Water Tank Cathodic Protection

Presented By:
Jim Dooley
Corrpro
310 Roma Jean Parkway
Streamwood, IL 60107
Tel. 630-483-2500
email: jdooley@corrpro.com
http://www.corrpro.com

Corrpro Companies, Inc.

“Preserving and Sustaining Global Assets & Infrastructure”
Water Storage Tanks
Corrosion related to infrastructure (O&G Pipelines, Water Systems, Bridges) costs the United States over 400 Billion Dollars per year in Renovation or Replacement Costs!

With Modern Technological Advances such as Cathodic Protection, it is estimated that a large % of these expenditures are preventable

CORROSION THEORY AND CORROSION PREVENTION

• Why Corrosion Happens
• Methods of Corrosion Control
• How Coatings & Cathodic Protection Work
• How Steel & Metallic Structures Are Effectively and Economically Maintained
• The Value of Utilizing Cathodic Protection
The Environmental Protection Agency now mandates corrosion protection for all underground fuel storage tanks in the US.
Magnesium anodes pre-packaged on underground fuel storage tanks
The Value of Using Cathodic Protection

- Economical initial cost of installation
- Economical to maintain
- Extends useful life of the coating
- Minimizes the need for coatings maintenance
- Minimizes the need for re-coating
- Minimizes metal repairs
- Minimizes the need for costly downtime
- Significantly lowers total cost of ownership
“Automatically Controlled Impressed-Current Cathodic protection for the Interior of Steel Water Tanks”

“The combination of coatings and cathodic protection may be more economical and effective than using coatings or cathodic protection alone”
NACE Standard Recommended Practice RP0388-95

“If the water is sufficiently corrosive to justify the use of coatings, then cathodic protection is also justified and provides a greater degree of protection than when either method is used alone”
National Fire Protection Association  

“The inspection interval for the interior surface areas shall be three (3 Years)”

Exception 1: If corrosion control is utilized the inspection interval shall be five (5) years”

“Cathodic protection corrosion control system should be inspected annually”
NSF 61
National Sanitation Foundation
Standard 61

Anything that comes in contact with drinking water is tested and certified to be safe for the drinking water supply.
For stand-alone coating systems re-coating is typically recommended at 1-5% failure. A standard AWWA D104 anode system is designed to protect up to 20% bare for a **minimum** of 20 years. Systems can be designed to protect up to 100% bare steel.
Approximate Cost Breakdown of a Typical Coating Project

Surface Preparation: 65%
Material: 10%
Application: 25%
Approximate Percentage of Coating Failure Occurrences, Grouped by Root Cause

% of Coatings Failures by Occurrence

Coating Failures by Root Cause

- Poor Surface Preparation / Application
- Poor Specification / Mat'l Selection
- Poor Coating Mat'l from Manufacturer
CORROSION IS DEFINED AS:

The deterioration of a substance (usually metal) due to a reaction with its environment
Corrosion - A Natural Process

IRON OXIDE + REFINING + MILLING =

IRON + CORROSION = IRON OXIDE
The Galvanic Energy Series

- Each metal requires a certain amount of energy to remain stable
- The metals in higher positions contain higher levels of energy
- When energy is released, metal loss occurs
- Energy release = corrosion
# Practical Galvanic Series

<table>
<thead>
<tr>
<th>Material</th>
<th>Potential*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Magnesium</td>
<td>-1.75</td>
</tr>
<tr>
<td>Magnesium Alloy</td>
<td>-1.60</td>
</tr>
<tr>
<td>Zinc</td>
<td>-1.10</td>
</tr>
<tr>
<td>Aluminum Alloy</td>
<td>-1.00</td>
</tr>
<tr>
<td>Cadmium</td>
<td>-0.80</td>
</tr>
<tr>
<td>Mild Steel (New)</td>
<td>-0.70</td>
</tr>
<tr>
<td>Mild Steel (Old)</td>
<td>-0.50</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>-0.50</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>-0.50 to + 0.10</td>
</tr>
<tr>
<td>Copper, Brass, Bronze</td>
<td>-0.20</td>
</tr>
<tr>
<td>Titanium</td>
<td>-0.20</td>
</tr>
<tr>
<td>Gold</td>
<td>+0.20</td>
</tr>
<tr>
<td>Carbon, Graphite, Coke</td>
<td>+0.30</td>
</tr>
</tbody>
</table>

