Section 16640

CATHODIC PROTECTION FOR PIPELINES

PART 1 GENERAL

1.01 SUMMARY

This Section includes:

A. Requirements for impressed current cathodic protection systems on steel, ductile iron and concrete cylinder pipe in water pipeline projects using rectifiers and deep anode groundbeds.

B. Requirements for sacrificial anode cathodic protection on steel, ductile iron, concrete cylinder and metallic fittings in plastic pipe systems using zinc and/or magnesium anodes.

1.02 MEASUREMENT AND PAYMENT

A. Unit Prices

1. This item will be measured and paid for as a lump sum item for the job.

2. Payment will be full compensation for all labor, equipment, materials and supervision for the installation of the cathodic protection system, complete in place including rectifier systems with deep anode groundbed and junction boxes, sacrificial anodes, power feed hookups, and all excavation, backfill, field welding, connections, adjustments, testing, cleanup, and other related work necessary for construction as shown on the Plans and specified herein.

1.03 REFERENCES

A. ASTM C94 - Ready Mixed Concrete.

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

C. ASTM B418 – Standard Specification for Cast and Wrought Galvanic Zinc Anodes

D. ASTM D1248 – Polyethylene Plastics Molding and Extrusion Material for Wire and Cable.

E. ASTM D4239 – Standard Test Methods for Sulfur in the Analysis Sample of Coal and Coke using High Temperature Tube Furnace Combustion Methods.

F. ASTM D5192 – Standard Practice for Collection of Coal Samples from Core.

G. AWWA M9 Manual - Concrete Pressure Pipe.

H. CSA C22.2 No. 107 – General Use Power Supplies

I. CSA C22.2 No. 66 – Low Voltage Transformers

J. City of Houston Electrical Code.

K. NACE SP0169-2013 - Control of External Corrosion on Underground or Submerged Metallic Piping Systems.

L. NACE SP0572-2007 - Design, Installation, Operation and Maintenance of Impressed Current Deep Groundbeds.

M. NFPA 70 – National Electrical Code.

N. NEMA TC6 - PVC and ABS Plastic Utilities Duct for Underground Installation.

O. NEMA TC9 - Fittings for ABS and PVC Plastic Utilities Duct for Underground Installation.

P. NEMA 4 – Type 3R Enclosures.

Q. UL 83 - Thermoplastic-Insulated Wires.

R. UL 467 - Bonding and Grounding Equipment.

S. UL 486A - Wire Connectors and Soldering Lugs for Use with Copper Conductors.

T. UL 506 – Specialty Transformers.

1.04 SUBMITTALS

A. Submittals to conform to the requirements of Section 01330 – “Submittal Procedures”.

B. All required computations and drawings shall be prepared by or under the direct supervision of a Professional Engineer, registered in the State of Texas with a minimum of ten years of corrosion control experience.

C. Submit manufacturer's catalog cuts for each item. Include the manufacturer’s name on the catalog cuts. Provide sufficient information to show that the materials meet the requirements of the Plans and specifications. Where more than one item or catalog number appears on a catalog cut, clearly identify the item proposed.

D. Provide the Project Manager a minimum of 48 hours notice prior to drilling the anode bore. Type and submit to the Owner or Owner’s Representative, copies of detailed geological and resistance logs of each deep anode bore.

E. The rectifier manufacturer to include a complete operation and maintenance manual with each rectifier shipped to the job site. In addition to operating instructions, include a circuit diagram and spare parts list in the manual. The rectifier manufacturer to reference each operating manual by rectifier model number and individual serial number.

F. Submit an electronic copy of monitoring and maintenance reports for the cathodic protection systems to the Project Manager. Include all test data as required by Paragraph Section 3.08.A.8 of this specification. Include operating instructions, maintenance data, product data and test procedures in the manuals.

G. Maintain as-built drawings of the cathodic protection installation during installation and construction. Revise drawings to show exact locations of all rectifiers, anodes, wiring, connections and terminal boxes. Properly identify all items of equipment and material. Submit the as-built drawings to the Project Manager.

