# CATHODIC PROTECTION

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1.0 SCOPE

1.1 General

1.1.1 Cathodic protection is a method of corrosion control that may be used to protect metal surfaces in contact with an electrolyte such as soil or water. Corrosion is mitigated by controlling the direction of flow of the current generated by the corrosion process thereby causing the entire metallic surface to be cathodic to the electrolyte.

1.1.2 Piping in contact with soil, natural waters or seawaters, tank bottoms in contact with soil or asphalt, buried tanks, and some heat exchanger components maybe protected from corrosion by using cathodic protection.

2.0 REFERENCE CODES AND STANDARDS

2.1 The latest edition of the following Codes and Standards shall form a part of this specification:

API American Petroleum Institute
RP 651 Cathodic Protection of Aboveground Petroleum Storage Tanks

NACE National Association of Corrosion Engineers
RP0169 Control of External Corrosion on Underground or Submerged Metallic Piping Systems

COMPANY Engineering Specification
CP-1.0.0 Cathodic Protection of Buried Piping
CP-2.0.0 Cathodic Protection of Storage Tank Bottoms

3.0 CRITERIA

3.1 Concept of Cathodic Protection - Metallic surfaces is contact with electrolytes corrode because the metallic surface is non-homogenous. One area of the surface will have an electrochemical reaction with an adjacent area. The fundamental corrosion reactions are:

Cathodic Reaction (Reduction)
\[ H^+ \rightarrow \frac{1}{2} H_2 - e^- \]

Anodic Reaction (Oxidation)
\[ Fe \rightarrow Fe^{+2} + 2e^- \]

Corrosion can be stopped by applying current to the metal surface and thereby preventing the anodic reaction from occurring by controlling current flowing from the metal to the electrolyte.

Cathodic protection has been established when the potential of the entire metallic structure has been shifted sufficiently negative to prevent the surface of the structure from reacting with the electrolyte.

3.2 For steel in soil, a potential of -0.85 volts (negative 0.85 volts) referenced to a saturated copper/copper sulfate reference electrode indicates an adequate voltage shift. The potential must be corrected for the resistance created in the electrolyte by the flow of current from the anode (called IR drop). See measurement procedures for performing the IR drop correction.

3.3 For steel in natural or seawater the potential is -0.80 volts (negative 0.80 volts) referenced to a silver/silver chloride electrode and corrected for the IR drop will indicate an adequate voltage shift.
4.0 CATHODIC PROTECTION SYSTEM TYPES

There are two types of cathodic protection systems: Sacrificial Anode Systems and Impressed Current Systems.

4.1 Sacrificial Anode Systems

4.1.1 Sacrificial anode cathodic protection systems are typically used to satisfy small current requirements. These systems use galvanic anodes to protect the structure. The galvanic anodes are consumed in order to protect the structure.

4.1.2 Sacrificial anode systems have the following components:

4.1.2.1 An anode or group of anodes. Anodes are usually packed in a bentonite backfill to enhance output.

4.1.2.2 Electrical leads from the pipe or tank bottom to the junction box.

4.1.2.3 Electrical leads from the anode(s) to the junction box.

4.1.2.4 Junction box where the anode lead(s) and pipe/tank bottom lead(s) are connected.

4.1.2.5 Test stations and bonding stations as required.

See Appendix II, Figure 1 for a graphic illustration of a sacrificial anode system.

4.2 Impressed Current Systems

4.2.1 Impressed current cathodic protection systems use DC power supplies to cause the current to flow in the desired direction and cause the structure to be the cathode by convention of the current flow. Considering conventional current flow, the current will leave the anode and flow through the electrolyte to the cathode. These systems are used to satisfy current requirements that exceed 5 amperes from a single location.

4.2.2 Impressed current systems have the following components:

4.2.2.1 DC power supply.

4.2.2.2 An anode bed (also called a groundbed).

4.2.2.3 The associated wiring to connect the system.

4.2.2.4 Test stations and bonding stations as required.

4.2.3 The DC power supply consists of a step down transformer, a full wave rectifier and an output filter. The step down rectifier must have adjustable output settings.

4.2.4 The most common impressed current anodes are:

4.2.4.1 Graphite or high silicon cast iron rods for soils and natural waters.

4.2.4.2 Precious metal or mixed metal oxide coated copper or titanium wires for natural and sea water.

See Appendix II, Figure 2 for a graphic illustration of an impressed current system.

5.0 DESIGN

5.1 General

5.1.1 Structural system that are under cathodic protection share the environment with other metallic structures. The ramification of the design on both the protected and unprotected systems can be substantial. Further, system configuration may require special considerations from the designer.

