City of Rochester’s Comprehensive Approach to Corrosion Prevention and Mitigation Keeps the Water Flowing

AWWA – New York Section
Edwin C. Tifft Jr. Water Supply Symposium
Syracuse, NY
September 21, 2017

Session 5: Lead and Corrosion Issues
Presented By: Chris LaManna, PE, Wendel
Hank Kleinfelder, CorrTech
Agenda

- Overview of Rochester’s Water Supply System
- Development of Rochester’s Corrosion Control Program
- Corrosion Control Techniques
- Current Cathodic Protection System Improvements Project
Rochester Water Supply System

- City of Rochester Bureau of Water
  - Began in 1876
  - Serves 210,000 People
  - 20 Wholesale Connections

- Water Sources
  - Primary: Hemlock and Canadice Lakes (30 Miles South)
  - Secondary: Lake Ontario Via Interconnection with MCWA

Rochester Water Supply System

Distribution System

Upland Transmission System
Distribution System

- Two Reservoirs
  - 25 MG Highland Reservoir
  - 144 MG Cobbs Hill Reservoir
- Distribution Water Main
  - 600 Miles
  - 6-Inch to 36-Inch Diameter
  - Cast Iron, Ductile Iron, PVC/PVCO
- No Pump Stations
- Interconnections with MCWA
Upland Transmission System

- Three Transmission Mains: “Conduits” 1, 2, and 3
- 66 MG Rush Reservoir
  - Transmission Reservoir
  - Liner and Floating Cover
- Gravity Conveyance
- Route – Mostly Rural, Cross Country, Agricultural Areas
Upland Transmission System

• **Conduit 1: 1874-1875**
  - 24-Inch Diameter Wrought Iron and Cast Iron Pipe
  - Lead Joints, Asphalitic Coating

• **Conduit 2: 1893-1894**
  - 38-Inch Diameter Riveted Steel Pipe
  - Welded Joints, Coal Tar Coating

• **Conduit 3: 1914-1918**
  - 37-Inch Diameter Lockbar Steel Pipe
  - Welded Joints, Coal Tar Coating
Upland Transmission System Conduits
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Who Needs A Corrosion Control Program?
Development of Corrosion Control Program

• 1874-1918:
  - Conduits 1, 2, and 3 Installed

• By 1900:
  - Over 1000 Joint Leaks Repaired in Conduit 1
  - Multiple Corrosion Holes Repaired in Conduit 2
  - Pipeline Recoating Process Initiated in Conduit 2 (10-Years)
Development of Corrosion Control Program

• 1940s to 1970s:
  - CML of Significant Portion of All Conduits (Significant Reduction in Leaks)
  - 9.6 Mile Section of Conduit 1 Taken Out of Service (Joint Leaks)
  - Begin to Install Cathodic Protection Systems (1960s)
Development of Corrosion Control Program

- **Late 1970s and 1980s:**
  - Two Studies Conducted on Condition of Conduits

- **1997 to 2001:**
  - Comprehensive Study of Conduit System
  - Corrosion Evaluation
  - Field Testing to Determine Electrical Continuity
  - Soil Sampling and Analysis – Corrosivity and Resistivity
  - Pitting and Ultrasonic Thickness Testing
  - Recommended: Installation of Impressed Current Cathodic Protection (ICCP) Systems
Development of Corrosion Control Program

- **2001 to 2003:**
  - ICCP System Pilot Study (CorrTech)
  - 4,000 Linear Feet of Conduits
  - Results:
    - ICCP Systems Feasible South of Rush Reservoir
    - ICCP Systems Not Feasible North of Rush Reservoir
Development of Corrosion Control Program

• 2004 to Present:
  o Further Development and Implementation of Corrosion Prevention and Mitigation Program
  o Different Approaches to Upland System and Distribution System
Agenda

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Corrosion Control Techniques

- Pipe Replacement and Rehabilitation
- Non-Metallic Pipe
- Pipe Coatings and Linings
- Cathodic Protection Systems
- Select Backfill
- Operations Personnel Training
CP Current Applied From an External Anode

Metallic Path - Cable

Power Volts

Metallic Path - Structure

Electrolytic Path

A

C

C

$I_{cp}$
Corrosion Control By CP is Achieved When:

