammer shall be used for adherence testing by striking a blow to the weld. Care shall be taken to avoid hitting the wires. All defective welds shall be removed and replaced.

C. After backfilling pipe, all test lead pairs shall be tested for broken welds using a standard ohmmeter. The resistance shall not exceed 150 percent of the theoretical wire resistance as determined from published wire data.

D. The Contractor shall inspect both the interior and exterior of the pipe to confirm that all coatings and linings removed or damaged as a result of the welding have been repaired. The Contractor shall furnish all materials, clean surfaces and repair protective coatings and linings

damaged as a result of the welding. Repair of any coating or lining damaged during welding shall be performed in accordance with coating or lining manufacturer's recommendations.

E. All exposed surfaces of the copper and steel shall be covered with insulating materials as indicated.

F. For dielectrically coated pipes, a bitumastic coating shall be applied to all exothermic weld locations. The coating shall be covered with a plastic weld cap. All surfaces must be clean, dry and free of oil, dirt, loose particles, and all other foreign materials prior to application of the coating.

G. For dielectrically coated pipes, a bitumastic coating shall be applied to all exothermic weld locations. The coating shall be covered with a plastic weld cap. All surfaces must be clean, dry and free of oil, dirt, loose particles, and all other foreign materials prior to application of the coating.

H. The Contractor shall be responsible for testing all test lead and bond wire welds. The Owner, at their discretion, shall witness these tests.

Pipe Joints

A. Bond wires shall be provided across flexible couplings and all nonwelded joints, as necessary to ensure electrical continuity, except where insulating joints have been installed to provide electrical isolation. Joint bonds shall be of the size and number shown on the Drawings and installed as indicated. The bond wires shall be at least 18 inches long and shall be installed to allow for movement of at least 2 inches in the pipe joint. The wire shall be attached by exothermic welding. At least two bonds shall be provided between all discontinuous joints.

B. For ductile iron pipe, the Contractor may, at his or her own expense, provide weld plates, installed by the pipe manufacturer, at the spigot end of the pipe. Provision of the weld plates does not relieve the Contractor from responsibility for repair of damage to the coating or lining as a result of exothermic welding of the pipe. Coating repairs shall be performed in accordance with coating manufacturer's recommendations.

Insulating Flanges

A. Install at locations indicated on the Drawings.

B. Test each insulating flange for electrical isolation prior to backfill. Provide the Owner a minimum of 1 week notice prior to testing.

1. If flange is not properly isolated, repair or replace all defective components at no additional cost to the Owner.
2. Test the repaired isolation flange.
3. Continue this process until the isolation flange is tested to be properly isolated.

Casing Insulators

A. Casing insulators shall be installed as indicated on the Drawings to effectively isolate the pipeline from the casing. The Contractor shall test the performance of the casing insulators before and after backfill.

B. After backfill, testing shall be performed by measurement of native pipe to soil potentials on the pipeline and the casing at both ends of the casing. If the difference in native pipe to soil potentials is greater than 50 mV, the casing shall be considered isolated from the pipeline. If the difference in native pipe to soil potentials between pipe and casing is less than 50 mV, then additional testing shall be performed as follows. Temporary cathodic protection current

shall be applied to the pipeline. “On” and “Instant Off” pipe to soil potentials shall be measured on the pipeline and the casing at both ends of the casing. If the “Instant Off” potential of the casing is more negative than the native potential of the casing, the pipe is not isolated from the casing and shall be repaired and retested at the Contractor’s expense.

Petrolatum Tape System Application

A. Petrolatum tape system shall be applied on insulating joints and as indicated on the Drawings. Petrolatum tape system shall be applied in accordance with NACE SP0375, and the Specifications. The materials shall be applied according to the manufacturer’s recommendations.

B. All loose scale shall be removed from the surface to be coated with hand tools (wire brush, scraper, rags). Debris and moisture shall be wiped from surface with clean rag. Petrolatum tape shall be applied immediately after applying the primer, using a 1-inch overlap. A spiral wrap shall be used and a slight tension shall be applied to ensure that there are no air pockets or voids. After applying the tape, the applicator shall firmly press and smooth out all lap seams and crevice areas. The tape shall be in tight intimate contact with all surfaces.

Remote Monitoring Units

A. Install at approximate locations shown on the Drawings.

B. Work to be completed by electricians licensed to perform these installations and are to follow local Electrical Code, NEC and NFPA 30.

