Monitoring Asset Integrity Using Installed Ultrasonic Sensors

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Outline

- Motivation
- Inspection vs. monitoring/trending
- Power of Data through Continuous Monitoring & Trending
- Applications
- Case Studies
Corrosion Damage Accounts for the Cost of one Major Facility Annually

- Pipeline, Oil/Gas Production $8 B
- Refining & Petrochemical $1.7 B

* NACE Cost of Corrosion Study

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Data Monitoring Evolution

1920s - Manual monitoring

1960s - Analog 4-20mA loop

1980s - Digital Conversion

1990s - Wireless

2010s - Age of Internet of Things (IoT)
Data-to-Desk & The Internet of Things (IoT)

Remote sensors leverage low-cost ubiquitous communication infrastructure
- Modbus / RS-485
- Cellular
- Satellite
- The Internet
- WiFi
- Etc.

24/7 asset health monitoring
Data to desk to decision in minutes
Mobile access by multiple parties
Structural Health Monitoring Meets NDT

Time-Based Maintenance vs. Predictive Maintenance

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Why Installed Sensors for ID Corrosion Monitoring?

Costs ($) associated with manual inspections

- Pre-inspection activities:
  - Excavation
  - Insulation preparation
  - Surface Preparation
  - Scaffolding
  - Rope access
- Access, permitting, approvals
- Personnel cost – technicians, equipment, training, etc.
- Cost per point is less for applications than manual data collection

Costs (other)

- Safety – ropes, ladders, radiation, non-invasive, etc.
- Damages – environmental, reputation,
- Time/productivity – short & long term decision making/planning
- Data quality – transcription errors, precision & repeatability
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 2010)

Least expensive/critical areas to inspect (circa 2017 and beyond)

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Data Quality Enhanced Using Installed Sensor Systems

**Precision**

- Operator variability
- Transducer placement variability
- Transducer coupling variability
- Sound velocity uniformity
- Measurement Precision
  - 6 picosecond resolution

**Accuracy**

- Temperature Compensation
- Accurate Corrosion Rates

**Resolution**

- Data Accessibility

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The Power of Data ...

- Sufficient for **inspection** probably NOT for **monitoring**
  - 1/1/2013 inspection = 10.00mm
  - 12/30/2013 inspection = 9.79mm
- Gross corrosion rate – cannot calculate, not enough information

Wall Thickness Data (1 msmt per year)

W.T. (mm)
• Various corrosion rates evident
• Trends evident but still large uncertainty due to measurement precision
• Summary – better!
The Power of Data (ctd) ...

- Various corrosion rates evident
- Regression can be used to obtain accurate corrosion rates over medium time scales.
Various corrosion rates evident
Regression can be used to remove measurement noise and produce very accurate corrosion rate data
GREAT!
Corrosion Rate Measurement

- Corrosion Rates (CR) used for maintenance & process.
- Monitoring enables accurate (CR).
- CR Precision enhanced by linear regression.
- Factors:
  - Standard deviation of the measurement system
  - Measurement frequency
  - Measurement interval

\[
S_m^2 = \frac{1}{n-2} \sum_{i=1}^{n} (y_i - Y(x_i))^2
\]

\[
\sum_{i=1}^{n} x_i^2 \frac{1}{n} - \left( \frac{\sum_{i=1}^{n} x_i}{n} \right)^2
\]

95% C.I. \( \approx m \pm 2s_m \) \( (n - 2 \geq 6) \)
Data-to-Desk & The Internet of Things (IoT)

- Data available across the organization – remote viewing for critical decision making
- Archiving & record retention simplicity
- Alarms & Warnings
- Saving raw data: RF Signal
- Google Maps & GPS
## Typical Applications

<table>
<thead>
<tr>
<th>Downstream</th>
<th>Midstream</th>
<th>Upstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement of invasive technologies – ER probes/coupons</td>
<td>Post repair or replacement baseline of new infrastructure</td>
<td>Wellhead monitoring for initial start-up &amp; injection/storage</td>
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<tr>
<td>Process control for chemical inhibitor optimization</td>
<td>Monitoring of known/existing localized corrosion events</td>
<td>High pressure pumping instrumentation health monitoring</td>
</tr>
<tr>
<td>High Temp Naphthenic acid monitoring</td>
<td>Used in lieu of pigging/ILI for river/road crossings or 49 CRF 192 &amp; 195</td>
<td>Sand erosion/wash-out for offshore platforms &amp; FPSOs</td>
</tr>
</tbody>
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**Notes:**
- ER probes/coupons
- Post repair or replacement baseline of new infrastructure
- High pressure pumping instrumentation health monitoring
- Sand erosion/wash-out for offshore platforms & FPSOs
### UT Sensor Case Studies – Oil & Gas

#### Process Control
- Corrosion RATE monitoring
- Chemical inhibitor injection mgmt.
- Different crude TAN rates require more/less chemical to reduce exposure to wall loss
- **Temporary UT wireless sensors** placed in misc. areas *(1 reading per hour for 3 months)*
- Reduction in chemical inhibitor spend varying based on crude slate (in this instance is estimated to be ~$20K/wk.)

#### Inspection
- Localized corrosion monitoring
- Gas spheres
- “underbelly” pitting/corrosion
- Inspection crews sent bi-weekly to inspect known areas on 4 spheres
  - **Cost $25K** each time
- Manual UT gauges marked “low” spots, **tethered UT sensors** placed *(3 readings per wk. using tablet)*
  - Saved >$150K in first 3 months of program

#### Re-Engineering
- TML reduction programs
- **Cellular UT sensors** in lieu of manual inspection *(2 readings per month)*
  - <1 mil/yr. for +5 yrs.
  - 27,000+ TML locations, cost >$3M to inspect 1/3 per year
  - Were able to reduce from 27,000 TML points to 13,000 TMLs
  - Saving ~$1.7M/yr in manual inspection cost

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## UT Sensor Case Studies – Power Gen.

### Transmission
- Regulation driven
- Buried river & road crossings
- UT sensors placed on defined areas - tethered/manual collection
- Junction boxes placed 100’ from road tethered UT sensors installed (1 reading per qtr.)
- Savings in government fines

### Storage
- Buried high pressure storage lines
- Installed tethered/manual UT sensors on new (replaced) segments of pipe where corrosion had previously been found (2-3 readings per yr. or as necessary via tablet)
- Savings from avoiding unplanned outages

### Inspection
- Ongoing projects & evaluation ...
- **FAC** programs
  - Corrosion rate R&D
- **MIC** programs
  - Installed sensors in lieu of manual inspections for known pitting between outages
- **High-point vent**
  - Installed sensors in lieu of manual inspection to detect gas voids
- **EHS** – avoid radiation areas where possible

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The digital world is changing quickly ... use it to your advantage

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

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 any project/program
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