

SECTION 1408

CORROSION MONITORING AND CATHODIC PROTECTION

1408.0100 GENERAL

1408.0101 Description of Work. The work under this section shall consist of furnishing all labor, tools, and equipment required to install or reinstall a corrosion monitoring system and cathodic protection system to 16-inch diameter or larger metallic material pipelines. This includes corrosion test stations (CTSs), sacrificial anodes, wiring, connections, and joint jumper bonds. Where applicable, the Contractor is responsible for obtaining all permits required to complete the work.

1408.0102 Reference Standard. The current version of the following publication existing at the time of bid advertisement shall form a part of these special specifications to the extent referenced:

- NACE SP0169-2007 Standard Recommended Practice, Control of External Corrosion on Underground or Submerged Metallic Piping Systems.

1408.0103 Submittals. The following submittals are required:

(A) Qualifications. Resumes and qualifications of the Cathodic Protection Specialists, Corrosion Technologists, and Corrosion Technicians whose services are proposed for this work.

(B) New Materials. New material submittals including drawings, catalog cut sheets, and other information regarding non-approved products to be furnished and installed on this project. Submittals for materials noted in this section and in TW Standard Details 700 through 711 are not required.

(C) Field Changes. The corrosion monitoring system shall be installed in accordance with the plans and specifications and TW Standard Details 700 through 711. Field changes to the corrosion monitoring system—including CTS locations and types, and the location and type of insulating fittings—shall be submitted with the Final Report and indicated on the redlined drawings.

(D) Final Report. Three copies of the Final Report—including field tests and data, Engineer's comments, and other pertinent information regarding the corrosion monitoring and cathodic protection systems—as specified in Subsection 1408.0305(C). One copy of the Final Report, including tables, shall also be provided in a digital format compatible with Microsoft Word and Microsoft Excel. All items shall be submitted to the Construction Section prior to final acceptance.

1408.0104 Delivery, Storage, and Handling. All materials shall be stored aboveground and protected against weather, condensation, and mechanical damage. Materials shall be handled with care to avoid damage.

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Equipment or materials damaged during shipment or in the course of installation shall be replaced. All damaged materials shall be promptly removed from the project site.

In order to minimize potential for damage during manufacture, shipment, storage, and installation, wire shall not be sharply bent nor tightly coiled.

1408.0200 PRODUCTS

1408.0201 Materials.

(A) Corrosion Test Stations (CTSs). Corrosion test stations shall be in accordance with TW Standard Details 700 through 711 and these specifications. Below-grade CTSs will be allowed on a case-by-case basis with the Project Manager's and Maintenance Quality Control Manager's approval. Above-grade CTSs shall be per TW Standard Detail 706. CTS stranded wire conductors shall be terminated on a linen grade phenolic resin board as per TW Standard Detail 705. The lid for below-grade test stations on potable water lines shall be painted using Seymour Precaution Blue, Sprayon APWA Blue, or approved equal. The lid for below-grade test stations on reclaimed water lines shall be painted using Seymour Safety Purple or approved equal. Concrete utilized in the installation of CTSs shall have a minimum 28-day compressive strength of 2,500 pounds per square inch.

(B) Wire and Cable. Wire and cable shall be continuous annealed, uncoated, stranded copper with 7/64-inch thick high molecular weight polyethylene (HMWPE) insulation conforming to ASTM D1248, Type 1, Class A, Category 5, Grades E4 and E5. The insulation shall be surface indented or printed. CTS wires shall be #6 and #10 AWG, joint bond wires shall be minimum #2 AWG, sacrificial anode and zinc ribbon ground mat wires shall be #8 AWG, foreign utility test wires shall be per Owner standards, and new cathodic protection rectifier structure leads shall be #4 AWG (HMWPE). Please note: new structure wire lead shall be one continuous lead from pipe to new or existing rectifier—no exceptions. Reference electrode leads shall be as provided by the manufacturer for the length being installed. Wire sizes other than those listed in this section are not acceptable.

