Next-generation Sensor system for ultrasonic wall thickness monitoring

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Outline

• Motivation
• Inspection vs. monitoring/trending
• The power of data through continuous monitoring/trending
• Applications
• System requirements and concept
Total Annual US Cost of Corrosion: $>1T

Utilities: $47.9B

Electric Utilities: $6.9B
(Nuclear Power: $4.2B)

Data Monitoring Evolution

1920s - Manual monitoring
1960s - Analog 4-20mA loop
1980s - Digital Conversion
1990s - Wireless
2010s - Age of Internet of Things (IoT)
Why installed sensors today?

Costs ($) associated with manual inspections

• Pre-inspection activities:
  • Excavation
  • Insulation preparation
  • Scaffolding
• Access, permitting, approvals
• Personnel cost increasing—technicians, equipment, training, etc.
• Monitoring costs decreasing—wireless, battery technology, IOT, power harvesting, etc.

Costs (intangibles)

• Safety — ropes, ladders, radiation, non-invasive, etc.
• More informed decision making — dig holes one time and benefit for potentially years of data, better planning for asset replacement, outage planning, etc.
• Time/productivity — short & long term decision making/planning
Installed vs Manual UT Systems

Corrosion/Erosion management
- Trending (wall loss per day/week/month, etc.)
- Inspection (is the pipe going to leak or fail)
- Verification of RBI, inhibitor, or other corrosion mitigation techniques

Complementary UT technologies
- Single point manual thickness readings
- Large area manual phased array scanning
- Long range guided wave UT collars

\[
\text{thickness} = \left( \frac{\text{transit time}}{2} \right) \times \text{acoustic velocity}
\]
Technology Comparisons

VS manual UT

• Accuracy and precision is improved due to permanent installation and removal of operator factors resulting in better data quality and trending.

• Installed UT sensors can replace manual UT points, particularly for high cost or critical locations.

• Can augment manual UT locations with a semi-continuous data stream.

VS LRUT

• Point, precise measurement vs. area coverage and screening.

• Use permanently installed sensors to complement LRUT, placing sensors at identified areas of interest.

VS PAUT

• Complement PAUT flaw detection with permanently installed monitoring using shear wave transducers.
The Inspection/Monitoring Pyramid

Cost vs. Necessity

• WHERE would I want to put an installed sensor and WHY?

Most expensive/critical areas to inspect (circa 2005)

Moderately expensive/critical areas to inspect (circa 2015)

Least expensive/critical areas to inspect (circa 2020 and beyond)
Factors Eliminated From Using Installed Monitoring Systems

- Operator variability
- Transducer placement variability
- Transducer coupling variability
- Sound velocity uniformity
- Measurement repeatability
- Re-measurements
  - Instantaneous
  - More frequent (trending)
- Data Accessibility

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**Precision**  
**Accuracy**  
**Resolution**

![Graph showing Flank Crossing and Zero Crossing]
Installed Sensor Corrosion Monitoring

Internal Diameter (ID) vs. Outside Diameter (OD)

- ID measurements: Sensor placed on OD, measure ID (piping)
  - Coatings ... recommended removal, however, if thin enough, can be calibrated out using dual sensor technology
  - Insulation ... can insulate over top of some sensors, not useful for CUI applications
- OD measurements: Sensor placed on ID, measure OD (tanks/containers)
  - Requires environmentally protected/housed, etc.
  - Data communications can be limited – often hard wired

Permanent (PMOD) vs. Temporary (TMOD) Solutions

- Magnetic
- Banded
- Adhere
- Clamped
- Weld direct or via bracket
Installed Sensor Corrosion Monitoring (ctd.)

Coverage

- Single point or multi-point/channel instruments
  - Grid, matrix, array, indiscriminate points (1”x1” housing w/ .250” contact face)
- High temperature & low temperature
  - Low: -30F – 300F
  - High: -90F – 900F

Communication

- Tethered (Modbus / RS-485) ... manual data collection
- Cellular
- Wireless
- Other (RPMA, Lora, etc.)

