Acoustic Fiber Optic Monitoring of PCCP and Pipelines of Other Materials

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Presentation Outline

• PCCP Common failure modes
• Metallic pipe failure modes
• PCCP & metallic pipe inspection solutions
• Fiber optic Monitoring
• Case studies
Reasons for doing condition assessment.

- Avoid replacing pipes that are still in good condition
- Rehabilitate individual pipes for a fraction of the full line replacement cost
- Optimize utility budgets
- Minimize the risk of significant pipeline failures
- Understand the true valuation of your underground infrastructure
Comprehensive Condition Assessments – Risk Based Approach

- Due to the difficulty and cost of inspecting these high consequence of failure pipelines, the assets should be prioritized for inspection.

Risk Rating

- Likelihood of Failure
  - Structural
  - Operational

- Consequence of Failure
  - Direct Cost
  - Health/Environment
  - Socio-Economic Cost
PCCP Cross Section

- Proven for a wide variety of pipe classes:
  - PCCP
    - Embedded cylinder pipe
    - Lined cylinder pipe
  - Non-cylinder pipe
  - Bar wrapped pipe
PCCP Deterioration

- Cracking of Outer Mortar
- Corrosion or Embrittlement of Wires
- Wires Break
- Bell and spigot corrodes and fails
- Cylinder corrodes and fails
- Mortar Coating Delaminates
- Concrete Core Delaminates
- Core Cracks
- Failure
Summary of Inspections

- Vast majority of PCCP which has been inspected is in good condition
- Trick is to find the “bad pipe” prior to failure and not waste money replacing pipes that are in good condition
Assessment Program Steps

• Desktop Study – Establish Priorities & Schedule pipelines for inspection
• Leak detection prior to dewatering (AWWA)
• Internal Inspection:
  1. Electromagnetic testing/leak detection
  2. Manned Visual and Sounding inspection
  3. Structural Analysis - Finite Element Analysis (FEA)
  4. Calibration or Validation of testing results
  5. Establish repair/replacement priorities – implement emergency repairs
  6. On-going acoustic fiber optic monitoring
Metallic pipe failure modes:

- Corrosion - internal, external
  - Cracking
  - Bedding issues
  - Joint failure
- All leading towards ultimate failure
Metallic Pipe Condition Assessment tools:

- Leak detection
- Acoustic Pipe Wall Assessment
- Magnetic Flux Leakage, 360 degree scan
- RFEC – multi sensor tool, 360 degree scan
- Broadband Electromagnetic
Inspect for Leaks Prior to Dewatering

**SmartBall® (free swimming)**
- Long point-to-point transmission pipelines
- Minimal laterals

**Sahara® (tethered)**
- Complex interconnecting networks
- Urban centers

Gives you the ability to inspect and fix leaks during shut down

Leak inspection prior to line shut-down as part of maintenance routine
2. Visual & Sounding

- Visual and sounding inspection complements other inspection methods
- Identify problems with joints that are not addressed by EM methods
- Find problems that are not related to wire breaks (i.e., over loading, cracking, etc.)
Electromagnetic Basics

Functions like a radio transmitter and receiver

Transmitter produces an electromagnetic field which is amplified by prestressing wires

Receiver captures the signal and:

- Detects and quantifies wire break damage
- Provides estimate of wire breaks in each pipe section
- Provides location of wire breaks
Electromagnetic tools

P-Wave® / RFTC
- Diameter: All
- Line Preparation: Dewatered or Depressurized
- Manned and track systems available

PureRobotics™
- Diameter: 18”+
- Line Preparation: Depressurized
- Multi-sensor inspection vehicle with EM, CCTV, Sonar, GIS mapping

PipeDiver™
- Diameter: 24”+
- Line Preparation: In Service
- Free swimming tool ideal for long distance inspections
P-Wave® / RFTC

- Proven technology platform
- Daily inspection distance:
  - Manned 3-6 miles
  - Track 0.5-2 miles

Small Diameter  Large Diameter  External Tool  Track System
Robotics™

- **Robotic EM** inspection benefits:
  - No need to de-water
  - Dewatering can be significant expense
  - No need for manned entry / safety and insurance
  - Can access smaller pipe diameters
  - Extremely robust dual track system
- **Designed** for 24”-42” PCCP lines (16”x14” min. access MH)
- **Inspection** of potable water lines (dedicated system)
- **Inspection** of sanitary lines (dedicated system)
PipeDiver™