Identification of individual test leads shall be made using vinyl electrical tape spaced at 3-foot intervals, except inside the test station where the tape spacing shall be at 6-inch intervals. Vinyl electrical tape shall be 3M super 33+ Scotch Brand, or approved equal. Color coding of the electrical tape shall be in accordance with Table 1408-1 below.

Stranded copper conductors shall be identified by surface markings indicating conductor size, manufacturer, and insulation material. All new HMWPE stranded copper conductors shall be continuous (without splices) from the connection at the pipe, anodes, fittings, valves, etc. to the CTS. Splicing of anode leads is acceptable in sacrificial anode header cable applications only. See TW Standard Detail 700.

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Table 1408-1
Wire Color Codes

Color	Source
White	New Transmission Main
Blue	Casing Pipe (Jack and Bores)
Black	Foreign Metallic Pipeline
Yellow	Permanent Reference Cell
Orange	Isolated Pipe, Valve, Fitting, or Existing Pipeline, etc.
Red	Anode
Green	Negative Structure Lead to Rectifier off of Protected Pipe

(C) Exothermic Brazing Materials. Exothermic brazing (weld) materials shall consist of wire sleeves, welders, weld cartridges, and molds in accordance with both Table 1408-2 below and the weld manufacturer's recommendations for each wire size and pipe or fitting size material. Weld materials and equipment shall be the product of a single manufacturer. Interchanging materials of different manufacturers is not acceptable.

See Table 1408-2 on the next page.

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**Table 1408-2
Exothermic Welding Materials for Ductile Iron Pipe**

Manufacturer	Welder	Weld Metal	Conductor	Sleeve	Pipe Diameter (inches)
	CAHBA-1G-16	CA25XF-19	#10	B133-1L	16
	CAHBA-1H-16	CA25XF-19	#6	--	16
	CAHBA-1V-16	CA45XF-19	#6	B112	16
	CAHBA-1V-16	CA45XF-19	#2	--	16
	CAHBA-1G-24	CA25XF-19	#10	B133-1L	24
	CAHBA-1H-24	CA25XF-19	#6	--	24
	CAHBA-1V-24	CA45XF-19	#6	B112	24
	CAHBA-1V-24	CA45XF-19	#2	--	24
	CAHBA-1G	CA25XF-19	#10	B133-1L	OVER 24
	CAHBA-1H	CA25XF-19	#6	--	OVER 24
	CAHBA-1V	CA45XF-19	#6	B112	OVER 24
	CAHBA-1V	CA45XF-19	#2	--	OVER 24
	M-159-16	45CI	#10	A-201	16
	M-157-16	25CI	#6	--	16
	M-161-16	45CI	#6	A-202	16
	M-161-16	45CI	#2	--	16
	M-159-24	45CI	#10	A-201	24
	M-157-24	25CI	#6	--	24
	M-161-24	45CI	#6	A-202	24
	M-161-24	45CI	#2	--	24
	M-159	45CI	#10	A-201	OVER 24
	M-157	25CI	#6	--	OVER 24
	M-161	45CI	#6	A-202	OVER 24
	M-161	45CI	#2	--	OVER 24

All exothermic welds, stranded copper conductors, and exposed portions of the pipe shall be covered with an approved exothermic welding cap in accordance with the manufacturer's recommendations, TW Standard Details 700 through 711, and the Approved Materials List (Appendix A). If not applicable, an approved coating product will be used as per manufacturer recommendations.

(D) Wire Connector Terminals. Wire connector terminals shall be installed in accordance with the manufacturer's recommendations, as well as TW Standard Details 700 through 711 and the Approved Materials List (Appendix A).

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(E) Flange Insulating Kits. Flange Insulating Kits shall be installed in accordance with the manufacturer's recommendations, as well as TW Standard Details 700 through 711 and the Approved Materials List (Appendix A).

