Pure Technologies

• Over 30 years of experience in pressure pipe assessment and management

• Provided inspection, assessment, and management of thousands of miles of pressure pipe

• Expertise includes non-destructive technologies, hydraulic transient monitoring, forensic evaluations, structural modeling, and life cycle assessment

• Inspection, assessment, and program management services for many large utilities

• Over 500 employees in 12 North American offices
Large Main Failure Cost

Total Failure Cost = Direct Cost* + Societal Costs**

Total Failure Cost = $500,000*** + ($5 x 15,000 pe x 5 days to repair)

Total Failure Cost = $875,000

*Repair, engineering, flooding damage, landscaping/restoration, etc.

**$5/day triple bottom line inconvenience charge per person for low pressure or no service

A good estimate of the total cost of large diameter main breaks based on these data is $500,000. Flooding damage is the largest type of cost associated with these breaks.* 30 large diameter (500-mm+) failures analyzed: repair average $1,700,000; mean $500,000.

Analysis of Total Cost of Large Diameter Pipe Failures, American Water Works Association Research Foundation, 2007
Managing Risk

- **High Risk Zone**
  - Strategy: Plan for asset renewal and/or risk mitigation

- **Medium Risk Zone**
  - Strategy: Mix of reactive and proactive strategies, dependent on owner preferences and site specific issues

- **Low Risk Zone**
  - Strategy: Proactive condition and/or performance monitoring

- **Probability of Asset Failure**

- **Consequences of Asset Failure**
1. Find the weak links
2. Repair
3. Manage pipeline
Failure Pressure
Leading Causes of Valve Failures

- Lack of Access
- Over Torqueing
- Lack of Training
- **Lack of Exercise**
- Lack of Lubrication
- Lack of Maintenance
- Gears out of Adjustment
- Wear and Tear on the Seat Gasket
- Valve Exercisers Out of Calibration
- Under-Designed: Light Duty Actuator
External Stops & Seats on Disc

External “Stops” on Gearbox

Seat Gasket on Disc
Seat Gasket & Disc Out of Adjustment

Left Side of 72-inch BFV Disc

Right Side 72-inch BFV Disc
Prestressed Concrete Cylinder Pipe
PCCP Construction

- Concrete core
- Steel Cylinder
  - rubber gasket
  - bell and spigot rings
- High strength wire
  - Wrapped under tension
- Mortar coating
  - Protect the pre
PCCP Design

AWWA C301 – Lined Cylinder PCCP (SP-5)

- Prestressing wires wrapped directly over steel cylinder
- 16-inch to 60-inch*

AWWA C301 – Embedded Cylinder PCCP (SP-12)

- Prestressing wires wrapped over concrete core
- 24-inch* to 244-inch
Early concrete pressure pipe added a steel cylinder for water retention. (1929)

First installation L-301 pipe – 1942

First AWWA standard 1949 (C301)

First installation E-301 pipe – 1953

Used in 90 of the 100 largest municipalities

>20,000 miles in N. America

Long service life
PCCP History
Primary Failure Mechanisms

Corrosion

• Loss in cross-sectional area of wire

• Wire breaks
  • Tension released

• Causes
  • Cracking and/or carbonation of the mortar coating
  • Infiltration of corrosion products
Primary Failure Mechanisms

Dynamic Strain Aging/Hydrogen Embrittlement

Good Quality Wire
Primary Failure Mechanisms

Dynamic Strain Aging/Hydrogen Embrittlement

Poor Quality Wire
PCCP Management

• Inspection
  • Leak Detection
  • Visual and Sounding
  • Electromagnetic

• Assessment
  • Hydraulic Analysis
  • Structural Evaluation
  • Risk Analysis
Visual & Sounding

• Identifies pipes in a state of incipient failure
• Actual distances and features used to compile actual laying schedule
Leak & Gas Pocket Detection
Acoustic Leak & Gas Pocket Detection

- Leaks are often precursors to failures
- Transmission main leaks major source of water loss
- Gas pockets may promote internal corrosion (force mains), compound the effects of hydraulic transients, and reduce capacity
Inline Acoustic Leak & Gas Pocket Detection Technologies

