Corrosion Control & Cathodic Protection for Water & Wastewater Systems

Presented By:

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The estimated annual cost to repair water piping breaks in North America alone is estimated to be*:

$1.5 Billion

*based on 250,000 breaks at a repair cost of $5,875.00 U.S.D. each
Corrosion is the leading contributor to cast and ductile iron water system breaks!
Corrosion
Corrosion - A Natural Process

IRON OXIDE + REFINING + MILLING = IRON, STEEL, PCCP

IRON, STEEL, PCCP + CORROSION = IRON OXIDE
Corrosion of Metallic Structure
Corrosion Pitting
Basic Corrosion Cell

1) Anode
2) Cathode
3) Electrolyte
4) Electrical Connection
Anodic Area

(-)

Current Flow

Cathodic Area

(+)

Electrolyte

(Soil)

Structure

(Metallic Path)
Water (Electrolyte) Current Flow

Tank Wall

Anodic Area (Corrodes)

Metallic Return Path

Cathodic Area (Protected)

Current Flow
History of Iron Pipe

**Cast Iron**
- Introduced to North America during the 1800’s and installed till the 1970’s.
- Early on, statically cast process produced a thick walled, heavy pipe.
- No longer produced in North America.

**Ductile Iron**
- Introduced in 1955 as an improvement to cast iron.
- Centrifugal casting process produces a thinner walled, lighter pipe which is stronger and more ductile than cast iron.
Cast (Grey) Iron

Graphitization leaves pipe brittle and weakened.
Graphitization of cast iron pipe.
Ductile Iron

Pitting (concentrated) corrosion attack on ductile iron pipe.
Adverse Conditions for Metallic Pipe

- High Chlorides
- Low Soil/Water Resistivity
- High Sulfates
- Acidic Soils
- Wet/Dry Fluctuations
- Bimetallic Couplings
- Stray Current Interference
# Practical Galvanic Series

<table>
<thead>
<tr>
<th>Material</th>
<th>Potential*</th>
</tr>
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<tbody>
<tr>
<td>Pure Magnesium</td>
<td>-1.75</td>
</tr>
<tr>
<td>Magnesium Alloy</td>
<td>-1.60</td>
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<tr>
<td>Zinc</td>
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</tr>
<tr>
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* Potentials With Respect to Saturated Cu-CuSO₄ Electrode
CARBON ROD (CATHODE) +0.30mV
ZINC CASE (ANODE) -1.10mV
MOIST PASTE (ELECTROLYTE)
Coupling to Dissimilar Metals

- Copper service (Cathode) - 300mV
- Iron pipe (Anode) - 500mV

Metallic Connection
Corrosion of iron when coupled to copper service line.
Bi-Metallic Corrosion Between Carbon Steel Tank & Stainless Steel Ladder
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)
- Low Oxygen (Anode)
- Pipe

CORRPRO COMPANIES INC
Dissimilar Surface Conditions

Pipe (Cathode)

Threads Bright Metal (Anode)

Scratches (Anode)
Stray Current Due to Impressed Current Cathodic Protection System
Impressed Current CP System on Oil/Gas Lines can Create Stray Current Problem on Water Lines
Stray Current
Bonding Across a Bell and Spigot or Slip-joint

Thermite brazed connection coated with bitumous compound

Copper wire with direct burial insulation
Stress Corrosion

Pipe

Metallic Coupling

Threaded Bolt
Higher Stress Area
(Anode)

Lower Stress Area
(Cathode)
Concrete Pipe
WARNING

THIS PIPELINE HAS THE POTENTIAL TO RUPTURE IN AN EXPLOSIVE MANNER WITHOUT WARNING.
KEEP AWAY

NO UNAUTHORIZED VEHICLES
How We Prevent Corrosion Attack?

- Corrosion occurs where current discharges from metal to electrolyte.
- To prevent corrosion we must make the pipe a cathode by forcing current to flow on to it.
- Follow manufacture's and AWWA recommendations to insure proper installation of polyethylene encasement.

- In extremely corrosive areas, additional methods (bonding of joints, cathodic protection, may be required).
Galvanic Anode on Polyethylene Encased Ductile Iron Pipe
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Galvanic Cathodic Protection

- Magnesium Anode
- Current Flow
- Structure
Cathodic Protection Test Station

Test Station

Magnesium Anode

Structure
Cathodic Protection for Hot Water Tanks
Repair of Break Should Include Anode Installation

Incomplete

Complete
Water Leak Repair Kit

Includes:

Installation instructions.

One day onsite technical assistance.

Cathodic protection components/connection materials suitable for 10 repairs.
Rehabilitation Options?

