Buried Pipe NDE Overview

6th International CANDU ISI Workshop/NDT in Canada 2016 Conference

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Author: Steve Kenefick – Principal Project Manager
Overview

- Operational experience (OE)
- US inspection requirements
- Overview of NDE technologies and methodologies
- EPRI related information and references
Buried Pipe Operating Experience

- Infrastructure in US is aging
- Buried and underground piping leaks have occurred
  - Low levels of Tritium has been detected on-site
  - Leaks to date have not had significant safety or radiological consequences
The Nuclear Strategic Issues Advisory Committee (NSIAC) developed an Initiative to address US industry buried pipe leaks
- NSIAC is composed of US Chief Nuclear Officers (CNO)
- Industry commitment, not regulation
- Goal to provide “Reasonable Assurance” of structural and leak integrity of buried pipe with special emphasis on piping that contained radioactive materials

The NEI Buried Piping Integrity Task Force (BPTIF) was formed to develop direction to meet Initiative
- Composed of utilities, NEI, INPO, Insurers, and EPRI
- Developed NEI 09-14 Initiative – Guideline for the Management of Underground Piping and Tank Integrity (Currently revision 4)
Scope of the NSIAC NEI 09-14 Initiative

- All buried and underground piping and tanks that are outside of a building and below grade (whether or not they are in direct contact with the soil) if they:
  - Are safety related,
  - OR
  - Contain licensed material or are known to be contaminated with licensed materials,
  - OR
  - Contain environmentally sensitive materials
Status of NEI 09-14

- All milestones are complete
  - Corrosion has been found but many systems are in good shape
  - Most corrosion is internal
  - Is now part of an ongoing engineering program

- NRC staff recommended to the Commission that no new regulation is necessary “Commission agreed”

- Ongoing oversight
  - NRC to continue to monitor
    - Objective a reduction in leak trends
  - INPO to continue to monitor
License Renewal

- NRC license renewal addresses underground piping and tanks in NUREG-1801 “*Generic Aging Lessons Learned*” (GALL)
  - Provides aging management programs (AMP) to manage aging effects of systems, structures and components (SSC)
  - Applicant may propose alternatives methods

- Interim Staff Guidance (ISG)
  - LR-ISG-2011-03 – Generic Aging Lessons Learned (GALL) Report Revision 2 AMP XI.M41, "Buried and Underground Piping and Tanks"

- GALL requirements have evolved
  - Rigor of buried pipe requirements has increased
  - Second license renewal (after 60 years) requirements will be more demanding for early implementers
Challenges of Examining Underground Pipe

- Many systems are difficult to access
  - Not designed or installed with inspection access in mind
  - Buried deep
  - In layers with other infrastructure
  - Under buildings
- Locations sometimes not well documented
- Some contain radioactive fluids
Challenges Presented by Underground Pipe

Wide ranging set of variables require careful selection of NDE technology

- Several material types: steel, cast iron, copper alloys, stainless, concrete, asbestos, PVC, polyethylene, FRP, etc.
- Diameters range from small bore to >10-ft
- Multiple joint types: butt-welded, socket welded, flanged, threaded, etc.
- Piping content include raw and treated water, gases, chemicals, and oil
- Coated and lined pipe: cement, high density polyethylene (HDPE), tar, tape wrap
- Varying damage mechanisms and flaw morphologies
Buried Pipe NDE Workshop Agenda

- Operational experience (OE)
- Inspection requirements
- Overview of NDE technologies and methodologies
- EPRI references and training

- Repository of buried pipe NDE information
  - Ultrasonic Technology
  - Guided Wave
  - Remote Field Testing
  - Magnetic Flux Leakage (MFL)
  - Electromagnetic Technology
  - Radiography
  - Visual Technologies
  - Surface Profilometry
  - Leak Detection
  - Radar and Microwave Inspection
Repository for buried pipe NDE information

- Discontinuity Morphologies
- Technology overview
- Sensor technology
- NDE selection considerations
- In-line Inspection Delivery Technology
## Buried Pipe NDE Methods