(F) Joint Bonds. All pipe sections, fittings, mechanically restrained fittings, bolted joint assemblies, gasket joint assemblies, and valves shall be coupled using no fewer than 2 bonding conductors/joint bonds. Fully welded concrete cylinder pipe and steel pipe joints shall not require joint bonds. Joint bonds shall be installed at all pipe connections except those connections called out to be electrically isolated. For ductile iron pipe, the number and size of joint bonds shall be as indicated in Table 1408-3 below.

**Table 1408-3
Joint Bonds for Ductile Iron Pipe**

Diameter (inches)	Class (psi)	Number of Conductors	Size (AWG)	Max. Length (inches)
16	250	2	2	24
16	350	2	2	18
24	200	2	2	16
24	350	3	2	18
30	200	4	2	22
30	350	4	2	18
36	200	5	2	18
36	350	5	2	16
42	200	6	2	16
42	350	7	2	16

The values in Table 1408-3 were determined using the following equation to calculate the electrical resistance in a length of pipe, based on the criteria that the electrical resistance due to bonding conductors per 1,000 feet of pipe shall not exceed 150 percent when compared to the electrical resistance of 1,000 feet of pipe:

$$I = (1 + R_B/R_P)100$$

Where:

I = Percent increase in electrical resistance

R_B = Resistance, in ohms, of the bonding conductors per 1,000 feet of pipe

R_P = Resistance, in ohms, of 1,000 feet of pipe calculated as follows:

Steel: $R_P = 0.22/W_P$

DIP: $R_P = 0.86/W_P$

W_P = Weight of pipe in pounds per linear foot

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The Contractor may submit to the Engineer for approval alternatives to the joint bonds contained in Table 1408-3 provided they meet these resistance requirements. However, the Contractor is required to submit to the Engineer for approval proposed joint bonds for CCP, PCCP, or steel pipe.

(G) Detectable Tape. Detectable tape shall be aluminum foil imprinted on one side, encased in a high-visibility blue, inert polyethylene jacket. Tape shall be 2 inches wide and no less than 5.5 millimeters thick. Imprinted lettering shall be 1 inch tall, permanent black, and shall read, "CAUTION – CORROSION TEST LEAD BURIED BELOW CONTACT TUCSON WATER". Joining clips shall be manufacturer's standard tin or nickel coated. Tape shall be as manufactured by Reef Industries (Terra "D"), Allen (Detectatape), or approved equal.

(H) Sacrificial Anodes. Sacrificial anodes shall be high-potential magnesium anodes, as manufactured by Harco, Farwest, Mesa Products, or approved equal. The bare anode ingot shall be either 17 or 32 pounds as indicated on the plans or in the special provisions. The anode ingot shall contain the alloy combination specified in TW Standard Detail 700, Sheet 5, Table 700-4.

The normal combined weight of the anode ingot and backfill shall be approximately 51 pounds for the 17-pound bare anode and 70 pounds for the 32-pound bare anode. Sacrificial anodes shall be prepackaged in a cloth bag with 75 percent gypsum, 20 percent bentonite, and 5 percent sodium sulfate. Anode lead wire shall be long enough such that no splices exist between the anode and the CTS, except in header cable applications. Anode lead wire shall be #8 AWG continuous stranded copper wire with HMWPE insulation, black. The anode lead wire shall be attached to the galvanized steel anode core by 45 percent silver solder connection.

(I) Splice Kit. 3M 82-A and 82-B1 series splice kits shall be used to insulate and moisture seal the magnesium anode lead to header cable connection. Splice kit shall be installed per the manufacturer's recommendations.

(J) Wire Connector. Anode wire to header cable connection shall be made with Burndy C crimp YC4C8 connectors, or approved equal. Crimp connector size shall be per manufacturer's recommendation for #8 AWG stranded copper to #6 AWG stranded copper wire connections.