5.1.2 Care should be taken to avoid excessive levels of cathodic protection, which can cause cathodic disbondment and damage to high-strength and special alloy steels.
5.1.3 The guidance of an experienced cathodic protection engineer must be solicited when a cathodic protection project is undertaken. Contact the Materials Engineer, Central Engineering Department.

5.2 System Boundaries

5.2.1 The structures being protected must be electrically isolated from other structures in order to control the cathodic protection system. The system boundaries must be at flanges, couplings or some other device that can be electrically insulated.

5.2.1.1 Piping should be have insulating flanges to separate them from tanks and other piping whenever possible. Pipe with insulating flanges have boundaries at the insulating flanges.

When insulation is not possible, the boundary is the next piece of equipment that has a cathodic protection system.

During the design phase, provisions must be made to provide adequate current to protect all unprotected structures that are not insulated from the structure being protected.

5.2.1.2 Tanks should have insulating flanges to separate them from other tanks and pipe whenever possible. The boundary for a cathodic protection system for a tank is the location of the first set of insulating flanges or the first piece of equipment with a cathodic protection system installed.

Unprotected structures that are not insulated from protected structures must be brought up to the protected system potential since there is no way to stop the unprotected structure from draining current from the protected one.

5.2.2 The system to be protected should also be composed of similar elements. Generally, tanks and pipelines should not be in the same system. Pipelines are usually well coated and have small current requirements. Tanks bottoms usually are not coated and have large surface areas that require large current requirements.

If tank bottoms and piping systems are combined into one system, it will be difficult to make the system function properly due to the different current requirements for each element.

5.3 Current Requirements

5.3.1 It is usually desirable to conduct a field test to determine the current requirements, although in some cases, the current can be calculated with sufficient accuracy for design purposes.

5.3.1.1 Field tests to determine current requirements are made by setting up a temporary cathodic protection system and applying current in increments until a potential shift is observed.

5.3.2 Current density requirements vary with structure configuration and electrolyte resistivity. In soils, a current density of 1.5 milliamperes per square foot of exposed metal is sufficient to protect most steel structures. Current density in water will vary from 1 milliampere per square foot in fresh water to 70 milliampere per square foot in warm aerated sea water.

5.3.3 Calculations

Current requirement calculations are based on the total surface area to be protected, the quality of the coating system and an estimation of the soil resistivity in the system area.

5.3.3.1 Current requirements may be calculated using the following formula:

\[ I = A \times B \times D \times L \text{ where:} \]
6.1.4 Pipelines that are not regulated by DOT that require casings shall conform with the requirement of the COMPANY Specification for DOT regulated pipeline casings. *(Spec. Number Here)*

**Note:** The design of impressed current anode beds is more complex than for sacrificial anode and should be performed by a cathodic protection engineer.

6.2 Tank Bottoms

6.2.1 Tank bottoms are usually bare and are constructed on a sandy base or a concrete support ring. Single tanks 50 feet or less in diameter can be protected economically by installing galvanic anodes around the periphery of the tank. Tanks larger than 50 feet in diameter may require impressed current systems because of the magnitude of current required.

6.2.2 Tanks may have grounding grids, electrical wiring, or fire fighting equipment that prevents the tanks from being effectively insulated.

6.3 Tank Farms

6.3.1 The bottoms of tanks located in a tank farm may be protected by a single cathodic protection system. The tank farm must be located such that it can be electrically isolated from other structures.

6.3.2 Tanks should be electrically isolated from each other, if possible, with a bonding station so that the current to each tank can be controlled separately.

6.3.3 Interference testing is essential in tank farms because of the interconnecting piping and fire fighting equipment.

6.4 Heat Exchanger

6.4.1 Magnesium anodes may be installed in the channels of exchanger when both of the following conditions are present:

6.4.1.1 Water is on the tube side, and
6.4.1.2 The tube sheet and/or tubes are of copper alloy or some other material that promotes galvanic corrosion of ferrous channel materials, such as carbon steel.

7.0 TESTING AND INSPECTION

7.1 Commissioning of the System

7.1.1 Sacrificial anode systems shall have potential surveys of the pipeline before and after the system is energized.

7.1.2 A potential survey shall be performed one month after the system is energized to determine if the system has polarized and is effective.

7.1.3 Impressed current systems shall have a baseline potential survey prior to energizing the system.

7.1.4 The system shall be started at the lowest tap settings with the location nearest the anode bed monitored for potential. The potential change with each tap setting change shall be recorded in the commissioning report.