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### In-line Delivery Methods
- Robotic Crawlers
- Flow through
- Pull through
## Buried Pipe NDE Technology Capabilities (General)

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Flow Through or Free Swimming In-line Ultrasonic Technology

- Ultrasonic tool inserted into piping system
  - Bi-directional tool – requiring one access point
  - Single direction tool – requires launcher and retriever
- Moved through piping by fluid flow
  - Fluid added behind tool
  - Speed of tool controlled by fluid flow
- Onboard pulser, receiver, digitizer, and data storage
- Can collect data at feet per second
- Axial location of data measured with encoder
- Sophisticated data analysis software
Flow-through In-line Ultrasonic Array Technology

Transducer array device

- Transducers positioned 360-degrees around tool circumference
  - Number of transducers dependent on diameter and desired coverage
  - Small-diameter tool may have as many as 48 / large-diameter 100s of transducers
- Small to large diameter pipe
Flow Through In-line Rotating 0-degree Ultrasonic Transducer
Flow Through In-line Ultrasonic Technology

Technology has been used at multiple plants (one example)

- 2300-feet of piping in ~2.5 hours
  - ~11.5 million measurements
- Ultrasonic Data Acquired
  - 2 degree circumferential increment
  - 10 mm axial increment
- Line contained several elbows
  - Maneuvered back to back elbows without issue
Robotically Driven Ultrasonic Rotating Array Technology

- Rotating head with 8 zero-degree transducers
- High resolution cameras
NDE Research Results – Phased Array

- Rapid scanning providing 100% coverage with increased sensitivity to corrosion type flaws
- Imaging with permanent data storage capabilities
- Technical basis published in: Buried Pipe NDE Technology Assessment and Development Interim Report (1025219)
- Area scanned in picture is 500-mm by 660-mm
  - ~80K measurements
  - Results can be extracted to a spreadsheet for analysis
  - Results shown in box
- Inspection vendors and utilities are using technology
Electromagnetic Acoustic Transducer (EMATS)

- Self-propelled EMAT and visual crawler
- Probes are placed in contact with inside surface and rotated
- Detects and measures wall thickness
- Examine through coatings and linings
- Reduced surface preparation
- Couplant is not needed
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**In-line Delivery Methods**
- Robotic Crawlers
- Flow through
- Pull through
Guided Wave Concept

- A guided wave is generated by a ring of piezoelectric transducers.
- The guided wave propagates down the pipe.
- Changes in the cross-section of the pipe or material properties create reflections.
  - Welds, flaws, corrosion, flanges, valves, wall thickness changes, etc.
- Reflections propagate back to the sensors.
- Signal is plotted as a function of distance from the sensors.
- Welds are typically used as reference markers and calibration for the test.
Guided Wave Data
Benefits of Guided Waves

- Efficient 100% volume inspection of a large section
- Can potentially propagate long lengths, although flanges and large valves act as obstructions
- Inaccessible locations including wall penetrations, buried, coated, or obstructed areas
- Limited cleaning and excavation (required at locations where transducer ring is applied), but does require removal of coating
- Does not require access to inside of pipe or cleaning of inside pipe walls
- May inspect while system is operating
- Potential for periodic monitoring via permanently mounting sensors
- Technology available from 2” to 96” diameter
Challenges of Guided Waves

- Thick viscous coatings attenuate signal, thus reducing effective inspection lengths and sensitivity to flaws
- Flanges are barriers for guided wave propagation – inspection beyond a flange is not possible
- Elbows distort the guided wave signal and reduce signal-to-noise making inspection beyond them difficult
- Distinguishing flaws from other nonaxisymmetric reflectors such as welded attachments
- Quantifying size of damage is often not highly accurate
Key Guided Wave Resource

- Buried Pipe Guided Wave Examination Reference Document (1019115)
  - Guided Wave Basic Theory
  - Data Acquisition
  - Data Analysis
  - Project Management
  - Literature Survey
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**In-line Delivery Methods**
- Robotic Crawlers
- Flow through
- Pull through
RFT Sensor and Energy Flow