(K) Rubber Splicing Tape. Rubber splicing tape shall be installed to cover all exposed copper at the crimp connection. Rubber splicing tape shall be 3M 23 Scotch Brand, or approved equal.

(L) Vinyl Electrical Tape. Vinyl electrical tape shall be 3M Super 33+ Scotch Brand, or approved equal.

(M) Zinc Caps. Threaded zinc caps shall be installed on the steel bolts of flange insulating kits. Zinc caps shall meet the requirements of MIL-A-18001J and ASTM B418-80. Threaded zinc caps shall be as manufactured by Mars Company, or approved equal.

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1408.0300 EXECUTION

1408.0301 General. The drawings indicate the extent and general arrangement of the corrosion protection system including CTSs, sacrificial anodes, impressed current systems, and appurtenances. Any changes to the corrosion protection system design or method of installation shall be reviewed by the Engineer prior to installation.

Reasons for proposed changes to the corrosion protection system design or method of installation—along with details of those changes—shall be submitted to the Engineer for review at least 10 working days prior to the proposed installation date.

The Contractor shall inspect the project site and shall review the location of existing utilities, structures, and appurtenances prior to starting construction. He/she shall also promptly notify the Engineer if the location, type, or number of existing utilities, structures, and appurtenances differs substantially from the information provided on the drawings.

The Contractor shall be responsible for notifying and coordinating the corrosion protection system installation with foreign utility company representatives prior to beginning construction. The Contractor shall notify El Paso Natural Gas Company, Southwest Gas Corporation, Kinder Morgan, and Central Arizona Project at least 5 working days prior to construction near gas pipelines.

The Contractor shall be responsible for the protection of existing utilities, structures and appurtenances, and the proper routing of buried cable and location of CTSs.

Installation of the corrosion monitoring and cathodic protection system, as described herein and shown on the drawings, shall be in accordance with the following:

- (1) Applicable portions of the latest National, State, County, and City electrical codes and regulations
- (2) Pima County and City of Tucson construction permit conditions
- (3) Manufacturer's recommendations and instructions
- (4) TW Standard Details 700 through 711

All work shall present a neat and finished appearance.

Elements of the corrosion protection system shall be installed within the limits of existing right-of-way and utility easements.

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All stranded copper conductors between the pipe and CTS shall be brought up from the pipe joint nearest to the CTS indicated on the drawings.

CTSs shall be installed at locations indicated on the drawings. CTS locations include:

- Beginning and end of the pipeline
- All insulating fittings
- All metallic foreign line crossings.
- Locations of dissimilar materials
- Intervals of approximately 1,000 linear feet along the pipeline

The Contractor shall salvage any existing corrosion test box(es), lid(s), extension(s), and phenolic resin terminal board(s). All salvage components shall be returned to the Tucson Water Maintenance Division, in accordance with TW Standard Detail 705.

1408.0302 Installation.

(A) General. All installation and testing shall be performed by or under the direct supervision of a NACE International Certified Corrosion Technologist. All work shall be consistent with sound corrosion engineering practice.

(B) CTS Locations. Flush-grade CTSs will be allowed on a case-by-case basis with the Project Manager's and Maintenance Quality Control Manager's approval. Above-grade CTSs shall be field located 12 feet beyond pavement edges where no curb exists or 2 feet from property line, fences, easements, or as otherwise shown on the plans.

(C) Foreign Test Leads. The Contractor shall notify the Engineer 5 working days prior to installing foreign line test leads, and the Contractor shall coordinate with the Owner of the foreign line for said installations. The Contractor shall contact the following utilities at least 2 weeks prior to excavating in the area of a foreign line owned by one of the following companies:

**Table 1408-5
Pipeline Contact Information**

Company	Phone
Southwest Gas	(520) 794-6025
El Paso Natural Gas	(520) 663-4258
Kinder Morgan Energy Partners	(520) 746-4985
Central Arizona Project	(623) 869-2333

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The Contractor may be required to uncover the foreign line so that others can attach the HMWPE stranded copper conductors to the foreign line. He/she shall furnish materials and may be required to install all HMWPE stranded copper conductors from the foreign line to the CTS.

