

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, including corrosion test stations (CTS), 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 RP 0169 Standard Recommended Practice, Control of External Corrosion on Underground or Submerged Metallic Piping Systems.

1408.0103 Submittals. The following submittals are required:

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

(B) 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 the Tucson Water SD-700 Series Standard Water Details are not required.

(C) The corrosion monitoring system shall be installed in accordance with the plans and specifications and Tucson Water SD-700 Series Standard Water Details. Field changes to the corrosion monitoring system, including corrosion test station locations and types, and the location and type of insulating fittings, shall be submitted with in the Final Report and indicated on the redlined drawings.

(D) Three (3) copies of the Final Report, including field tests and data, ENGINEER'S comments, and other pertinent information pertaining to the corrosion monitoring and cathodic protection systems, One (1) copy of the Final Report, including tables, shall also be provided on a compact disc (CD) in a format compatible with Microsoft Word and Microsoft Excel. All items shall be submitted to the Construction Section prior to final acceptance.

1408.0104 Personnel. 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.

1408.0105 Qualifications. Firms providing services for the installation of the corrosion monitoring and cathodic protection systems shall meet the following qualifications:

- Minimum of five (5) years experience designing corrosion monitoring systems for 16-inch diameter or greater pipelines, for the pipe material being installed.
- Maintain a full time NACE International-Certified Cathodic Protection Specialist on staff.

SECTION 1408

- Minimum of five (5) years experience in conducting corrosivity studies on the pipe material being installed for corrosion problems and mitigation of stray current interference.
- Minimum of five (5) years experience in installation of sacrificial anode or impressed current cathodic protection systems on 16-inch diameter and greater pipelines of the pipe material being installed.

The CONTRACTOR, upon request, will be required to submit verification of these qualifications prior to Notice to Proceed.

1408.0200 PRODUCTS

1408.0201 Materials

(A) **Corrosion Test Stations.** Corrosion test stations (CTS) shall be in accordance with Tucson Water Standard Water Details SD-700 Series and these specifications. Below grade CTS shall be per Tucson Water Standard Detail SD-705. Above grade CTS shall be per Tucson Water Standard Detail SD-706. CTS stranded wire conductors shall be terminated on a linen grade phenolic resin board as per SD-705. The lid for below grade test stations on potable water lines shall be painted using Seymour Precaution Blue, Spray on 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 2500 psi.

(B) **Wire and Cable.** Wire and cable shall be continuous stranded copper with 7/64-inch thick high molecular weight polyethylene (HMWPE) insulation. Corrosion Test Station 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. Identification of individual test leads shall be made using vinyl electrical tape spaced at three foot intervals, except inside the test station where the tape spacing shall be at six 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 the following table:

**Table 1408-1
Wire Color Codes**

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

SECTION 1408

Stranded copper conductors shall be identified by surface markings indicating conductor size, manufacturer, and insulation material. All new HMW/PE stranded copper conductors shall be continuous (without splices) from the connection at the pipe, anodes, fittings, valves, etc. to the corrosion test station (CTS).

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

**Table 1408-2
Exothermic Welding Materials for DIP**

Erico-Cadweld:				
Welder	Weld Metal	Conductor	Sleeve	Pipe Dia.
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"
Continental-Thermoweld:				
Welder	Weld Metal	Conductor	Sleeve	Pipe Dia.
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"

Each exothermic weld, stranded copper conductors, and exposed portions of the pipe shall be covered with an approved exothermic welding cap as per manufacturer recommendations. If not applicable, an approved coating product will be used as per manufacturer's recommendations. Welding caps shall be

SECTION 1408

Calpico Model “T” Cap, Royston Handy Cap, or approved equal. Primers shall be Calpico #22 primer, Royston Robond 747 primer, or approved equal. Exothermic weld coating products shall be Royston Roskote R-28, Calpico #10 mastic, or approved equal.

(D) Wire Connector Terminals. A one piece compression connector shall be installed on the end of all stranded wire before connecting to the corrosion test station terminal board in accordance with Tucson Water Standard Water Details SD-705.