1.05 RELATED REQUIREMENTS

A. Section 01330 – "Submittal Procedures".

B. Section 01785 – "Project Record Documents".

C. Section 16061– "Joint Bonding and Electrical Isolation".

D. Section 16062 – "Corrosion Control Test Stations".

E. Section 16645 – "AC Interference Mitigation Systems for Pipelines Gradient Control Systems".

1.06 QUALITY ASSURANCE

A. Provide manufacturer's certification that all components of the cathodic protection system meet the requirements of the Plans and specifications. Reference the applicable section of the specifications and the applicable standard detail on the certification.

B. The specification reference drawings for the cathodic protection system are diagrammatic and not scaled for exact locations unless scales are explicitly stated on the specific drawing. Determine exact locations by field conditions and non-interference with other utilities or mechanical and structural features. Specific site drawings shall be approved by the Engineer.

C. Note other existing utilities in the area and during excavation, do not damage these utilities. Repair any damaged utilities to the satisfaction of the Owner at the Contractor's expense.

D. Operate the rectifier under full load conditions at the factory and thoroughly inspect and test by the manufacturer prior to delivery to the job site. Report results of this testing on a manufacturer's quality control form and include in the operation manual.

E. All materials, fabrication, and installations are subject to inspection and testing by the Owner or its designated representative. Testing and inspection by the Owner does not relieve the Contractor of any obligation for full compliance with this Specification.

1.07 – 1.13 NOT USED

PART 2 PRODUCTS

2.01 MANUFACTURER(S) (NOT USED)

2.02 MATERIALS AND/OR EQUIPMENT

A. Sacrificial Anodes - Magnesium

1. Magnesium Anodes: Use high potential magnesium anodes. Follow the metallurgical composition of the magnesium anodes as listed below:

Element	Percent Composition
Aluminum	0.01 Maximum
Manganese	0.50 to 1.3
Copper	0.02 Maximum
Nickel	0.001 Maximum
Iron	0.03 Maximum
Other - (each)	0.05 Maximum
Other - (total)	0.30 Maximum
Magnesium	Balance

2. Magnesium Anode Current Capacity: Magnesium anodes require a current capacity of no less than 500 amp-hours per pound of magnesium.

3. Anode Backfill Material: Use chemical backfill material around all galvanic anodes. Backfill provides a reduced contact resistance to earth, provides a uniform environment surrounding the anode, retains moisture around the anode, and prevents passivation of the anode.

a. All galvanic anodes come prepacked in a backfill material conforming to the following composition:

1) Ground hydrated gypsum: 75 percent

2) Powdered bentonite: 20 percent

3) Anhydrous sodium sulfate: 5 percent.

b. Have a grain size backfill such that 100 percent is capable of passing through a 20 mesh screen and 50 percent is retained by a 100 mesh screen.

c. Completely surround the anode with the backfill mixture within a cotton bag.

d. For standard cast magnesium ingots, the required weight of backfill follows:

Anode Weight (Pounds)	Backfill Weight (Pounds)	Total Weight (Pounds)
9	15	24
17	25	42
20	50	70
32	38	70
48	48	96
60	70	130

4. Anode Lead Wires:

a. Use a 20-foot length of No. 12 AWG solid copper wire equipped with TW or THW insulation for standard lead wires for a galvanic anode, unless otherwise stated on the Plans.

b. Color code all anode lead wires green when terminated in test stations.

5. Lead Wire Connection to Magnesium Anode:

a. Cast magnesium anodes with a galvanized steel core with the weight of the core not to exceed 0.10 pounds per linear foot.

b. Recess one end of the anode to expose the core for the lead wire connection.

c. Silver-solder the lead wire to the core and fully insulate the connection by filling the recess with an electrical potting compound.