Components

- Tablet (commissioning/data collection)
- Instrument (single/multi-channel)
- Sensors
The power of data...

Wall Thickness Data (1 msmt per year)

- Sufficient for **inspection** probably NOT for **monitoring**
  - 1/1/2013 inspection = 10.00mm
  - 12/30/2013 inspection = 9.77mm

- Gross corrosion rate – cannot calculate, not enough information
The power of data...

• Various corrosion rates evident
• Trends evident but still large uncertainty due to measurement precision
• Summary – better!
The power of data...

- Various corrosion rates evident
- Regression can be used to obtain accurate corrosion rates over medium time scales.
The power of data...

- Various corrosion rates evident
- Regression can be used to remove measurement noise and produce very accurate corrosion rate data
- GREAT!
Remote sensors leverage low-cost ubiquitous communication infrastructure
- Modbus / RS-485
- Cellular
- Satellite
- WiFi
- Etc.

24/7 asset health monitoring
Data to desk to decision in minutes
Mobile access by multiple parties
## Data/Cyber Security

<table>
<thead>
<tr>
<th></th>
<th>Proprietary (In-House) Network</th>
<th>Public Network</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>Expensive (To purchase, manage &amp; maintain)</td>
<td>Cheap</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>Managed internally (good &amp; bad)</td>
<td>Rely on outside data repository (cloud) ... Amazon Web Services, Google Cloud, etc., standard encryption schemes: HTTPS</td>
</tr>
<tr>
<td><strong>Compromise-ability</strong></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Data Relevancy</strong></td>
<td>Confidential / regulated: Ex. SSNs, medical records, salaries, banking information etc.</td>
<td>Not Relevant: Ex. Thickness data, asset temperatures &amp; pressures</td>
</tr>
<tr>
<td><strong>Access</strong></td>
<td>Within Site or through VPN</td>
<td>Global</td>
</tr>
</tbody>
</table>
Web-based Data Management

- Remote collaboration / accessibility
- Archiving & record retention simplicity
- Alarms & Warnings
  - Ex. .500”, .300”, .100”
- Automated reporting
- Google Maps & GPS
Field Applications
Buried / Underground Assets:

- Pigables – verification of ILI reports
- Unpigables – information & general maintenance
- Known defect monitoring from guided wave/other NDE mass screening techniques
- Single point or mat sensors
  - Low profile / rugged / durable
  - Tethered, no battery (20+ year life)
Oil and Gas / Petrochemical

Crude Unit Overhead w/ chemical Injection and/or Water Washes
  • Utilization of installed UT sensors for corrosion rate calculations of inhibitor optimization

Sand erosion in offshore production

Naphthenic acid detection
  • High temperature monitoring

Baseline of new infrastructure
  • Flow, pressure, product evaluation for understanding effects on localized corrosion

Daily monitoring of known defects b/t outages
Power Generation

- High point vent (gas void detection, measurement & evaluation)
- Microbiological corrosion (MIC) monitoring
- Flow accelerated corrosion (FAC) trending/modeling
The Future for Installed Sensors

• Internet of Things (IoT) is fueling the flame
  • In the next 5 years*:
    • $6 trillion will be spend on equipment and infrastructure
    • IoT will connect over 20 billion assets
    • Projected revenues from IoT are estimated at $14.4 trillion

• Communication / Data Transmission
  • Internal vs. public networks (trending to public)
  • Why public?
    • Cheaper
    • More widespread, data accessibility
    • Google/Amazon/etc. are getting better at security/managing data
    • Faster acquisition, higher bandwidth, longer range

• Lower cost per point sensors
• Longer battery life / further reaching
• Other?

*Source: BusinessInsider 2016
Summary

The world is changing ... use it to your advantage!

Installed sensors can be used to optimize **inspection** as well as **monitoring** for corrosion/erosion & cracks

Installed sensors should be evaluated on a “cost per point” basis as it relates to tangible & intangible accumulated costs over an assets’ useful life

The power of data ... predictive uptime, real-time asset health monitoring, reduced unplanned outages

Applications for installed sensors exist everywhere, know your short and long term goals for the project
Questions

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