Corrosion Control and Cathodic Systems

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Corrosion Control is typically:

- Less than 10% of the Replacement Cost
- 1%-3% of the Cost of a New Structure
Corrosion - A Natural Process

IRON OXIDE + REFINING + MILLING

IRON + CORROSION = IRON OXIDE
# 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-CuSO$_4$ Electrode
Prerequisites for Corrosion

- Anode
- Cathode
- Electrical Connection Between Anode and Cathode
- Electrolyte
1) ANODE
2) CATHODE
3) ELECTROLYTE
4) ELECTRICAL CONNECTION

Anode
-600mV

Cathode
-550mV

-575mV
Underground Structures

Causes of Corrosion

- Dissimilar Metals
- Non-Homogeneous Soil
- Differential Aeration
- Microbiological Attack
Coupling to Dissimilar Metals

Iron Pipe (Anode) - 500mV

Brass Valve (Cathode) - 300mV

Iron Pipe (Anode) - 500mV
Coupling to Dissimilar Metals

Metallic Connection

Copper service (Cathode) - 300mV

Iron pipe (Anode) - 500mV
Corrosion of iron when coupled to copper service line.
Dissimilar Soils

Pavement
Sandy Loam
Clay
Sandy Loam

Cathode
Anode
Cathode

De-icing salts?
Fertilizers?
Corrosion Caused by Differential Aeration

Aerated Soil

Oxygen Available (Cathode)

Pipe

Low Oxygen (Anode)
Corrosion Cell

Anode

Electrolyte

Metallic Path

Cathode
How Cath Protection Works

- Corrosion occurs where current discharges from metal to electrolyte
- The objective of cathodic protection is to force the entire surface to be cathodic to the environment
Cathodic Protection

- Anode
- Cathode (Anode)
- Metallic Path
- Cathode
- Electrolyte
Galvanic Anode

- Current is obtained from a metal of a higher energy level
Galvanic Cathodic Protection

- Magnesium Anode
- Current Flow
- Structure
Impressed Current

Cath

- Anodes
- Rectifier
- Wiring
Impressed Current System

- Rectifier
- Anode
- Groundbed
- Pipeline (Structure)
- Current Flow

( - ) ( + )
Galvanic

- No external power
- Fixed driving voltage
- Limited current
- Small current requirements
- Used in lower resistivity environment
- Usually negligible interference

Impressed

- External power required
- Voltage can be varied
- Current can be varied
- High current requirements
- Used in almost any resistivity environment
- Must consider interference with other structures
Stray Current Due to Impressed Current Cathodic Protection System
Stray Current
Bonding Across a Bell and Spigot or Slip-joint

Thermite brazed connection coated with bitumous compound

Copper wire with direct burial insulation

Pipe
Corrosion is the leading contributor to cast and ductile iron water system breaks!
Anode Installation

- Augered hole
- Galvanic anode
- Connection to piping
Anode lead wire connection to pipe using spot welder.
Water Storage Tanks and Treatment Facilities Possess the Four Requirements for 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
Typical Horizontally Suspended Anode Systems

[Diagram of a vertically mounted anode system with labels:
- Steel anchors welded to side wall
- Polyester rope supports
- Platinized niobium wire anode or titanium rod with mixed precious metal oxide
- Permanent reference electrodes
- Bowl anode
- Submerged anode support system
- Steel anchors welded to riser wall
- Polyester rope supports
- Platinized niobium wire anode or titanium rod with mixed precious metal oxide
- Automatic potential control rectifier
- Pressure entrance fitting
- Permanent reference electrode

[Diagram of a horizontally suspended system with labels:
- Steel anchors welded to side wall
- Polyester rope supports
- Platinized niobium wire anode or titanium rod with mixed precious metal oxide
- Permanent reference electrodes
- Submerged anode support system
- Automatic potential control rectifier
- Pressure entrance fitting]
Typical Horizontally Suspended Anode Systems

- Steel anchors welded to side wall
- Polyester rope supports
- Permanent reference electrodes
- Platined niobium wire anode or titanium rod with mixed precious metal oxide
- Styrofoam flotation buoys

- Steel brackets welded to dry access column
- Schedule 80 PVC suspension supports
- Polyester rope support
- Platined niobium wire anode or titanium rod with mixed precious metal oxide

- Anode suspension system
- Permanent reference electrodes
- Pressure entrance fitting
- Automatic potential control rectifier
- Pressure entrance fitting
Typical Vertically Suspended Anode Systems
Typical Vertically Suspended Anode Systems

- Permanent Reference Electrodes
- Platinized Niobium Wire Anode or Titanium Rod with Mixed Precious Metal Oxide
- Support System Bolted to Tank Roof for Anodes and Reference Electrodes
- Permanent Reference Electrode
- Automatic Potential Control Rectifier
- Platinized Niobium Wire Anode or Titanium Rod with Mixed Precious Metal Oxide
- Permanent Reference Electrodes
- Support System Bolted to Roof for Bowl Anodes and Reference Electrodes
- Automatic Potential Control Rectifier