B. Sacrificial Anodes - Zinc

1. Zinc Anodes: Use high purity zinc anodes. The metallurgical composition of the zinc anodes conform to ASTM B418, Type II and the following:

Element	Percent Composition
Aluminum	0.005 Maximum
Cadmium	0.003 Maximum
Iron	0.0014 Maximum

Lead	0.003 Maximum
Zinc	Balance

2. Zinc Anode Current Capacity: Zinc anodes require a current capacity of no less than 335 amp-hours per pound of zinc.

3. Anode Backfill Material: Use chemical backfill material around all galvanic anodes. Backfill provides a reduced contact resistance to earth, provides a uniform environment surrounding the anode, retains moisture around the anode, and prevents passivation of the anode.

   a. All galvanic anodes come prepackaged in a backfill material conforming to the following composition:

      1) Ground hydrated gypsum: 75 percent

      2) Powdered bentonite: 20 percent

      3) Anhydrous sodium sulfate: 5 percent.

   b. Have a grain size backfill such that 100 percent is capable of passing through a 20 mesh screen and 50 percent is retained by a 100 mesh screen.

   c. Completely surround the anode with the backfill mixture within a cotton bag.

   d. For standard cast zinc ingots, the required weight of backfill follows:

Anode Weight (Pounds	Backfill Weight (Pounds)	Total Weight (Pounds)
30	40	70
45	55	100
60	70	130

4. Anode Lead Wires:

   a. Use a 20-foot length of No. 12 AWG solid copper wire equipped with TW or THW insulation for standard lead wires for a galvanic anode, unless otherwise stated on the Plans.

   b. Color code all anode lead wires green when terminated in test stations.

5. Lead Wire Connection to Zinc Anode:

   a. Cast zinc anodes with a 1/4-inch diameter galvanized steel core.

b. Extend one end of the core beyond the anode for the lead wire connection.

c. Silver-solder the lead wire to the core and fully insulate the connection.

C. Impressed Current Anodes

1. Description: Use high silicon-chromium-iron anode centrifugally cast in tubular form in accordance with the following specifications.

a. Anode Alloy: The anode consists of Durichlor 51, high silicon, chromium iron. This alloy to be made in accordance with ASTM A518, Grade 3 with nominal percentages as follows:

Chemical Composition

Element	Composition, Weight %
Carbon	0.70 - 1.10
Manganese	1.50, max
Silicon	14.20 - 14.75
Chromium	3.25 - 5.00
Molybdenum	0.20, max
Copper	0.50, max

b. Casting Method: Centrifugally cast anodes in tubular form with a hollow, straight walled design. Do not exceed ¼" bowing and malformation tolerances over the seven-foot anode length. Do not allow anode designs which include enlargement of the outside diameter, at the center or elsewhere, or constrictions of a venturi type of the inside wall.

The anode body to have solid walls of a uniform thickness with an open cylindrical interior. Do not allow static casting methods, such as sand, die or metal mold techniques, in order to avoid the risk of shrink cavities and internal stresses caused by non-uniform wall thickness.

Use of extraneous materials such as chaplets, spacers or chills to center the anode mold are not to be permitted. Restrict any slag deficiencies to one end of the casting only allowing for simple inspection techniques to ascertain metal density and absence of slag inclusions.

c. Mechanical and Physical Properties: The mechanical and physical properties of the anode are as follows:

Tensile Strength (1/2" dia. bar) psi.	15,000
Compressive Strength, psi.	100,000
Hardness, Brinell	520
Density, gr/ml	7.0
Melting Point, °F	2300
Specific Resistance, micro-ohms-cm (20°C)	72
Coefficient of expansion, 32° to 212° F	7.33 X 10^6

d. Size: Conform to the following sizes for anode castings:

Type	Weight (pounds)	O.D. (inches)	Length (feet)
TA-2	46	2.19	7
TA-3	63	2.66	7
TA-4	85	3.75	7
TA-5	110	4.75	7

The anode type for each location shall be per the specific site Plans.

