Investigation & Remediation of Corrosion Issues in City Tunnel 3

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Presentation Outline

• Background of New York City Water Supply System
• City Tunnel 3
• Corrosion Remediation Project
  ➢ Condition Assessment
  ➢ Major Findings
  ➢ Proposed Mitigation
New York City’s Water Supply System

- Water from reservoirs - Upstate New York
- Supplying clean drinking water to:
  - over 8.5 million City residents
  - millions of tourists and commuters
  - approximately 1 million residents - Westchester, Putnam, Orange, and Ulster counties
City Tunnel No. 1
- In Service from 1917
- 18 Miles long

City Tunnel No. 2
- In Service from 1936
- 20 Miles long
City Tunnels

City Tunnel No. 3
- Stage 1
  - In service from 1998
  - 13 Miles long
- Stage 2 Manhattan leg
  - In service from 2013
  - 9 Miles long
- Stage 2 Queens/Brooklyn leg
  - Activation Ready
  - 11 Miles long

NEW YORK CITY WATER TUNNELS AND DISTRIBUTION AREAS
City Tunnel 3 Shafts and Chambers

Tunnel system:

- Valve Chambers to control flow
  - Van Cortland Park Valve Chamber
  - Central Park Valve Chamber
  - Roosevelt Island Valve Chamber
- Numerous distribution shafts

Cross Section along City Tunnel 3

Water Tunnel No. 3
A Cross Section

Underground chambers
• Most of the piping were installed in the 1980s
• Designed to allow groundwater
• Not all laterals are in operation

Environment inside the deep chambers
• Cool (40°F - 50°F)
• Damp (around 90% relative humidity)
• Condensation on metallic components

Over the years……..
• Signs of Corrosion
• Coating failures
Project Objectives

DEP initiated the project:

• To determine the root causes of corrosion
• Develop a detailed design to remove corrosion on affected components
• To protect the components from further corrosion
• To apply lessons learned from this project to future tunnels

If left unaddressed, corrosion may lead to:

• Significantly reduced life expectancy of equipment
• Potential significant leaks
• An emergency tunnel shutdown
• Service interruptions
• Significant financial consequences
Condition Assessment

- **Visual Inspection and in-situ testing**
  - Coating thickness measurement
  - Carbonation testing with indicator solutions
  - Concrete sounding
  - Schmidt Hammer (Rebound Hammer) Testing

- **Sampling and Laboratory Analysis**
  - Coatings on piping
  - Brown deposits for MIC
  - Infiltrated and condensed water
  - Mineral deposits
  - Concrete coring
Corrosion Mechanisms

Corrosion of Pipes in Valve Chambers
- Oxygen driven corrosion
  - Low temperature
  - Very high humidity
  - Dissimilar metals
- Microbiologically influenced corrosion (MIC)
- Localized Corrosion of Stainless Steel

Corrosion mechanisms for Cast-in-place concrete
- Carbonation
- Chloride attack
Major Findings - Carbon Steel Components

• No indication of underlying steel corrosion

• Coating degradation and mineralization
  ➢ At pipe-wall interface
  ➢ At six o’clock position

• Thick anti-condensation coating was not applied for flange faces and edges – shows rusting
Major Findings - Carbon steel components

Galvanic Corrosion

Carbon steel cradle on top of stainless steel base

Carbon steel counterweight and stainless steel arm
Major Findings - Stainless Steel Components

Stainless steel components

- Generally in very good condition
- Some minor stains
- Brown deposits on split sleeve couplings and sump discharge piping

Borescope Inspection of Sump Discharge Piping

- At each circumferential weld, tubercles consistent with MIC were observed.
- Both interior and exterior stains tested for the presence of bacteria commonly associated with MIC using a MICkit® 5 test kit.
- Positive indication for bacteria commonly associated with MIC

Tubercles at weld

Interior of removed pipe section showing thin scale

Simplified diagram showing MIC corrosion
Major Findings

• Of the three valve chambers assessed:
  ➢ Van Cortlandt Park Valve Chamber is comparatively in the best condition
  ➢ Roosevelt Island Valve Chamber is comparatively in the worst condition

• Chloride contents:

<table>
<thead>
<tr>
<th></th>
<th>Van Cortland Park VC</th>
<th>Central Park VC</th>
<th>Roosevelt Island VC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride Concentration (ppm)</td>
<td>59-989(^1)</td>
<td>52-148</td>
<td>10-1070(^2)</td>
</tr>
</tbody>
</table>

\(^1\) Out of the seven samples collected from Van Cortland, only one sample had chloride content of greater than 500 ppm, and the average chloride content, excluding that sample, was 167 ppm.

\(^2\) Six out of twelve samples had chloride content beyond 200 ppm.
Major Findings - Concrete

Observations at Roosevelt Island Valve Chamber

• Mineralization
  ➢ Mineral deposits oozing out of walls and pipe penetration
• Reinforcing steel exposed at majority of pedestals
• Riser concrete casing (hollow with multiple cracks)
• Hollow concrete on walls and pedestals
• Delaminated concrete and various spalls
Proposed Mitigation - Carbon steel components

Wax Tape Wrapping

• microcrystalline wax – synthetic fabric
• Applied with a primer
• Entire coating removal if necessary

Proposed Components:
• Pipe Stubs
• Flanges of Shaft Caps, Valves etc.

Benefits:
• Prevent water intrusion to base metal
Proposed Mitigation - Carbon steel components

Conventional Coating

• Re-coating surfaces with necessary surface preparation
• Rust inhibiting primer and top coat

Proposed Components:

- Shaft caps
- Carbon Steel Cradle - Pipe Supports
- Riser valve counterweights
- Overhead Cranes
Proposed Mitigation - Carbon steel components

Replacement of Components
• If necessary, replacement with corrosion-resistant components
• Cast iron components with stainless steel components e.g. Cast iron air relief valves with stainless steel valve etc.

Infrared Lighting for Shaft Caps
• Already installed in Valve chambers; Additional units recommended
Proposed Mitigation - MIC

Handling Suspected MIC

• Possible camera inspection around sleeve coupling location of laterals

• If MIC is confirmed, depending on the condition, possible mitigation include:
  ➢ Disinfection – shock treatment
  ➢ Mechanical Removal

  Recommendation for mitigation cannot be made until extent of damage to stainless steel internals is known.

For Sump Discharge Piping,

• Plastic Lining – Cured in Place Lining (CIPP)
Proposed Mitigation - Concrete

Chloride Removal from walls
Alternates considered:
  • Mechanical Removal
  • Electrochemical Chloride Extraction
  • Cathodic Protection

Galvanic cathodic protection is recommended

  • Consists of multiple anodes (E.g. every 2 feet spacing)
  • Anodes can be various shapes (e.g. ribbons tied to rebar, anode mesh placed on the surface of concrete, etc.)
  • Depletes every 15 to 20 years
  • Less maintenance after installation
  • Low capital and maintenance cost compared to Impressed Current CP
Proposed Mitigation – Ancillary Items

• Improving Drainage
  ➢ Cleaning weep holes
  ➢ Installing additional weep holes beneath the pipe penetration
  ➢ Installing cover for drainage channels

• Improving Ventilation
Next Steps

• DEP conducted studies in 2002, 2006 and 2017
• Results revealed that conditions haven’t been deteriorated significantly since the last inspection.
• Facility Planning Phase:
  o Independent Technical Review to provide an independent assessment of the adequacy of the design
  o Recommendation for facility planning alternatives
  o Basis of Design Report

Proposed Design: 2018 - 2020

Procurement: 2020 - 2021

Proposed Construction to begin 2021
Questions?