(D) Trenches. Direct burial cables, underground conduit, and wires shall be installed in a clean trench free of debris, rocks, or other material that may damage the insulation or conduit. All cables shall be placed in the trench with sufficient slack to prevent strain. All cables shall be installed a minimum of 36 inches below final grade. Blue detectable tape shall be installed over wires and 24 inches below grade. Detectable tape shall be installed along the centerline of the wires.

Trenches shall be carefully backfilled with clean excavated soil and compacted as required by local code, or to 90 percent relative compaction as referenced by ASTM D698. Care shall be taken to prevent damage to the cable during backfill and compaction of trenches.

(E) Splicing. If splicing of stranded copper conductors is required and approved by the Project Manager and Quality Control Manager, the new conductor shall be spliced to the old conductor of the same size by “butting” stripped conductor ends inside an appropriately sized aluminum compression connector. The connector shall be crimped using a tool specified by the connector manufacturer, and the new connection shall be sealed with a hot shrink splice for non-shielded conductors. The shrink splice shall be sized to completely cover the aluminum compression connector and any exposed wire, and shrunk to form a watertight seal. If existing conductors are not #6, #8, or #10 size, the Tucson Water Inspector shall be contacted for instruction. Splices in underground cable shall be made only where specified or approved by the Engineer. Splices to new or existing cathodic protection rectifier systems are prohibited. In the event a splice is required, a new lead will be installed from the rectifier to the pipeline.

(F) Sacrificial Anodes. Sacrificial magnesium anodes shall be installed at the locations indicated on the drawings. The sacrificial anode paper bag shall be removed and soaked thoroughly with water just prior to installation. Anodes shall be laid horizontally in the trench, equidistant from the water line and foreign utility, if applicable. Clean fill free of rocks and debris shall be used to backfill the anode to a height of 1 foot above the anode. Water shall be used to saturate the soil backfill around the anodes immediately after installation. The soil backfill shall be saturated immediately after the sacrificial anodes are installed. Care shall be taken to prevent stressing or damaging the anode lead wire during installation and backfill procedures. The anodes shall not be suspended by the lead wire at any time, prior to or during installation. 24 hours prior to burial, the Contractor shall verify that the anodes are properly installed. At a minimum, verification shall include testing and photography of each anode.

(G) Exothermic Welding. All exothermic welding and coating shall be performed in accordance with TW Standard Detail 703.

(H) Wire to Zinc Ribbon Connections. Wire to zinc ribbon connections shall be made by removing 2 inches of the zinc material from the galvanized core. The ribbon core and wire shall

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be spliced using a C-Type crimp connector of appropriate size per the manufacturer's recommendation. All exposed ribbon core and copper wire shall be thoroughly covered with 2 layers of 50 percent overlap spiral-wrapped rubber splicing tape. Rubber splicing tape shall then be covered with 2 layers of vinyl electrical tape extending no less than 1 inch beyond the rubber tape on both ends of the spliced area.

1408.0303 Warranty. All workmanship, materials, and equipment provided and installed by the Contractor shall be guaranteed for a period of 2 years from the date of substantial completion.

1408.0304 Quality Assurance. Firms providing services for the installation of the corrosion monitoring and cathodic protection systems shall meet the following qualifications:

- (1) Maintain a full-time NACE International Certified Cathodic Protection Specialist on staff
- (2) Possess a minimum of 5 years' experience in each of the following areas:
 - (a) Designing corrosion monitoring systems for pipelines 16 inches in diameter or greater for the pipe material being installed
 - (b) Conducting corrosivity studies on the pipe material being installed for corrosion problems and mitigation of stray current interference
 - (c) Installing sacrificial anode or impressed current cathodic protection systems on pipelines 16 inches in diameter or greater of the pipe material being installed
 - (d) Installing sacrificial anode or impressed current cathodic protection systems on water reservoirs and tanks

Upon request, the Contractor will be required to submit verification of these qualifications prior to issuance of the Notice to Proceed.