2. Anode Lead Wire Connection:

a. Use a No. 8 AWG seven strand, copper conductor equipped with HMWPE/HALAR insulation for the lead wire for an impressed current anode. Require the length of the lead wire sufficient to reach the anode terminal box without splicing additional wire.

b. Attach the anode lead wire at the center of the anode. Have a minimum pull-out strength of one and one-half times the breaking strength of the No. 8 AWG lead wire or 788 pounds for the center connection.

c. Do not exceed 0.004 ohms for the electrical contact resistance as measured across the lead wire-to-connector junction.

3. Impressed Current Anode Backfill: Use SC3 calcined fluid petroleum coke as manufactured by Loresco, Inc. to backfill impressed current anodes. Anode backfill properties to be as follows:

a. Typical Chemical Analysis:

Component	Percent Composition
Carbon (fixed)	99.35 minimum
Ash	0.6 maximum
Volatiles	0 (950 ◦ C)

Moisture	0.05

b. Physical Properties: Bulk density of 74 pounds/cubic foot.

c. Particle Analysis: Dust free with a maximum particle size of 1 mm.

D. Miscellaneous Deep Anode Groundbed Hardware

Include the following miscellaneous components of a deep anode groundbed:

1. Venting Facilities:

   a. Use plastic vent pipe from the bottom anode to the surface for dissipating gases to the atmosphere.

   b. Require 1-inch diameter with 1/8-inch holes drilled on 6-inch centers in the area of the anodes for the plastic vent pipe. Do not drill holes in the vent pipe above the anodes.

   c. Extend the plastic vent pipe above grade, screen the vent outlet, and install in an inverted manner.

E. Rectifiers

Cathodic protection rectifiers to be air-cooled, tap adjust Super Custom model as manufactured by Universal Rectifiers, CorrPower or approved equal, conforming to NEMA MR-20-1958 and listed in CSA File No. 45382.

1. DC Output Ratings: Rate rectifiers as shown on the Plans. Supply units that are capable of operating at continuous, full rated output at an ambient temperature of 45° C, in full sunlight with an expected life in excess of 10 years.

2. AC Input Ratings: Full rated DC output shall be obtainable with an AC input voltage at 5% below the nominal value. Continuous AC input voltage at 10% above the nominal value shall not damage the transformer, the diode bridge assembly, or exceed any component rates. (Note: This shall apply provided that the rectifier has not been previously adjusted to exceed the maximum DC voltage or amperage rating of the unit.)

3. Cooling: Cool by natural air convection. Vent cabinets for natural air convection and screen against insects.

4. Voltage Adjustments: Provide adjustment of the output voltage by means of not less than 25 approximately equal steps of secondary taps from 5 percent of rated voltage to full-rated voltage.

5. Rectifying Elements: Rectifying elements to be silicon diodes sized as follows:

   a. The Peak Inverse Voltage (PIV) of the diode shall be 300% of the maximum impressed voltage on the diode or 400 volts, whichever is greater.

   b. Configure diodes into a full-wave bridge assembly. Size diodes to carry a minimum average current of one half of rated rectifier output.

   c. Size heat sinks to keep diode junction temperatures less than 100° C at rated output and maximum ambient temperature.

   d. Protect diodes against overload by means of semiconductor fuses, located in the transformer secondary leg to the diode bridge assembly.

   e. Equip diodes with supplemental Metal Oxide Varistor (M.O.V.) surge arrestors at the diode bridge assembly sized to provide protection against secondary over-voltage surges.

6. AC Circuit Breakers: Provide input overload and short circuit protection by magnetic trip circuit breakers. Size the circuit breaker to hold 100 percent of rated load. It may trip between 101 percent and 125 percent of rated load, and must trip at 125 percent and above.

7. Surge Protection: Provide separate AC and DC surge protection by means of high energy Metal Oxide Varistors rated at 500 joules on the DC output and 750 joules on the AC input.