PipeDiver™ inspection benefits:
– Line remains in service / no need to dewater
– Minimize pipe recharge risk
– Ideal for lines with no redundancy
– No disruption to service
– Long distance inspections
– Modular design allows for valve and bend navigation
– Insertion/removal via hot tap, open channel, reservoir, chamber

Small diameter tool (24” – 72”)

Large diameter tool (> 48”)

Battery Module | Sensor Module | Transmitter Module | Navigation & Retrieval Aid
PipeDiver™ Process

Insertion sleeve with guide

Extraction sleeve with net
GIS Mapping

**Web based data management**

• Visual consequence of failure and risk management

• Accurate asset monitoring for repair and replace programs

• Data inputs: manual inspections, electromagnetic inspections, leak identification, fiber optic monitoring
Understanding the Inspection Results
Extending the life of critical assets

“Solutions for Sustainable Infrastructure”
EM Data Analysis

Pipe #

Joints

Amplitude

Phase

Distance

Pipe #

Joints

Amplitude

Phase

Distance

6 7 8 9 10 11

0' 20' 40' 60' 80' 100' 120'

6 7 8 9 10 11

TR5-UIR 2012, Niagara Falls Ontario
Interpreting the Results....

.... Failure Risk Analysis & Repair Prioritization
## Combined Results

<table>
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<tr>
<th>Pipe No.</th>
<th>Pipe Class</th>
<th># of Wire Breaks</th>
<th>Wire Break Positions</th>
<th>Total # of WB</th>
<th>Repair Priority</th>
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<td>150</td>
<td>10; 15</td>
<td>4, 16</td>
<td>25</td>
<td>1C</td>
</tr>
</tbody>
</table>

Failure/risk analysis provides repair priority
3. Structural Analysis – Finite Element

- Often referred to as performance or risk curves
- Establish criticality of individual pipe designs (impact of broken wires)
- Based on certain assumptions (# wire breaks, cover, design/surge pressure, current design criteria)
5. Repair Options

- Carbon Fiber Repairs
- Post tensioned Tendons
What is AFO?

- AFO stands for:
  - Acoustic Fiber Optics

- We use fiber optics to monitor the breaking of pre-stressed wires in Pre-stressed Concrete Cylinder Pipe (PCCP). AFO is also, currently in service as a continuous leak detection system.

- The fiber optic cable is able to LISTEN, IDENTIFY, and LOCATE breaks of the pre-stressed wires in the PCCP.
How does AFO work?

- Fiber optic cable is laid on the inside surface of PCCP and acts as one long underwater microphone.
- Data Acquisition Unit interprets, timestamps and saves the Data.
- AFO works as a two part system using two different fibers:
  - The first fiber LISTENS to the pipeline (acoustic fiber).
  - The Data Acquisition Unit IDENTIFIES events, and saves the information.
  - The second fiber LOCATES the wire break along the length of the pipeline (locating/OTDR fiber).

Both fibers operate differently, but with the same principle that pressure waves from wire breaks will create light reflections in the fiber bundles which are then measured and interpreted.
DAQ Cabinet

- The cabinet contains all electronic components which monitor the fiber optic line
- All the information acquired by the DAQ system is sent to Calgary via the internet for analysis
- Extra fiber bundles can be used for IT and SCADA applications

The Data Acquisition Unit is able to LISTEN, IDENTIFY, and LOCATE breaks of the pre-stressed wires in the PCCP, leaks in both PCCP and metallic pipes

“Solutions for Sustainable Infrastructure”
AFO Long-term Monitoring

“AFO installation

Data acquisition

AFO Wet installation – permanent or multiple site

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Long-term Monitoring Success

Potomac 96-inch Transmission Main – Emergency Repairs
• 8 wire breaks detected in less than 10 hours (6 in ½ hour)
  • WSSC immediately mobilized for repairs
  • Mandatory water restrictions issued for 1.8 million customers

“Solutions for Sustainable Infrastructure”
AFO Projects in Canada

To date we have two operating projects in Ontario – three more are being designed:

• The first is in London Ontario – 20km system, phase one installed in 2010, second phase scheduled for fall of 2011.
• In April/May of 2011 a 6km system was installed for the City of Ottawa.
Thank you!