* Potentials With Respect to Saturated Cu-CuSO₄ Electrode
THE ENERGY HILL
GALVANIC ENERGY SERIES

MAGNESIUM
ALUMINUM
ZINC
STEEL & CAST IRON
COPPER
CARBON
SILVER
PLATINUM
GOLD
Cathodic Protection introduces an external DC current which makes the entire structure a cathode.
MAINTAINING THE ENERGY LEVEL

CATHODIC PROTECTION

NOBLE OR PASSIVE (+)

ACTIVE (-)

CORROSION

REFINED METAL

METAL ORE
Four Requirements for a Corrosion Cell

- **Electrolyte**: Ionic current path (moisture)
- **Anode**: Metal in contact with the electrolyte where corrosion occurs
- **Cathode**: Metal in contact with the electrolyte where no corrosion occurs
- **Conductor**: Electronic current path
Corrosion

1) ANODE
2) CATHODE
3) ELECTROLYTE
4) METAL PATH
Corrosion

1) ANODE

2) CATHODE

3) ELECTROLYTE

4) METAL PATH

Copper  -300mV
Steel  -600mV
Magnesium  -1.7V
Cathodic Protection

1) ANODE
2) CATHODE
3) ELECTROLYTE
4) METAL PATH

Copper -300mV
Steel -600mV
Magnesium -1.7V
Cathodic Protection

1) ANODE
2) CATHODE
3) ELECTROLYTE
4) METAL PATH
Water Storage Tanks and Treatment Facilities Possess the Four Requirements for Corrosion Cells to Form

- **Electrolyte**: Water and/or Wastewater
- **Conductor**: Steel Tank or Equipment
- **Anode**: Metal in contact with the electrolyte
- **Cathode**: Metal in contact with the electrolyte
A Battery is an Example of a Corrosion Cell

- Electrolyte: chemical paste
- Anode: zinc container
- Cathode: Carbon electrode
- Conductor: metal connection

The electrical energy of the corrosion process is measurable in the form of light
Metals Connected together can form a Corrosion cell

<table>
<thead>
<tr>
<th>ANODE (corrodes)</th>
<th>CATHODE (protected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• New Steel</td>
<td>• Old Steel</td>
</tr>
<tr>
<td>• Steel</td>
<td>• Copper</td>
</tr>
<tr>
<td>• Galvanized Steel</td>
<td>• Steel</td>
</tr>
<tr>
<td>(ladders &amp; safety climbs)</td>
<td>(ladders &amp; safety climbs)</td>
</tr>
<tr>
<td>• Steel</td>
<td>• Stainless Steel</td>
</tr>
<tr>
<td>• Magnesium</td>
<td>• Steel</td>
</tr>
<tr>
<td>• Steel</td>
<td>• Reinforcing Steel</td>
</tr>
</tbody>
</table>
Galvanic Corrosion Induced by a Stainless Steel Ladder
Galvanic Corrosion reaction between steel and rebar in a treatment facility
Homogeneous Metal Corrosion
Example: Steel Plate or Iron Pipe

- Corrosion cells are created by different electrical levels in each grain of steel
- When in contact with an electrolyte (moisture) energy transfers between grains of steel
- Grains discharging energy corrode
- Grains accepting energy do not corrode
Basic Corrosion Cell

1) Anode
2) Cathode
3) Electrolyte
4) Electrical Connection
Water (Electrolyte)

Tank Wall

Anodic Area (Corrodes)

Metallc Return Path

Cathodic Area (Protected)

Current Flow
To Prevent Corrosion, one or more of the four requirements of a corrosion cell must be eliminated or minimized

- Not practical to eliminate the electrolyte
  
  WATER

- Not practical to eliminate the conductor
  
  TANK OR EQUIPMENT
For Corrosion Control it is Practical to eliminate or minimize

- Exposed metals (anodes and cathodes) in contact with the electrolyte: **Protective Coating**

- Change all anodic metal areas (where corrosion occurs) to cathodic metal areas (where no corrosion occurs): **Cathodic Protection**
Cathode (Protected)
Continued active corrosion on a weld seam after two years in service and one attempted touch-up
Q. Why are small areas of corrosion activity NOT small problems??    A. Area effect concentration cells
Area effect: “Corrosion of the anodic area may be 100 - 1000 times greater than if the anodic and cathodic areas were equal in size”