8. Electrical Panels: Construct electrical panels from a minimum thickness of 1/4" NEMA "XX" laminated phenolic, rated for Class "B" operation (105° C maximum). Equip rectifiers rated at 100 amperes DC or higher with panels constructed from a minimum sheet thickness of 1/4" "UTR" fiberglass reinforced laminate rated for Class "F" operation (155° C). Permanently silk-screen rectifier front panel identifications onto the panel.

9. Connection Hardware: Use only copper or high conductivity brass electrical hardware, suitably sized, and finished in electroless nickel plating for superior corrosion resistance. Tightly secure all connections with lock washers and nuts torqued to manufacturer's recommended specifications.

10. Enclosures:

    a. For outdoor units mount rectifier, disconnect switch and anode junction panel in a single enclosure. For indoor units wall-mount rectifier, disconnect switch and anode junction panel.

    b. Outdoor enclosure to be free standing, NEMA 4X, 36” wide x 48” high x 24” deep, 12 gauge, type 304 stainless steel with lifting eyes.

c. Equip with single, louvered door with provisions for padlocking. Provide drip shield and inside insect screen.

d. Include ground lug, sized for No. 6 AWG wire.

e. Place stickers on all four sides that read “Danger, High Voltage, Keep Out.”

f. Provide permanent engraved nameplate with black letters on white background that reads “Cathodic Protection Cabinet, Property of North Harris County Regional Water Authority."

11. Rectifier Instrumentation.

a. Equip rectifier with separate digital ammeter and voltmeter.

b. Meters to be a minimum of 3-1/2" size, with a minimum scale length of 2-7/8".

c. Meters to be 0 - 50 millivolts full scale deflection, taut-band movement with four-to-one swamping (i.e. internal meter resistance comprised of 25% winding resistance and 75% fully temperature compensated dropping resistor for wide temperature range performance).

d. Provide meters with accuracy $\pm$ 2% full scale deflection at 25° C., temperature compensated to 0.085% per degree C.

e. Scale rectifier meters to have rated output no less than 70%, or greater than 85% of full scale deflection.

f. Meter shunts to be panel-mounted Holloway type "SW" style, with an accuracy of $\pm$0.25%.

12. Transformers: Construct transformers to meet UL 506, Specialty Transformers and the following:

a. Transformer designed as full isolation with separate isolated primary and secondary windings and a minimum efficiency of 95%.

b. Equip transformer secondary with a minimum of 25 steps of secondary voltage adjustment (5-COARSE, 5-FINE). Provide tap adjustment by means of tap bars.

c. Rate transformer materials and construction for Class "H" operation (180° C). Further enhance insulation materials by dipping in thermosetting varnish and baking.

d. Rate transformer for a minimum dielectric strength of 2250 volts applied for one minute between the windings and the core.

13. Potential Monitoring Connections: Provide two, five-way binding posts on the front of the rectifier instrument panel. One to be labeled “Reference” and one to be labeled “Structure”.

14. Miscellaneous:

a. Supply rectifiers capable of operating on either 115 or 230 volt, single phase, 60 hertz AC input.

b. All cathodic protection rectifiers to be 100% quality control tested as outlined in this specification.

c. During manufacture, subject the rectifier to frequent visual and performance testing to assure a high degree of quality.

d. Subject rectifiers to 100% testing of the following rectifier electrical parameters:

1) AC input voltage, current, apparent power and true power.

2) DC output current, voltage and power.

3) AC power factor.

4) AC to DC conversion efficiency.

5) Output ripple.

6) Correct operation of optional features such as interrupters, filters, etc.

e. Give each rectifier a final overall visual inspection prior to packaging.

F. Anode Junction Panel

1. Enclosure: For outdoor units, mount the anode junction panel in the stainless steel rectifier enclosure as shown on the Plans. For indoor units, wall-mount the anode junction panel under the rectifier. Provide positive terminal, 0.01 ohm type S~~R~~S Holloway shunts, and a minimum 3/16” thick, NEMA Grade “XX” phenolic panel. For size and terminal configurations, see specification drawing No 28.