(E) Flange Insulating Kits. Flange Insulating Kits shall be “Trojan Quad Seal” type E phenolic with one piece integral sleeves and phenolic washers as manufactured by Advance Products and Systems, or approved equal, and installed per Tucson Water Standard Water Detail SD-704. CONTRACTOR shall install threaded zinc caps on the ASTM A307, Grade A steel bolts on the flange insulating kits.

(F) Joint Bonds. All pipe sections, fittings, mechanically restrained fittings, bolted joint assemblies, gasket joint assemblies, and valves shall be coupled using a minimum of two (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 pipe connections called out to be electrically isolated. For ductile iron pipe, the following table outlines the number and size of joint bonds:

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

Diameter (in)	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 utilizing Equation 1408-1 below for calculating the electrical resistance in a length of pipe and the criteria that the electrical resistance due to bonding conductors per 1000 feet of pipe shall not exceed 150 percent when compared to the electrical resistance of 1000 ft of pipe.

$$I = (1 + R_B/R_P)100 \quad \text{Equation 1480-1}$$

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 1000 feet of pipe calculated as follows:

SECTION 1408

$$R_P = 0.22/W_P \text{ (Steel)} \quad R_P = 0.86/W_P \text{ (DIP)}$$

W_P = Weight of pipe in pounds per linear foot

The CONTRACTOR may submit, to the ENGINEER for approval, alternatives to the joint bonds contained in Table 1480-1, provided that they meet the resistance requirements outlined above. 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 a minimum of 5.5 mils thick aluminum foil imprinted on one side, encased in high visibility blue inert polyethylene jacket. Tape shall be 2-inches wide. 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 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 pounds or 32 pounds as indicated on the plans, or in the special provisions. The anode ingot shall contain that alloy combination contained in Table 1408-4 below.

**Table 1408-4
Anode Ingot Composition**

Component	Fraction by Weight
Aluminum	5.3% - 6.7%
Zinc	2.5% - 3.5%
Manganese	0.15% Min.
Silicon	0.10% Max.
Copper	0.02% Max.
Nickel	0.002% Max.
Iron	0.003% Max.
Impurities	0.20% Max.
Magnesium	Remainder

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% gypsum, 20% bentonite, and 5% sodium sulfate. Anode lead wire shall be long enough so 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% 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 manufacturers recommendations.

SECTION 1408

- (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 manufacturers 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. The threaded zinc caps shall be as manufactured by Mars Company, or approved equal.

1408.0300 EXECUTION

1408.0301 General

(A) The drawings indicate the extent and general arrangement of the corrosion protection system including corrosion test stations, 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.

(B) The reasons for proposed changes to the corrosion protection system design or method of installation, and details of proposed changes, shall be submitted to the ENGINEER for review at least ten (10) working days prior to date of proposed installation.

(C) The CONTRACTOR shall inspect the project site and shall review the location of existing utilities, structures, and appurtenances prior to the start of construction. The CONTRACTOR shall 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.

(D) The CONTRACTOR shall be responsible for notification and coordination of the corrosion protection system installation with foreign utility company representatives prior start to construction. The CONTRACTOR shall notify El Paso Natural Gas Company, Southwest Gas Corporation, Kinder Morgan, and Central Arizona Project at least five (5) working days prior to construction near gas pipelines.

(E) The CONTRACTOR shall be responsible for the protection of existing utilities, structures and appurtenances, and the proper routing of buried cable and location of corrosion test stations.

(F) The installation of the corrosion monitoring and cathodic protection system, as described herein and shown on the drawings, shall be in accordance with the following: applicable portions of the latest National, State, County, and City electrical codes and regulations; Pima County and City of Tucson construction permit conditions; manufacturer's recommendations and instructions;

SECTION 1408

and Tucson Water Standard Water SD-700 Series Details. All work shall present a neat and finished appearance.

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

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

(I) Corrosion Test Stations (CTS) shall be installed at the locations indicated on the drawings. CTS locations include the beginning and end of the pipeline, at all insulating fittings, at all metallic foreign line crossings, at locations of dissimilar materials, and at intervals of approximately 1,000 linear feet along the pipeline.

(J) 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 Operations and Maintenance Division, in accordance with SD-705.