- **Replace Piping**
  - Costly
  - Disruptive

- **Repair Breaks**
  - Reactive approach
  - Disruptive
  - Does not address corrosion problem
  - Leaks will continue to occur

- **Implement BRLE^{SM}**
  - Addresses Corrosion Problem
  - Reduces breaks and extends life
  - Virtually non-disruptive
  - Economical
Access to Pipe
Hot Spot Galvanic Anode Program on Water Mains
1988 C.P. Totals
Length Protected = 12,780 feet

Break Records for Water Mains Cathodically Protected in 1988
Break Records for Water Mains Cathodically Protected in 1993

1993 C.P. Totals
Length Protected = 55,360 feet

- 94 Breaks Prior to Cathodic Protection
- 1 Breaks After Cathodic Protection

Year

Number of Breaks
Anode Lead Wire Connection

Galvanic Anode

Metallic Coupling

Cathodic Protection of Metallic Fitting
Computerized Potential Logging Survey

- Test Station
- Backpack Computer Unit
- Chainer/Wire Dispenser & Counter
- Reference Cells
- Bonded Joints
- Pipeline
Annual Cathodic Protection Survey
Corrosion Monitoring Test Station

Test Station

Structure
Computerized Potential Logging Survey

- Test Station
- Backpack Computer Unit
- Chainer/Wire Dispenser & Counter
- Reference Cells
- Bonded Joints
- Pipeline
Bond Clip for Concrete Pipe Joints
Corrosion of pre-stressed concrete cylinder pipe (P.C.C.P.).
CIS Survey

PG/WFA Survey
Close Interval Data

Interrupted Survey
Close Interval Data
PG/WFA Survey

CIS Survey
Inspection of CP System
Suspended Horizontal Anode System

Top View Diagram

- Steel Anchors Welded to Side Wall
- Polyester Rope Supports
- Platinumized 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
Horizontally Submerged Cathodic Protection System in Water Storage Tank
Suspended Vertical Anode System

Support System Bolted to Roof for Bowl Anodes and Reference Electrodes

Automatic Potential Control Rectifier

Top View Diagram

PLATINIZED NIOBIUM WIRE ANODE OR TITANIUM ROD WITH MIXED PRECIOUS METAL OXIDE
PERMANENT reference ELECTRODES
Independent cell tests verify the operating cells performance
ABOVEGROUND STORAGE TANK

CATHODIC PROTECTION

3" ∅ PVC 20% Exposure

Test/Access Station

Aboveground Storage Tank

Grade

10' Typical

Anode Material

Anode Tube

ABOVEGROUND STORAGE TANK

CATHODIC PROTECTION
Corrosion of Clarifier Center Well
Sewage Lift Stations
Factory Installed Cathodic Protection Systems
Depleted & Refurbished Cathodic Protection for Lift Stations

Depleted cathodic protection system allows corrosion to occur.

Effective cathodic protection system prevents corrosion and extends life of lift station.
AC Mitigation
Investigative Structure (Existing)

Corrosion Assessment
- Review of General Characteristics of Water System
  - Age
  - Material Type
  - Wall Thickness
  - Construction Practices
- Review Break / Leak History
- Field Survey
  - Soil Conditions (Resistivity, Moisture Content, Chemical Analysis)
  - Electrical Test
- Data Analysis & Risk Management
- Priority Index (Identification of Opportunities to Reduce Replacement / Repair Costs)
PHASE I

- Obtain drawings of proposed route
- Conduct independent field investigation:
  a) Soil resistivity study
  b) Identify foreign pipeline crossing
  d) Identify AC potential influence
  e) Collect soil samples (moisture content, chlorides, pH, sulfate ions concentration, conductivity)
- Stray current investigation
Corrosion Protection Design
Phase II

Prepare Bid Quality Specifications for:

- Coatings or Polyethylene Encasement
- Test Stations (Monitor Corrosion Rates)
- Bonded Joints
- Stray DC/AC Mitigation
- Cathodic Protection
- Combination of Multiple Items
- Review Submittals/Onsite Periodic Inspection
Summary

- Reducing corrosion rates on existing water distribution and transmission 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 installations.
Traffic Disruptions

Water Loss

Fire Protection

Legal & Environmental Claims

Damages
QUESTIONS?

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Structures

- Piping (Distribution/Transmission)
- Metallic Fittings
- Water Storage Tanks
- Clarifier Units
- Lift Stations
Corrosion Can be Defined as Either:

- **Practical**
  Tendency of a Metal to Revert to its Native State

- **Scientific**
  Electrochemical Degradation of Metal as a Result of a Reaction with its Environment
Design Decision Model

For Ductile Iron Pipe
Anode lead wire connection to pipe using spot welder.
Yard Piping Deep Anode Groundbed
Impressed Current System

- Anode Junction Box
- Rectifier
- Impressed Current Anodes
- Piping
Impressed Current System

Rectifier

( - )         ( + )

Pipeline (Structure)

Anode Groundbed

Current Flow
Actual size of AWWA Specification Thickness Reductions for 36-inch Diameter Cast and Ductile Iron Pipe - 1908 to Present (150 PSI Operating pressure)
Stray Current by DC Operated Transit Systems

Power Station

Pipeline

Current exit (Anode)

Current entrance (Cathode)