2. Positive Cable: Use cable size ~~#4~~ #6 AWG, red insulation, single conductor, seven strand, copper with THHN insulation for the positive cable from the junction box to the transformer-rectifier.

G. Negative Cables

1. Cables: Use cable size ~~#4~~ #6 AWG, black insulation, 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.

2. Test Lead: The test lead to be No. 12 AWG, solid copper wire with white, THHN insulation and of sufficient length to extend from the protected structure to the rectifier without splicing.

H. Permanent Reference Electrodes

1. Type: Provide a copper/copper sulfate, double membrane, ceramic cell in a geomembrane package such as a Permacell Plus or approved equal.

2. Wire: Equip the electrode with No. 14 AWG stranded copper wire with blue HMWPE insulation of suitable length to attach to the terminal board of the test station without splicing.

I. Exothermic Weld Equipment

1. Charges and Molds: Select weld charges and mold size for the specific surface configuration in accordance with manufacturer recommendations. Use Erico Cadweld, or Continental Industries Thermoweld weld charges and molds.

2. Repair coating to be 2-part epoxy repair kit SPC SP-2888 or approved equal. Specific coating system used shall be completely compatible with pipe and factory-applied pipe coating materials.

J. AC Power Service

1. Products: All AC power components must meet local power company requirements.

2. Meter Base: Meter base to be 120/240-volt, single phase, 30-ampere.

3. Disconnect Switch: Provide fused disconnect switch in NEMA 1 enclosure. Mount in cathodic protection cabinet with rectifier.

4. Ground Rod: Ground rod must conform to the requirements of the utility company having jurisdiction.

5. Ground Wire and Clamp: Ground wire to be bare, No. 6 AWG solid copper wire. Use a bronze, bolt-on ground rod clamp.

PART 3 EXECUTION

3.01 – 3.02 NOT USED

3.03 ERECTION/INSTALLATION APPLICATION AND/OR CONSTRUCTION

A. Cathodic Protection System Installation

1. Installation of Sacrificial Anodes

a. Install sacrificial anodes at locations specified on the Plans.

b. Install anodes in native soil, in a vertically augured hole as shown on the Plans. If a vertical installation of the anodes is not feasible, the anodes may be installed horizontally, such changes to the design shall be submitted to the Project Manager for approval by the Engineer prior to the installation.

c. After the hole is augured, lower the packaged anode into the hole and firmly tamp the soil around the package so that it is in intimate contact with the package.

d. Run lead wires from the anodes underground at a minimum depth of 36 inches. Connect the wires through a test station as indicated on the Plans.

e. Handle galvanic anodes carefully to avoid damaging anode materials and wire connections.

2. Installation of Deep Anode Groundbeds

a. A qualified well driller who is recognized as a fully experienced specialist in the installation of deep anode cathodic protection systems is required to perform the drilling and installation of the deep anode systems. The deep anode system installer is required to have a minimum of 5 years experience installing deep anode systems with a minimum of 10 successful deep anode groundbed installations. The Contractor is required to obtain and submit all applications for well drilling permits required by any City, County or State agency.

b. Locate the anode groundbed as shown on Plans. Contractor is responsible for verifying actual field conditions, location of underground structures, and assuring adequate physical separation from other structures and utilities. Any concerns regarding obtaining AC power from the utility at specified rectifier locations or any other construction related questions shall be addressed to the Project Manager and Engineer prior to the installation. Contractor is responsible for any repairs associated with inadequate installation.

c. Perform drilling with rotary bit equipment designed specifically for this purpose. Use standard techniques (i.e. trough and vacuum truck) to capture and contain the drilling fluids, mud and cuttings at the top of the hole. Select the type and consistency of drilling fluids to be consistent with soil characteristics. Level the drilling rig to provide a round, straight and plumb anode hole.

d. Drilling of the holes may require the installation of temporary well casings. Remove all temporary casings by the end of the job.

e. As the hole is drilled, maintain a record describing the depth and type of the geological formations encountered. Submit typed copies of the log as required by Paragraphs 1.04.D and 3.08.A.8 of this specification.