Corrosion Engineering Fontana & Greene 1978
Pitting Corrosion can lead to costly welding repairs or the use of “pit fillers” or even........
A Corrosion Penetration Failure
A Cathodic Protection System will send a D.C. electrical “charge” through the water to both the metallic structures arresting galvanic corrosion.
Calcereous deposits often form over “holidays”
Protection of holidays in coating along the edges of the support column
Exposed “holiday” with no active corrosion
AWWA Standard D104-97

• “Automatically controlled impressed current cathodic protection for the interior of steel water storage tanks”
Cathodic Protection is Effective When:

- Current distribution from anode to cathode meets “criteria for protection”
- Criteria is defined as a structure to water potential of -0.850V to -1.050V relative to a copper-copper sulfate reference electrode
- Protective current is distributed over the entire submerged surface area
- Protective current is maintained continuously
In Reference to AWWA D104-97 the Major Components of a Cathodic Protection System Are:

- Automatically controlled rectifier
- Reference electrodes
- Anode
- Anode suspension system
- Hardware and wiring
Automatic Rectifiers

The purpose of an automatically controlled rectifier is to adjust the current output as conditions in the electrolyte change due to:

- Water Level
- Temperature
- Water Chemistry
- Water Turbulence
- Polarization
Properly Calibrated Automatic Potential Control Rectifier
This rectifier has achieved its protective potential level and has stopped applying current. The unit will *automatically* start up again when the potential drops below its “set point”
10 year old Automatic Rectifier with analog meters still in near perfect condition & operating properly to provide corrosion control within criteria for protection
Reference Electrodes

The purpose of long life reference electrodes is:

• To constantly monitor the protection levels in the system

• Transmits a signal to the automatic controller to adjust the current output as required
Copper-Copper Sulfate Reference Electrode
Waterworks Anodes

Long life anodes should have an average design life of ten to twenty (10 - 20) years. Anode Materials Typically Include:

- Titanium with precious metal oxide coating
- Platinized Niobium with a copper core
DESIGN
by a corrosion engineer

• Certified by N.A.C.E.
  (National Association of Corrosion Engineers)
• Experienced in Cathodic Protection
• Experienced in Cathodic Protection of Waterworks Structures
The Corrosion Engineer Determines

1. Total submerged surface area
2. Percentage bare
3. Current density
4. Resistivity of water
5. Consumption rate of anode material
6. Anode size, length and layout
7. Anode suspension system
8. Rectifier unit output
9. Number and location of reference cells
10. Number and type of electrical connections
11. Location of rectifier
12. A.C. requirements
13. National and local codes
Anode Suspension Systems Vary Depending Upon Icing or Non-icing Conditions

- For icing conditions the standard design is a horizontally suspended anode system supported from the side wall or interior dry access column.
- For non-icing conditions the standard design is a vertically suspended system from the roof of the tank.
Vertically Suspended Mixed Metal Oxide Anodes
Advantages of the Vertical System

- Systems are easily installed without the need to drain the tank
- Systems can be completely serviced, upgraded, repaired and replaced without the need to drain the tank
Horizontally submerged anode system
Advantages of the Horizontal System

• Supported in the lower portion of the tank to avoid contact with ice
• Eliminates the need for seasonal anode replacement
• Eliminates build up of old anodes in the bottom of the tank
Examples of System Designs

• System designs which are typically utilized for various styles of water storage tanks
Typical Vertically Suspended Anode Systems
Typical Vertically Suspended Anode Systems
Typical Horizontally Suspended Anode Systems
Typical Horizontally Suspended Anode Systems
Start-up and Calibration

- Start-up service verifies the system is operating at optimum performance levels
- Calibration adjusts the system to perform within “Criteria for Protection”
- Independent tank-to-water potential profile verifies the systems output levels
- Complete written report with data and evaluation furnished to the owner
Annual Maintenance Services

• Complete system evaluation
• Potential testing to verify system performance
• Calibration to maintain corrosion control per AWWA & NACE criteria
• Written report with recommendations
Annual Service Inspection by a Qualified Technician is Recommended by AWWA D104