- Sufficient current is applied to all surfaces of the structure in contact with the electrolyte to:
  
  - Polarize the potential of all the anodic areas in the negative direction so that the net current flow to all surfaces is on to the structure (cathodic current)
  
  - And the pH of the electrolyte at these surfaces is increased into the passive (pH>12 for carbon steel) range
Corrosion Control - Training

• Continual Training and Education on Corrosion Control

• Appalachian Underground Corrosion Short Course (NACE), Morgantown, West Virginia (Campus of WVU)
Corrosion Control – Upland System

• Cathodic Protection
  o Sacrificial Anode Bed System: Urban Areas
  o ICCP Systems: Rural Areas

• Pipe Replacement
  o Areas Where ICCP Not Feasible

• Pipe Lining
  o CML
  o Cured-in-Place Pipe (CIPP)
Corrosion Control – Upland System

• Pipe Replacement
  o Two Miles of Sections of Conduits 2 and 3 in Urban Areas (2009 to 2013)
  o Spiral Welded Steel Pipe (CML and Tape Coating)
  o Sacrificial Anode Bed Systems

• Pipe Lining
  o Sections of Conduits 2 and 3 Under Canal (CIPP)
Corrosion Control – Upland System

• Cathodic Protection
  o Rural Areas of Conduits
  o Primarily ICCP Systems

• 26 Miles Cathodically Protected To Date
  o ICCP for 17 Miles of Conduits 2 and 3 in 2006-2008
  o ICCP for 4 Miles of Conduits 2 and 3 Planned 2018-2020
ICCP System Components

- Source of Electrical Power
- Rectifier
- Anodes
- Cabling
- Test Stations
- Insulating Connections
ICCP System Planning

• Field Investigation
  o Used to Determine Electrical Continuity of Pipe
  o Measure Pipe Resistance Using Temporary Circuits and Two-Wire Test Stations
  o 700 to 1,000 Linear Foot Long Test Segments (Shorter is Better)
  o Pipe Considered Electrically Continuous if:
    ➢ Actual Resistance/Theoretical Resistance < 1.15
  o Discontinuities: Unbonded Gasketed Joints, Sleeve-Type Couplings, Valves
ICCP System Implementation

- Typical ICCP System Layout

TWO ANODES (8” DIA X 28’ DEEP WELL) AT 150-FT SPACING

ANODE HEADER CABLE

CONDUIT 2

CONDUIT 3

NEW ELECTRICAL SERVICE

RECTIFIER
ICCP System Operation and Maintenance

- **Electrical Service:** $200 to $300/Year
- **Rectifiers**
  - Confirm All Connections Property
    - Tightened Annually
  - Some Overheating Issues – Loose Steel
    - Connections Suspected (Replaced with Copper)
  - Cow Ear Tags for Bee/Hornet Control
ICCP System Operation and Maintenance

• Test Stations
  o Record Readings Twice Annually (Spring and Fall)
  o Monitor for Significant Changes
  o Increase in Voltage / Decrease in Amperage Could Indicate Deteriorating Anodes
  o Repair if Damaged (Hit By Agricultural Equipment)
ICCP System Operation and Maintenance

• Anodes
  o 25 Year + Anticipated Life
  o Eventually Require Replacement – Monitor Performance Via Test Stations
ICCP System Challenges

- Electrically Discontinuous Pipe
  - Most Significant Issue
  - Finding Locations of Discontinuity Can Be Difficult and Time Consuming
  - Close Internal Survey
  - Detailed Field Investigation Required During Planning/Preliminary Design
ICCP System Challenges

- Thermite Welding to In Service Pipe
  - Heat Pipe First to Dry Surface to Avoid Instantaneous Steam
- Large Diameter Insulating Sleeve Type Couplings Not Always Reliable
  - Use Spools of Non-Metallic Pipe (PVC) As Alternative
Corrosion Control – Distribution System

• New/Replacement Water Main Planning
  o Soil Corrosivity Testing
  o Environmental Site Review - Identify Potential Areas of Impacted Soils
    ➢ Petroleum Hydrocarbons
    ➢ Chlorinated Solvents
    ➢ Soil Sampling and Testing
  o Results Used to Determine Water Main Materials
Corrosion Control – Distribution System