f. Record an electric log of the hole using one of the anodes. Previously mark the anode lead wire in five-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 volt DC 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-volt DC 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. Record the data, time and location and submit as required under Paragraphs 1.04.D. and 3.08.A.8 of this specification.

g. 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.

h. The number of anodes and interval is per the Plans. Center the anodes in the hole using anode centralizers. Install the anodes by lowering them individually into the hole. Mark the lead wires for the nominal anode depth. Record the final depth with the first anode in the hole (i.e. the bottom anode) identified as anode number one (1). Do not damage the anode lead during handling or lowering into the hole. Under no circumstances, clamp or pinch the anode lead wires around another object while lowering the anodes into the hole. If the insulation for any anode lead wires are cut, broken, or nicked during this operation or at any other time, reject the complete anode and remove from the job site immediately. Replace all damaged anodes at no additional expense to the Owner.

i. 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 sufficient amount of backfill such that the coke breeze column extends above the top of the uppermost anode per the Plans. Install the coke backfill uniformly with no voids around the anodes.

j. Terminate the 1-inch diameter internal vent pipe with a gooseneck fitting. Leave the top end of the vent pipe open to allow gases from the anode hole to exit. The inactive column shall be filled with soil or bentonite per the Plans and environmental requirements. If bentonite is required, use Aquaplus or approved equal.

k. 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.

l. Dispose of drilling mud, cuttings and other waste in accordance with the methods and procedures of the best recognized practices and comply with the rules and regulations of the State, City and County.

m. Cap PVC casing aboveground. Pour a 4’ x 3’ steel reinforced concrete pad as shown on the Plans.

3. Installation of Cathodic Protection Rectifiers

a. Comply with the latest edition of the NFPA National Electrical Code and with all City of Houston, and local power company codes and standards.

b. Mount rectifiers on reinforced concrete pad as shown on the Plans. Place at elevation above the 100-year flood plain.

c. Equip rectifiers with permanent engraved nameplates to identify the units as "Cathodic Protection Cabinet, Property of North Harris County Regional Water Authority.”

d. Place all wiring to the rectifier in rigid galvanized steel conduit when run above grade.

1) Use insulating bushings at the ends of all conduits.

2) Extend steel conduit 12 inches below grade.

e. Provide AC electrical service for each rectifier unit. Furnish and install the necessary wiring, conduits, wires, meter sockets, splice boxes and equipment to the service connection as required by the local power company.

f. Notify Project Manager for Engineer to inspect the rectifier installation prior to energization. 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.

4. Installation of Wire and Cable

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

1) Use insulating bushings at the ends of all conduits.

2) Extend conduit 12 inches below grade.

5. Installation of Anode Junction Panel

a. For outdoor units, 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 one foot above grade. For indoor units, wall-mount the anode junction panel in a fiberglass box, at a distance of one foot under the rectifier.

b. Contractor is responsible for replacing all malfunctioning anodes at no cost to the Owner.

6. Negative Cable and Test Lead Attachment

a. 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.

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

c. 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.

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

e. Using the proper size exothermic weld mold as recommended by the manufacturer, place the wire between the graphite mold and the prepared metal surface. Use a copper sleeve crimped over the wire for all wires No. 12 AWG size.

f. Place the metal disk in the bottom of the mold.

g. Pour the exothermic charge to the mold. Squeeze the bottom of the weld charge container and spread ignition powder over the charge, in case that it is consistent with the manufacturer specification.

h. Close the mold cover and ignite the starting powder with a flint gun. Hold the mold firmly in place until all of the charge has burned and the weld has cooled slightly.

i. Remove the exothermic weld mold and gently strike the weld with a hammer to remove the weld slag. Pull on the wire to assure a secure connection. If the weld is not secure or the wire breaks, repeat the procedure.

j. If the weld is secure, coat all bare metal and weld metal with 2-part epoxy.