1408.0302 Installation

(A) **Protection of Materials.** All materials shall be stored above the ground, and protected against weather, condensation, and mechanical damage. 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. Materials shall be handled with care to avoid damage. All wire shall not be sharply bent or tightly coiled to minimize potential for damage during manufacture, shipment, storage, and installation.

(B) **CTS Locations.** Flush grade CTSs shall be field located for permanency 2 feet behind present or future curb. 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 is to notify the ENGINEER five (5) working days prior to the installation of 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 two 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

The CONTRACTOR may be required to uncover the foreign line so that others can attach the HWM/PE stranded copper conductors to the foreign line. The CONTRACTOR shall furnish materials

SECTION 1408

and may be required to install all HWM/PE 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, which 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 inched 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% 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, 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 utilizing a tool specified by the connector manufacturer. The new connection shall be sealed with a hot shrink splice for non-shielded conductors. The shrink splice shall be of the appropriate size to completely cover the aluminum compression connector and any exposed wire, and shrunk to form a water tight seal. If existing conductors are not of the #10, #8, or #6 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.

(F) Sacrificial Anodes. Sacrificial Magnesium Anodes shall be installed at the locations indicated on the drawings. The sacrificial anode shall be soaked thoroughly with water just prior to installation. Anodes shall be laid horizontally in the trench, at an equal distance between the water line and the 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. Verification shall include, at a minimum, testing and photography of each anode.

(G) Exothermic Welding. All exothermic welding and coating shall be performed in accordance with Tucson Water Standard Water Detail SD-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 be spliced using a C Type crimp connector of appropriate size per manufacturers recommendation. All exposed ribbon core and copper wire shall be thoroughly covered with two each layers of 50 percent overlap spiral wrapped rubber splicing tape. Rubber splicing tape shall than be covered with two layers of vinyl electrical tape extending 1 inch minimum beyond the rubber tape on both ends of the spliced area.

1408.0303 Warranty

SECTION 1408

(A) All workmanship, materials, and equipment provided and installed by the CONTRACTOR shall be guaranteed for a period of two (2) years from the date of substantial completion.

1408.0304 Tests, Inspection, and Reporting

(A) **General.** The CONTRACTOR shall provide all testing and start-up services required to verify that the corrosion protection system is installed and operational. The CONTRACTOR shall furnish all equipment and labor required to perform all testing and start-up services. All testing and start-up 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.

(B) **Testing.** the following tests on the Corrosion Protection and Monitoring System, if applicable:

- (1) Test station integrity 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 prior to 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" four 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;

SECTION 1408

- (12) Pipe-to-soil potentials before and after connection of sacrificial anodes;
- (13) The current output of each anode or anode header cable as measured across a 0.01 ohm shunt; and,
- (14) The 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-days advance notice before beginning tests. All testing shall be performed under the direct supervision of a NACE certified Corrosion Technologist. All tests shall be reviewed and verified by a NACE certified 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 a final report which includes the results of the testing, for approval, to the ENGINEER within 30 calendar days of the completion of the testing.

(C) Final Report. Within 60 calendar days of the completion of all corrosion monitoring and cathodic protection system installation, the CONTRACTOR shall submit three (3) hard copies of the Final Report, including field tests and data described above, ENGINEER's comments, and other pertinent information pertaining to the corrosion monitoring and cathodic protection systems. The report shall also include:

- (1) Verification that each new, or related corrosion component is installed per the City of Tucson Standard Waterworks Specifications and working as designed;
- (2) Identification of any existing or potential "hot spots" where corrosion is a concern; and,
- (3) Comparison of the theoretical resistivity to the actual resistivity of the transmission main;
- (4) List of all equipment and labor required to perform the testing outlined above; and,
- (5) Photographs, with descriptive captions, of all corrosion monitoring and cathodic protection system components which were installed by the contractor.

One (1) copy of the Final Report, including tables, shall also be provided on a compact disc (CD) in a 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 of the need for revisions. Acceptance of the Final Report will be required prior to substantial completion of the project.

1408.0305 Record Drawings

(A) The CONTRACTOR shall red line the project drawings at each corrosion test station, foreign line crossing, and sacrificial anode installations. The red lined drawings shall be performed per acceptable standards and OWNER approval.