7.1.5 The tap settings shall be increased slowly as the potential on the structure stabilizes.

7.1.6 The tap settings shall be increased until the structure has a protective potential; then, the entire structure shall be surveyed.

7.1.7 The final adjustments shall be made bringing the lowest potential on the structure to the minimum protective potential.

7.1.8 The system shall have a potential survey one month after it is energized and adjusted as required.

7.1.9 The output voltage and amperage for each tap setting along with the time between tap setting changes shall be recorded in the commissioning report.

7.1.10 Potential reading for each tap setting shall be recorded in the commissioning report.

7.1.11 Information from the baseline survey and the final potential survey shall be recorded in the commissioning report.

7.2 Testing for Interference

7.2.1 Cathodic protection systems can interfere with other structures in the area. Interference can be described as creating a possible corrosive condition on a foreign metal structure (not part of the protected structure) which is located in the field of the cathodic protection anode bed. The anode field extends a distance from the anode equal to:

\[ I = \frac{200X}{R} \]

\[ I = \text{Current output} \]

\[ R = \text{Soil resistivity} \]

7.2.2 Interference problems are usually corrected by installing resistance bonds between the protected and unprotected structures. Interference problems are most common in impressed current systems.

7.3 Test Stations

7.3.1 Periodic testing is required to ensure that the cathodic protection system is working properly. In order to perform the necessary test, test stations must be installed as part of the project.

Pipelines that are not regulated by DOT shall have pipeline markers and test stations located along the pipeline at intervals that are close enough to allow for location and monitoring of the pipeline. Pipeline markers and test stations shall conform with the requirements of the COMPANY Specifications for DOT regulated pipeline markers and test stations (See DOT Procedures and Specifications).
7.3.2 Tanks bottoms with cathodic protection shall have test stations installed at least at each quadrant on small tanks and more often on larger tanks. Refer to Appendix II, Figure 3 for details on test stations for tank bottoms.

7.4 **Periodic Survey**

7.4.1 Potential surveys should be performed periodically to ensure that the structure is fully protected. Refer to Section 3.0 of this standard for criteria for protection. Structures with no history of leaks and that are coated should be surveyed annually. Poorly coated and bare systems should be surveyed semi-annual. Systems with a history of leaks should be surveyed quarterly.

8.0 **DOCUMENTATION**

8.1 All of the design information including soil resistivity surveys and interference surveys along with all design calculations, design drawing and special installation instructions shall be included in the package provided to the responsible operating unit.

8.2 All information collected during commissioning of the unit shall be provided to the responsible operating unit.
Appendix I
POTENTIAL MEASUREMENTS

Structure to electrolyte potentials measurements are made in accordance with the schedule in Section 7.3 of this document.

1.0 EQUIPMENT

1.1 Measurements for cathodic protection systems require high internal resistance instruments capable of reading millivolts as well as volts. Multi-meters such as Fluke or Beckman having 10 megaohms input resistance have performed well for cathodic protection use.

1.2 Copper/copper sulfate electrodes are used for structure to soil measurements; and, silver/silver chloride electrode are used for structure to water measurements.

2.0 PROCEDURE

2.1 The common terminal of the multi-meter is connected to the structure and the positive terminal is connected to the electrode.

2.2 The electrode is placed in contact with the electrolyte.

2.3 The voltage reading on the multi-meter should be negative.

3.0 COMPENSATION FOR IR DROP

3.1 The voltage read on the multi-meter includes the voltage caused by the current flow through the electrolyte (called IR drop) and the polarization voltage on the structure. The polarization voltage is the part of the reading that needs to be determined to see if the structure is fully protected.

3.2 The polarization voltage is determined by interrupting the protective current and measuring the current decay. When the current is interrupted, an immediate voltage shift will occur. The voltage reading after the immediate shift is the polarized potential for the structure.
### Appendix II

#### Table 1

**MAGNESIUM ANODE SPACING FOR NEW COATED STEEL PIPE**

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>17#</th>
<th>32#</th>
<th>48#</th>
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<tbody>
<tr>
<td>4”</td>
<td>225</td>
<td>480</td>
<td>847</td>
</tr>
<tr>
<td>6”</td>
<td>153</td>
<td>328</td>
<td>578</td>
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</tr>
<tr>
<td>12”</td>
<td>80</td>
<td>170</td>
<td>299</td>
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</table>
APPENDIX II
FIGURE 1
CATHODIC PROTECTION TEST STATION
APPENDIX II
FIGURE 2

CATHODICALLY PROTECTED
BY IMPRESSED CURRENT

APPENDIX II
FIGURE 2

Specification for Cathodic Protection

Engineering Services, L.I.