7. Permanent Reference Cell

a. Install the permanent reference cell at all test station locations.

b. Remove the permanent reference cell from the shipping package. Totally submerge the reference electrodes in a 5-gallon bucket of potable water for a minimum period 15 minutes. Brackish water or saltwater will not be allowed. Measure the accuracy of each copper/copper sulfate reference electrode before installation by measuring the DC voltage difference between it and another reference electrode of known accuracy. The measurements shall be within the written DC voltage calibration as specified by the reference electrode manufacturer. Reference electrodes that do not comply with the manufacturer's stated calibration shall not be used. The reference electrode data shall be recorded and included in the as-built documentation submitted to the Owner.

c. Place below the springline and 6-inches from the pipeline.

d. 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.

e. Backfill the reference electrode with six inches of select, native soil and compact by hand. Moisten the soil, if necessary, for good compaction.

3.04 – 3.07 NOT USED

3.08 DEMONSTRATION / TESTING AND INSPECTION

A. Post Installation Testing of the Cathodic Protection Systems

1. General: Inspect, energize, and adjust the cathodic protection as soon as possible after the equipment has been installed.

2. Continuity testing: 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.

a. 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 and no more than 1,000 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.

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

c. 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% 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% 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.

3. Energization: Perform the energizing of the cathodic protection system by a Corrosion Engineer to achieve compliance with the referenced corrosion control standards set forth by NACE and/or AWWA.

4. Notice: Prior to native state and polarized potential testing, give a minimum of 48 hours notice to the Project Manager and Engineer to facilitate observation of the tests by the Owner's Representative.

5. Method: The Corrosion Engineer to:

   a. Measure native state pipe-to-soil potentials at all test stations, permanent reference cells, electrical isolation devices, and locations of exposed pipe prior to energizing the cathodic protection system. Contractor to provide corrosion engineer proof of isolation devices including flange isolators and casing spacers are installed and operating properly.

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

   c. Energize the cathodic protection system and adjust the DC current output such that the pipe-to-soil potentials near the cathodic protection current source (either transformer-rectifier or sacrificial anodes) is approximately -1000 millivolts to a permanent copper sulfate reference cell (CSE). Record the DC voltage and current of the power supply.

   d. Allow a minimum time for the pipeline to polarize, typically 2 weeks.

   e. Using a current interrupter, cycle the power supply "On" and "Off". If multiple rectifiers are installed and the pipeline is continuous, interrupt all the rectifiers simultaneously.

   f. Record "On" and "Instant Off" potentials at all water pipeline test stations, permanent reference cells, electrical isolation devices, locations of exposed pipe, casings and foreign pipelines.

   g. For steel and ductile iron pipe, adjust the cathodic protection power supplies to satisfy the criteria of a minimum 100 millivolts of polarization or an "Instant Off" potential at least as negative as -850 millivolts CSE.

   h. For concrete cylinder pipe, adjust the cathodic protection power supplies to achieve a minimum 100 millivolt of polarization without any "Instant Off" potentials more negative than -1000 millivolts CSE.

   i. Record all final adjustments of the DC power supplies.

j. Verify that interference does not exist with foreign pipelines. Perform joint tests and provide recommendations for mitigation any interference.

6. After initial energization and after rectifiers have been adjusted as necessary for compliance with NACE SP-0169-2013, perform a walk-through inspection with Project Manager to verify that all corrosion control components have been installed in accordance with Plans and specifications.

7. Make a punch list of outstanding work identified during walk-through inspection. Once Contractor has completed all work on punchlist, pipeline will be allowed to polarize for 30 days before final testing. Perform final testing and adjustment after 30-day polarization period. Repair deficiencies discovered during final testing at Contractor's expense and at no additional cost to the Owner.

8. Equipment: All cathodic protection testing instruments to be in proper working order and calibrated according to factory specifications.

9. Report: Submit a written report in accordance with Section 1.04, Submittals.

3.09 – 3.10 NOT USED

END OF SECTION