Implementing and Managing a Large Water Utility’s Underground Corrosion-Control Program

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Topics to be Covered

- Corrosion Problems Facing Water Utilities
- Water Infrastructure Asset Management
- Definitions and Terminology
- Pipe Materials and Anti-Corrosion Coatings/Barriers
- DMWW Cathodic Protection Projects
  - CP Anode Retrofit Program for Existing Distribution Mains
  - CP Anodes at Water Main Breaks
  - CP for New Water Transmission Mains
  - CP for Small Diameter Distribution Mains
- Cathodic Protection Operation & Maintenance
Corrosion Problems Facing Water Utilities

Water Infrastructure Asset Management

Definitions and Terminology

Pipe Materials and Anti-Corrosion Coatings/Barriers

DMWW Cathodic Protection Projects

CP Anode Retrofit Program for Existing Distribution Mains
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CP for Small Diameter Distribution Mains

Cathodic Protection Operation & Maintenance

State of the Water Industry – Year 2011

“The ticking time bomb related to failing infrastructure – it is just a matter of time and will affect every community in the U.S.”

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Asset Management: A Real-World Definition

“A water utility’s asset management plan is an optimization process that attempts to meet the competing objectives of cost minimization and reliability maximization.”

*Source: Rubin, S.J., A Call for Reliability Standards, Journal AWWA (Jan-2011)*
Asset Management – The Core Framework

1. What is the current state of your assets?
2. What level of sustainable service is required?
3. Which assets are critical to sustainability?
4. What are the minimum life cycle costs?
5. What is the long-term funding strategy?


Asset Management – The Questions to Ask

1. Know what is owned, where is it located, and assess its condition
2. Understand water main performance and regulatory standards
3. Determine critical assets and evaluate their risk of failure
4. Know costs of continual asset repairs versus replacement
5. Evaluate capital expense funds versus current rate structures

Assess the Risk of a Water Main Failure

Risk = (Consequences of Failure) x (Likelihood of Failure)

- **Consequence of Failure**
  - 1: Do nothing
  - 2: Low priority
  - 3: Monitor
  - 4: Investigate more
  - 5: Action

- **Likelihood of Failure**
  - 1: Very low
  - 2: Low
  - 3: Medium low
  - 4: Medium
  - 5: Medium high
  - 6: High
  - 7: Very high

- **Actions**
  - Investigate more
  - Monitor
  - Action

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Anodes & Cathodes on a Buried Metallic Pipe

The Simplified Corrosion Cell

1. Anode
2. Cathode
3. Electrolyte
4. Metal Path

Copper at -200 mV
Steel at -600 mV
Components of a Familiar Corrosion Cell

Why is the open-circuit voltage of a common flashlight battery 1.5 volts?

CARBON ROD (Cathode)
ZINC CASE (Anode)
NH₄ and Cl⁻ Paste (Electrolyte)
WIRE (Metallic Path)

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>Mild Steel (New)</td>
<td>-0.70</td>
</tr>
<tr>
<td>Mild Steel (Old)</td>
<td>-0.50</td>
</tr>
<tr>
<td>Cast / Ductile 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>Gold</td>
<td>+0.20</td>
</tr>
<tr>
<td>Carbon, Graphite, Coke</td>
<td>+0.40</td>
</tr>
</tbody>
</table>

* Potentials in Volts Versus a Saturated Cu-CuSO₄ Electrode
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Corrosion of Prestressing Wires on Concrete Cylinder Pipe
Are Pipeline Coatings/Tape-Wrap Always Effective?

Ductile Iron Water Pipe – Reduced Wall Thickness

3/8” thick (Pressure Class 150)
Loose Polyethylene Wrapping

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Corrosion occurs where DC current discharges from the metal to the electrolyte. The objective is to allow your water main to receive DC current (be cathodic) from an expendable anode placed in the soil.