The annual service visit includes:

- Complete electrical system check for continuity of anode and reference cell circuits
- Independent reference cell potential test to verify system performance
- Calibration and adjustment of the system to maintain corrosion control within “criteria”
- Written evaluation and recommendations
Service Visit

- **Electrical measurements** shall be conducted with a portable high impedance voltmeter and a calibrated copper-copper sulfate reference electrode.
- **Adjustments** shall be made in accordance with “criteria for protection” for optimum corrosion control.
- **Data** shall provide sufficient information to evaluate the performance of the system relating to “Criteria for protection”.
- If additional work is required, a written report will be furnished with recommendations.
Resistance readings verify electrical system continuity
Technician Recording the Readings During the Independent Cell Test
Technician Performing Visual Inspection of Vertical Anodes
Independent cell tests verify the operating cells performance
# Field Services Work Report

**CUSTOMER:**

Customer Contact Name and Number:  
Customer P.O.:  
Schedule:

**Ship To:**

Tank Capacity and Type:  
Type of System:  
Type of Service:  
Region:  
Customer No.:  
Job No.:  
Ship No.:  
Rating:  
Tank Address:  
County:  
Rating:  
Anode Configuration:  

Measurements prior to testing, evaluation and adjustments:

<table>
<thead>
<tr>
<th>Off</th>
<th>On</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Rectifier Tap Setting at:</td>
<td>Auto [ ] Manual [ ] Water Level</td>
</tr>
<tr>
<td>b) Rectifier Operating at:</td>
<td></td>
</tr>
<tr>
<td>Bowl Volts</td>
<td>Amps</td>
</tr>
<tr>
<td>Riser Volts</td>
<td>Amps</td>
</tr>
<tr>
<td>c) Resistance</td>
<td>Anode - Bowl</td>
</tr>
</tbody>
</table>

Independent Tank-to-Water Potential Profile Within Tank:

<table>
<thead>
<tr>
<th>Tank Bottom</th>
<th>Instant OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rectifier Operation Adjusted To:

<table>
<thead>
<tr>
<th>Off</th>
<th>On</th>
</tr>
</thead>
<tbody>
<tr>
<td>e) Rectifier Operation Adjusted To:</td>
<td>Tap Setting:</td>
</tr>
<tr>
<td>Bowl Volts</td>
<td>Amps</td>
</tr>
<tr>
<td>Riser Volts</td>
<td>Amps</td>
</tr>
</tbody>
</table>

**WORK ORDER**

- Installation [ ]  
- Startup [ ]  
- Service [ ]  
- Other [ ]

**Evaluation - Overall System Performance for Corrosion Control:**

Recommendations:

Operator Instructions provided to:  
Do NOT adjust rectifier in automatically controlled mode of operation. Record voltage, current and potential meter readings at intervals not to exceed sixty (60) days.

**HARCO/CPS WATERWORKS**  
**SUBSCRIBER’S ACCEPTANCE**

By: [ ]  
Date:

(CLEVELAND)  
(ATLANTA)  
(NEW YORK)  
(PH OENIX)
Continuing Maintenance

• Owner should check the meters on the rectifier at intervals not to exceed 60 days
• Compare the volts, amps and potential readings to set point and previous readings
• If report cards are furnished by the cathodic protection constructor, fill them out and mail them to the constructor for review
• Remote Monitoring Technology is quickly evolving as an economical means of monitoring system performance
External Corrosion of Tank Bottom

- Anodic Area: -600mV
- Cathodic Area: -550mV

Current Flow: SAND → CURRENT FLOW
Tank to Soil Potential Measurements
Corrosion Cell Caused by Foreign Material in Sand Cushion
Bimetallic Corrosion

Corrosion occurs on tank bottom

Steel Tank Floor

SAND

CURRENT FLOW

Copper Ground Rod
Corrosion Caused by Poor Water Drainage
Summary

- Reducing corrosion rates on existing water distribution piping will result in a reduction of the number of breaks and also extend the operational life.

- Corrosion control measures should be considered during the design stage for any new metallic piping and storage tank installations.
Traffic Disruptions
Water Loss
Fire Protection
Legal & Environmental Claims
Damages
QUESTIONS?

Jim Dooley
Corrpro Companies, Inc.
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