**SmartBall®**
- Free swimming
- All pipe materials
- 150mm diameter and greater
- +/- 1.5 m location accuracy
- 100mm insertion
- Inspection length up to 20 km
- Pipeline mapping available

**Sahara®**
- Tethered
- All pipe materials
- 300mm diameter and greater
- +/- 0.5 m location accuracy
- 50mm insertion
- Inspection length up to 1.5 km
- Pipeline mapping not available
SmartBall Leak and Gas Pocket Detection Technology
Leaks Per 150 km Inspected by Type

Source: Free Swimming database
Types of Leaks Found by Pipe Type

- **PCCP**
  - Unknown: 25%
  - Barrel: 1%
  - Joint: 15%
  - Feature: 59%

- **Steel**
  - Unknown: 36%
  - Barrel: 1%
  - Joint: 12%
  - Feature: 51%

- **Ductile Iron**
  - Unknown: 22%
  - Barrel: 7%
  - Joint: 11%
  - Feature: 60%

- **Cast Iron**
  - Unknown: 8%
  - Barrel: 22%
  - Joint: 39%
  - Feature: 31%

Source: Free Swimming database
Insertion Setup (Hydrant)
Overview Map with **Leak Locations**
SmartBall Case Study – North Cowichan

Magnetometer data

150mm lateral or inline valve

Leak #1 location: ~20m downstream of the 150mm lateral or inline valve

Joints

Flow
Pipe Material Change and Un-documented Feature

SmartBall data is used to locate possible pipe material changes and undocumented features by carefully looking for changes in the:

✓ Pipes natural magnetic field
✓ SmartBall rolling motion
✓ Background acoustic signature

Note: Not all pipe material changes or features will provide a noticeable signal change.
Confirmation of Pipe Alignment

SmartBall data is analyzed to identify and locate bends for the purpose of confirming pipeline alignment.

✓ Measured heading changes are correlated to elbows seen in drawings and or GIS

✓ Areas with discrepancies will be identified in a table and visual format
Sahara Leak and Gas Pocket Detection Technology
Kingston – Woodbine Road Watermain

300mm Ductile Iron

Installed in 1990

Approximated 1km

Average operating pressure of 90psi

Only pipeline to subdivision which includes a school
Condition Assessment Platforms for Wall Assessment

**PipeWalker**
- PCCP, BWP, Steel, DIP
- Dewatered
- 36” – 60”

**PipeDiver**
- PCCP, BWP, Steel, DIP
- In-service
- 16” – 120”

**PureRobotics**
- PCCP, BWP, Steel, DIP
- Depressurized
- 16” – 120”

**PureMFL**
- Steel, DIP
- Dewatered
- 54” – 99”
Large-Diameter Watermain Condition Assessment

Electromagnetic - Free-Swimming
Large-Diameter Watermain Condition Assessment

Electromagnetic - Free-Swimming
Electromagnetic Inspection

Amplitude

Phase
Electromagnetic Inspection
Structural Analysis

54 inch ECP Water Main Mark 164 under 9 feet of cover

- Microcracking
- Visible Cracking
- Yield
- Strength
- Operational Pressure
- Operational+Surge Pressure
- Steel Cylinder Yield Strength
- Steel Cylinder Ultimate Strength
Transient Pressure Monitoring
Palo Verde

- Arizona Public Service owns a major stake (29.1%) in the Palo Verde Nuclear Generation Station and operates the facility.
- Construction began in 1976. There are three units, the last of which was completed in 1988.
- About 4 million people in California, Arizona, New Mexico and Texas receive power generated by the Palo Verde plant.
Palo Verde
## Palo Verde Details