• Non-Metallic Pipe for New/Replacement Mains If Possible
  - PVC or PVCO (Since 2005 +/-)
  - HDPE (Primarily for Services)
  - Not Used in Areas of Impacted Soils
  - Ductile Iron Fittings
    - Epoxy Coated (ANSI/AWWA C116)
    - Petrolatum Wax Tape Coating System (ANSI/AWWA C217)
    - 9 LB Magnesium Anode Thermite Welded to Each Fitting
Corrosion Control – Distribution System

- **Anode**
- **PVCO Pipe**
- **Epoxy Coated MJ Restraint**
- **Anode Lead Wire**
- **Ductile Iron Fitting with Petrolatum Wax Coating**
Corrosion Control – Distribution System

• New/Replacement DIP Main
  o Joint Bonding
  o PE Encasement (Since 1990)
  o Sacrificial Anodes (Since 2000)
  o Select Backfill – Minimize Contact with Corrosive Soils

• New/Replacement Copper Services
  o Sacrificial Anodes
Corrosion Control – Distribution System

**NOTEs:**
1. Use #8 AWG stranded copper wire with hmwpe insulation for joint bonds on pipe sizes 12 inches in diameter and smaller and use #4 AWG stranded copper wire with hmwpe insulation for joint bonds on pipe sizes larger than 12 inches in diameter.
2. Joint bonds are not required at mechanical joints where mechanical joint restraint glands have been installed.
3. Pipe and fitting gaskets are to be covered and protected from damage when installing joint bonds.

**CITY OF ROCHESTER**

**Joint Bond for Metallic Water Main Pipe/Fitting**

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**CITY OF ROCHESTER**

**Anode at New Ductile Iron Water Main or Ductile Iron Fitting on New Plastic Water Main**

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Corrosion Control – Distribution System

- Annual Cleaning and Cement Mortar Lining Program

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Legend: Water Mains to be Cleaned & Lined

City of Rochester
Department of Environmental Services
Bureau of Water
January 2016
Agenda

• Overview of Rochester’s Water Supply System
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Current CP Improvements Project

• Field Tested 3.4 Miles of Conduits 2 and 3 to Determine Electrical Continuity
  - 3.4 Miles = 85% of Total 4 Miles of Parallel Conduits
  - Majority Electrically Continuous – Eight New ICCP Systems Designed
  - Approximately 1 Mile of Conduits 2 and 3 Within Existing County Highway - Discontinuous
    ➢ Reconnected CML Access Locations Suspected Cause of Discontinuity
    ➢ Records of Locations Not Available
    ➢ Locations of Discontinuity Difficult to Determine Cost Effectively
    ➢ Alternate Method of Corrosion Control to be Considered
Current CP Improvements Project

• Assess Sections of Out of Service Conduits for Use as Anodes
  o Electrical Continuity Testing
  o Joint Bonding
  o Pipe Removal to Eliminate Physical Contact
  o Cost Effective ICCP System Using 1,300 Linear Feet of Parallel Out of Service Conduits
  o Avoid Excavation Through Designated Wetlands
  o Fill Out of Service Conduits with Flowable Fill
Use Out of Service Conduits as Anodes

**OUT OF SERVICE C2** (38” RSP)

**OUT OF SERVICE C3** (37” LSP)

**THERMITE WELD CONNECTION**

**AWG #2 NEGATIVE RETURN CABLE AND AWG #10 TEST WIRE**

**ICCP SYSTEM RECTIFIER**

**AWG #2 POSITIVE FEED CABLE**

**AWG #2 BOND CABLE**

**IN SERVICE C2** (38” WSP)

**IN SERVICE C3** (38” WSP)
Final Thoughts

• Corrosion Control Requires Comprehensive Approach
  o Not “One Size Fits All”
  o Multiple Techniques Necessary

• Thorough Evaluation of Existing Conditions Necessary to Understand:
  o How Corrosion is Occurring
  o Which Control Methods are Feasible

• Personnel Training is Important Component
Questions / Discussion

Thank you.

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