- Uses Two coils
  - Exciter (transmitter or send)
  - Detector (receiver or pick-up)
  - Coils typically separated by 2 to 3 pipe diameter

- Measures
  - “Time-of-flight” (phase shift) between coils which indirectly relates to the wall thickness
  - Signal strength (amplitude) between coils

Courtesy of Russell NDE Systems Inc
Remote Field Testing (RFT)

- In-line pipe inspections technique
  - Metallic pipe such as carbon steel, cast iron, and ductile iron
  - Pipe diameters ranging from 2-inches to 7 feet
- Can measure wall thickness
- Equal sensitivity to external and internal flaws
- Can be used in fluids such as water and oil
RFT Application

- Sensors can operate approximately 1-inch from the pipe surface allowing for examination through:
  - Internal scales, tubercles, sand, deposits, and layers of mud
  - Liners such as high density polyethylene
  - Concrete lined piping
  - Coatings such as cement, bitumen, and cold tar wrap
  - Operates both in air or water

- Reduces / eliminates the need for extensive pre-cleaning in most situations
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**In-line Delivery Methods**
- Robotic Crawlers  
- Flow through  
- Pull through
Saturated Low Frequency Eddy Current (SLOFEC)

Loss-of-material on the far surface alters the magnetic flux, which in turn alters the eddy currents

- Loss-of-material on the near surface directly interrupt the flow of eddy currents.
- These two responses alter the phase angle of the eddy current
Saturated Low Frequency Eddy Current (SLOFEC)

• In-line pipe inspections technique for ferromagnetic materials
  – Detection and resolution of pitting
  – Can differentiate between inside and outside surface discontinuities
  – Can tolerate coatings and liftoff from pipe surface
  – Cannot measure wall thickness
NDE Technology: Saturated Low Frequency Eddy Current (SLOFEC) Robotics

- Examines through coating and linings
- Self-propelled tethered robot
- Traversed 1.5-diameter bends
- Technology available and used in other industries
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#### In-line Delivery Methods
- Robotic Crawlers
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Magnetic Flux Leakage (MFL)

- Magnetic lines of flux flow between the magnetic poles
  - Areas of corrosion or cracking interrupt this flow
- Flux lines are monitored with various sensor types placed between the magnet poles
- Data is recorded and subsequently analyzed to identify and characterize damage

Courtesy of Inline Devices – A Mears Group Company
Magnetic Flux Leakage (MFL)

In-line pipe inspections of ferromagnetic materials

- Detection and resolution of pitting
- Cannot measure wall thickness but can measure changes in wall thickness
- Cannot differentiate between ID and OD flaws
- Can tolerate coatings
- Fast scan speeds

Photo courtesy of Microline Technology Corp
MFL Field Application

Extensively used to examine transmission pipelines

Courtesy of Inline Devices – A Mears Group Company
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**In-line Delivery Methods**
- Robotic Crawlers  
- Flow through  
- Pull through
Pulsed Eddy Current

- Detection of area corrosion in ferromagnetic materials
  - Non-contact technique
  - Can be used to examine through liners, insulation, and coatings
  - Broad assessment – may miss localized damage
  - Requires minimal cleaning
  - Spot measurement
  - Can be slow
Pulsed Eddy Current

- Probe generates multiple frequencies in the material
  - Measurements are made in the time domain
  - Features near the inspection coils will be seen first and more distant features will be seen later in time
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**In-line Delivery Methods**
- Robotic Crawlers
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- Pull through
3D Optical Scanner

- Development funded by EPRI, Pipeline Research Council International (PRCI), and Chevron
  - Developments demonstrated 2012 Q4
  - Now commercially available
  - Identify region of interest and extracts; length, depth, area extent, and volume loss
Summary

- The US Industry committed to develop processes to manage buried pipe degradation
  - Goal was to provide “Reasonable Assurance” of structural and leak integrity
- EPRI has worked with the nuclear and petrochemical industry to develop a comprehensive NDE guide that assists nuclear utilities meet this commitment
- US regulators have accepted the industry process
Related Information and References
# EPRI Buried Pipe NDE Reports

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