540.11 Continuity Testing

A. Continuity testing of joint bonds shall be performed by the Contractor’s qualified corrosion technician as defined in this Section after backfill. The electrical continuity test may additionally be performed before backfill at the Contractor’s option.

B. The pipe shall be tested for electrical continuity. Continuity shall be verified using the linear resistance method. The pipe shall be tested in spans that are no less than 250 feet unless the pipe is shorter than 250 feet. Each test span shall have two test leads connected to the pipe at each end. Existing test stations can be used. A direct current shall be applied through the pipe using two of four test leads. The potential across the test span shall be measured using the other two test leads. The current applied and voltage drop shall be recorded for a minimum of three different current levels.

C. The theoretical resistance of the pipe shall be calculated. It shall take into account the pipe wall thickness, material, and joint bonds.

D. Acceptance of the test span; The average measured resistance shall be compared to the theoretical resistance of the pipe and bond wires. If the measured resistance is greater than 125 percent of the theoretical resistance, then the joint bonds shall be considered deficient and shall be repaired and retested at the Contractor’s expense. If the measured resistance is less than 100 percent of the theoretical resistance then the test and/or calculated theoretical resistance shall be considered deficient and the test span shall be retested and/or recalculated at the Contractor’s expense. If the piping forms a loop which allows current to flow both in and out of the test span, then consideration shall be made for current circulating through both the loop and the test span.

540.12 Final System Checkout

A. Prior to native state and polarized potential testing, give a minimum of 48 hours' notice to the Owner's Engineer to facilitate observation of the tests by the Owner representative.

B. Measure native state pipe-to-soil potentials at all test stations, sacrificial anodes, permanent reference cells, electrical isolation devices, and locations of exposed pipe prior to energizing the cathodic protection system.

C. Measure casing-to-soil potentials and foreign line potentials, prior to energizing the cathodic protection system.

D. Verify electrical isolation at all insulating joints, insulating unions, and casing insulators per NACE SP0286.

E. Energize the cathodic protection system by either:

1. Turn on rectifier(s) setting outputs at a minimum of current values determined during design phase. Record rectifier output voltage and current values, along with tap settings, AC and DC ratings and adjust the DC current output such that the pipe-to-soil potentials at the nearest test station is approximately -1000 mV to a copper sulfate electrode (CSE).
2. Measure and record current output from each anode at each anode groundbed junction box with rectifiers operating at final output settings.
3. Connect galvanic (sacrificial) anodes as indicated on the Drawings.
    a. Measure and record the initial potential from all test leads.
    b. Measure and record current output from each anode.

F. After initial startup, allow system to operate for minimum period of 2 weeks.

1. For Impressed Current cathodic protection systems:
    a. Install synchronized current interrupters to cycle the power supply "On" and "Off."
    b. Measure and record "On" and "Instant Off" potentials at all test stations, permanent reference cells, electrical isolation devices, locations of exposed pipe, casings, and foreign pipelines. Record interruption cycle (seconds on, seconds off).
    c. If testing described in the above paragraph indicates pipeline is not meeting established cathodic protection criteria, NACE SP0169, output of all rectifiers shall be increased to a level that will achieve full protection without excessive potentials.
    d. Measure and record final rectifier voltage and current outputs.
    e. Measure and record the final current output from each anode at each groundbed junction box.
2. For Galvanic (Sacrificial) cathodic protection systems:
    a. Measure and record "On" and "Instant Off" potentials at all test stations, permanent reference cells, electrical isolation devices, locations of exposed pipe, casings, and foreign pipelines.
    b. Measure and record the final current output from each anode.

G. Test results shall be analyzed to determine compliance with NACE SP0169.

H. Test results shall be analyzed to determine if stray current interference is present. Stray current interference is defined as a +/-50 mV shift in a pipeline's pipe-to-soil potential that is

caused by a foreign current source. Stray current interference shall be tested on the project pipeline and foreign pipelines that have a reasonable chance of being affected by stray currents.

I. Final Report: Prepare a final report after all testing has been completed and system is in compliance with NACE SP0169. Include at minimum the following:

1. Marked-up as-built drawings.
2. All field test data as described in section above.
3. Discussion of the installation.
4. Recommendations for maintenance of the system.
5. Operations and maintenance manual.

540.13 Measurement and Payment

Cathodic protection will be paid for in lump sum. The Contractor shall consider the supply and installation of the cathodic protection to all construction of pipeline projects.

End