<table>
<thead>
<tr>
<th>Unit 1</th>
<th>Capacity Net MW(e)</th>
<th>Generation in 2003 Megawatthours</th>
<th>Capacity Factor in 2003</th>
<th>Type</th>
<th>On-line Date</th>
<th>License Expiration Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>1,243</td>
<td>10,587,107</td>
<td>97%</td>
<td>PWR</td>
<td>June 1, 1985</td>
<td>Dec. 31, 2024</td>
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<tr>
<td>Unit 2</td>
<td>1,243</td>
<td>8,439,236</td>
<td>77.3%</td>
<td>PWR</td>
<td>April 24, 1986</td>
<td>Dec. 9, 2025</td>
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<tr>
<td>Unit 3</td>
<td>1,247</td>
<td>9,554,710</td>
<td>87.2%</td>
<td>PWR</td>
<td>Nov. 25, 1987</td>
<td>March 25, 2027</td>
</tr>
</tbody>
</table>
Circulating Water PCCP

- Ruptures on this piping are unacceptable
- Extended repair outages would also compromise the ability of the power plant to supply clients with electricity
- Proactive action
  - assess the condition of this water piping
  - began in the 1980’s with a detailed look at the design of the pipeline and the surrounding soil conditions
• Water Reclamation line and Unit cooling and return lines inspected at least 4 times
• Distressed pipes identified
• Risk assessment taking place
Prestressed Concrete Cylinder Pipe

- EM provides a picture of the current state of prestressing wires
- AFO provides the rate wires break
Cable Installation

Unanchored installation

Fully anchored installation

Splice Points
Data Acquisition

- Continuous monitoring
- Single DAQ up to 12.5 miles
- Dual DAQ up to 25 miles
- Requires 2 dedicated circuits
- Standard includes power backup (45mins)
Monitoring Process

Fiber Optic Cable

DAQ

Acoustic Data

Location Data

Analysis

pure TECHNOLOGIES
AFO Monitoring

Data Acquisition System

Fiber Optic Cable

Data Analysis

E-mail Notification
AFO Monitoring
Metallic Pipelines
Electromagnetics (Metallic)
Project Overview

- PipeDiver inspection in April 2016
- 800-mm (32-in) steel water main
- 2.8 km (1.7 mi)
- 3 runs, 1 Butterfly valve

Click here to watch video made by Evides
Inspection Results

• 4 pipes identified with wall loss
• 30% to 60% wall loss
Validations

- 3 pipes excavated for validation
- 2 areas of wall loss confirmed
- Unknown welded patch identified

<table>
<thead>
<tr>
<th>Location</th>
<th>Expected Loss</th>
<th>Actual Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60%</td>
<td>Not Excavated</td>
</tr>
<tr>
<td>2</td>
<td>40%</td>
<td>Welded Patch</td>
</tr>
<tr>
<td>3</td>
<td>30%</td>
<td>25%</td>
</tr>
<tr>
<td>4</td>
<td>30%</td>
<td>35%</td>
</tr>
</tbody>
</table>
Inspection Overview of Water Main

Condition Assessment

Sahara Leak detection

PureEM PipeDiver

Transient Pressure Monitoring

Structural Engineering FEA
PureEM Results

- **Steel Pipe**: 8% Anomalous, 92% Good Condition
- **Bar Wrap Pipe**: 2% Anomalous, 98% Good Condition
- **Ductile Iron Pipe**: 1% Anomalous, 99% Good Condition

Map showing:
- **Steel Pipe (Yellow)**
- **Ductile Iron Pipe (Pink)**
- **Bar Wrapped Pipe (Blue)**
Validation

- Pipe 127 chosen for validation
- Large EM anomaly
- Visual indications in video
Validation of Pipe 127

EM Anomaly
How did we do?

- Circumferential location ✔
- Longitudinal location ✔
- Estimate of size:
  Analysists: 2.83-inch$^3$
  5”x5”x90% - 8”x8”x40%
- Actual: ~2.5-inch$^3$
  8”x8”x35%
How much deterioration before pipe fails?
Pipe Performance Curves

- **Yield Limit**: 80 psi allowable for pipe with 20% wall loss
- **Strength Limit** (Pipe Failure): 20% wall loss at current Operating Pressure 40 psi
- **40% allowable wall loss at 40 psi**