**Sacrificial Anode**: DC current is obtained from more active metal anodes connected directly to the structure.
Sacrificial Anode Installation

- Grade
- Sacrificial Anode
- Connection to Pipe
- Coating Defect

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Des Moines Water Works – An Overview

DMWW Summary Stats

- 521 miles out of 1380 miles* has already reached its life expectancy
- 620 miles out of 1380 miles* will reach its life expectancy by 2020

*Includes approximately 380 miles of non-metallic pipe used for a rural water distribution system

DMWW’s Long-Term Main Break Data (1994-2011)

[Graph showing the number of main breaks over time]
DMWW’s More Recent Main Break Data (2004-2011)

DMWW – Anode Retrofit Program Purpose

- Reduce Number of Broken Water Mains
- Extend Service Life of Water Mains
- Reduce Operating Costs of Water Mains
Implementing DMMW’s Anode Retrofit Program

The ARP Objective Site Selection Model Considers:

- Number of pipe failures
- Pipe material/age/diameter
- Pipe condition
- Ease of anode installation
- Soil characteristics
- Traffic disruption
- Excavation/restoration costs

Typical Anode Retrofit Installation Method
Years 2004 – 2008 Connection Methods

Years 2004 – 2005: Stud Welding

Neither Work on Pit Cast Iron Pipe!

Years 2006 – 2008: Pin Brazing

Exothermic Weld Connection and Hardware

Exothermic Welds Can Be Used On:
- Pit-Cast Iron Pipe
- Spin-Cast Iron Pipe
- Ductile Iron Pipe

Year 2008+: Exothermic Welding
Keyhole to Pipe & Wire Connection

Installation in Paved Roadways – Asphalt or Concrete
DMWW Main Break Comparison – ARP vs. No-ARP

DMWW Economics - Water Mains Installed w/ARP
DMWW Anode Retrofit Program: 2004-2011 Summary

- ARP installed on 82,370 feet of 6” to 16” water mains
- Total ARP Installation Cost = $1,028,838
- Main Break Cost (over 25 years) w/o ARP = $4,700,833
- Cost of New Mains would have been >$10 Million
- A 25-year service life extension is expected
- An average reduction of 90% in water main breaks

DMWW Economic Analysis: 2004-2011 Summary

*Over the estimated 25-Year Effective Service Life* of the
Anode Retrofit Program…

- Anode Retrofit Program vs. Pipe Replacement
  $40,683 Annualized Savings
- Anode Retrofit Program vs. Main Break Repairs
  $125,783 Annualized Savings

*After the initial anode installation, CP anodes must be replaced 3 times over the replacement pipe life*
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What's Your Biggest Cost to Repair a Main Break?
The Biggest Cost is for the Excavation & Restoration!

Do I really want to re-excavate this hole for another water main break?

Install a sacrificial CP anode while the water main repair excavation is already open!

Anode Installation and Connection Method
AWWA WRF Recommendations for Water Utilities

- Document all leak and main break repairs as recommended by Water Research Foundation (formerly AWWA Research Foundation)
- Install a sacrificial anode every time the water main is exposed for repairs or tapping
- Utilize water main failure data as a portion of your Asset Management System


Cathodic Protection Is **Proactively** Inexpensive

*Consider the cost of repairing a water main break versus the cost of installing a sacrificial anode during the pipe repair…*

**Average Cost of a Main Break**

>$5,000*

**Cost of CP Anode & Connection Device**

**Less than $200!**

*For comparison, the average cost for each main break in Des Moines, IA was $5,372 in 2011*
The DMWW considers corrosion protection as part of its design analysis for the following types of pipe materials used for new water mains:

- **Prestressed Concrete Cylinder Pipe (AWWA C304/C301)**
- **Ductile Iron Pipe (AWWA C110)**
- **Welded Steel Pipe (AWWA C200)**
Why Install CP on a Water Transmission Main?

The CP system will extend the life of the new water transmission main by at least 25 years at a cost that is much less than…

- Pipe repairs or,
- Main replacement or,
- The potentially more significant (but incalculable) indirect costs that could occur as a result of a service disruption to a key facility that the water main serves.

Sacrificial Anodes Installed in the Pipe Trench
What is the additional cost of installing cathodic protection on a new water transmission main?
In general, the total initial cost to install a CP system should be less than 3-5% of the total construction cost of the water main.

When expressed over the 25-year life expectancy of the CP system, the annual cost is ≤0.20%.

The effectiveness of any CP system is highly dependent upon the quality of any coating and or wrapping system applied to the external pipe surface.

Higher quality pipe coatings will reduce the cost of the cathodic protection.
So What Have We Missed?

- Anode Retrofit Program
- Anodes at Main Breaks
- CP for New Large Water Transmission Mains
- CP for Smaller Metallic Water Distribution Mains!

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Why Bother to Collect Corrosion Control O&M Data?

CP Performance Can Be Easily Verified
Do You Have Any Questions?

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