1408.0305 Testing.

(A) General. The Contractor shall provide all testing and startup services required to verify the corrosion protection system is installed and operational; this includes furnishing all equipment and labor required to perform all testing and startup services. All testing and startup services shall be performed by or under the direct (in the field) supervision of a NACE International Certified Cathodic Protection Specialist and shall be consistent with sound corrosion engineering practice. The Contractor shall verify the installation of zinc caps on the steel bolts of flange insulating kits and note this information in the Final Report.

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(B) Requirements. The Contractor shall perform the following tests on the Cathodic Protection and Corrosion Monitoring System, if applicable:

- (1) Station integrity test. This shall be performed by applying current to the pipeline and recording the I(on) and I(off) potentials at each CTS.
- (2) Pipeline native (static pipe-to-soil) potentials at each CTS.
- (3) Pipeline electrical continuity (current test).
- (4) Effectiveness of flange insulating kits (insulating joints) both before and after burial.
- (5) Verification of casing isolation.
- (6) Measurement of soil resistivity at each test station at 5-, 10-, and 15-foot depths using the Wenner 4-pin method.
- (7) Stray current tests. The Contractor shall coordinate with the foreign utility Owner for joint test procedure.
- (8) Potentials of foreign structures before and after correction of stray current interference.
- (9) Evaluation of interference effects from or to adjacent utility systems and structures. A description of all corrections made for interference effects shall be documented. These tests and corrections shall be coordinated with respective utility operators.
- (10) Pipeline span resistance between adjacent test stations.
- (11) Rectifier location and outputs in volts and amperes from impressed current systems on foreign pipelines and from locations used to perform the current tests.
- (12) Pipe-to-soil potentials before and after connection of sacrificial anodes.
- (13) Current output of each anode or anode header cable as measured across a 0.01-ohm shunt.
- (14) Location, size, and drainage current of each resistance bond installed for mitigation of stray current effects (if necessary).

The Contractor shall provide the Engineer with 3-day advance notice before beginning tests. All testing shall be performed under the direct supervision of a NACE International Certified Corrosion Technologist, and then reviewed and verified by a NACE International Certified

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Cathodic Protection Specialist. If any tests reveal that the installation does not meet the project specifications, the Contractor shall perform all repairs and retests at no cost to the Owner.

The Contractor shall submit for the Engineer's approval a final report, including all test results, within 30 calendar days of completion of testing.

(C) Final Report. Within 60 calendar days of completing all corrosion monitoring and cathodic protection system installation, the Contractor shall submit 3 hard copies of the Final Report to the Engineer for approval. The report shall include the following:

- (1) Field tests and data outlined in Subsection 1408.0105(B), above
- (2) Engineer's comments
- (3) Verification that each new or related corrosion component is installed per the standard specifications and working as designed
- (4) Identification of any existing or potential "hot spots" where corrosion is a concern
- (5) Comparison of the theoretical resistivity to the actual resistivity of the transmission main
- (6) List of all equipment and labor required to perform the testing outlined above
- (7) Photographs with descriptive captions of all corrosion monitoring and cathodic protection system components installed by the Contractor
- (8) Other pertinent information regarding the corrosion monitoring and cathodic protection systems

One copy of the Final Report, including tables, shall also be provided in a digital format compatible with Microsoft Word and Microsoft Excel. The Engineer will review the report for compliance with the plans and specifications and will notify the Contractor of final acceptance or the need for revisions. Acceptance of the Final Report will be required prior to substantial completion of the project.

1408.0306 Record Drawings. The Contractor shall redline the project drawings at each CTS, foreign line crossing, and sacrificial anode installation. The redlined drawings shall be performed per acceptable standards and Owner approval.