Quantification of Risk Associated with Vintage Piping Systems and Tools to Optimize Mitigation Strategies

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Addressing Legacy Materials

> Identified Needs / Gaps:
  
  – Industry-standard, risk-based model for main replacement programs; to include cast iron, PE, and steel piping systems. Utilities need to be able to prioritize assets with a focus on safety and reliability.
    
    > Identification of high risk materials and prioritization of highest risk pipes/segments.
    
    > Material and environmental assessment to assist with prioritization of high risk materials (assist with prioritization)
  
  – Alternative pipe replacement options; splitting, insertion, etc.
  
  – New material acceptance; composite piping systems and structural liners
  
  – Tracking and traceability for new piping systems; standardized information on materials, assembly details, operator information, etc.
A Few Current Programs

> Vintage Piping Identification/Analysis
  – Analysis and understanding risk/life of various aged assets.
  – Collect information on material and identify threats.

> Threat Identification and Smart Forms
  – Program to collect potential threat information from operators and regulators.
  – Provide information on existing and emerging threats to operators for their use in identifying and assessing risks.

> Composite pipe / Structural liner program
> PE pipe splitting guideline project
> Material and Fusion tracking and traceability project
Vintage Piping Identification/Analysis

> Need:
  − Enable utilities with vintage piping systems (Aldyl A polyethylene, cast iron, and other vintage materials) to develop risk profiles of these system to allow for the prioritization of replacement.

> Current projects –
  − Identify risk associated with specific vintages and/or areas of Aldyl A pipe.
  − Assessment of Frost Impact on Cast Iron Pipes
    > Provide a relative risk-based approach to enhance the response to frost impact on cast iron (CI) piping systems
  − Risk and Decision Analysis (RDA) program
    > Leak Rupture Boundary Model (fail by leak or rupture)
    > Advanced Crack Propagation Model (correlates pressurizations to crack growth rates)
Aldyl A Material: Rate Process Method (RPM)

- Hydrostatic test data covering various vintages of material/pipe has been and continues to be assembled.
- RPM models have been generated for reference.
Aldyl A Material: Bi-Directional Shift Factors

> Bi-Directional shift factors are developed based on test data for each batch of pipe sampled.

> Pipe batches include:
  - Various vintages
  - Different resins
  - Various geometries and field conditions
  - Etc.
Aldyl A Material: Finite Element Method (FEM) to Determine Application Stress

> Application stresses are determined in order to:

- Assess the likelihood of introducing damage through short term loading such as squeeze-off
- Determine the stress concentration factors for various geometries or likely damage configurations
Stress Risers due to Geometry & External Loading

<table>
<thead>
<tr>
<th>Pipe or Fitting Configuration</th>
<th>Stress Intensification Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socket Coupling – Coupling Edge</td>
<td>1.25</td>
</tr>
<tr>
<td>Saddle Tee</td>
<td>2.7</td>
</tr>
<tr>
<td>Socket Coupling – Coupling Center</td>
<td>1.8 – 2.9</td>
</tr>
<tr>
<td>Pipe with Bend Radius of 100 Pipe Diameters</td>
<td>3.0</td>
</tr>
<tr>
<td>Pipe with Bend Radius of 80 Pipe Diameters</td>
<td>3.6</td>
</tr>
<tr>
<td>Pipe with Bend Radius of 50 Pipe Diameters</td>
<td>4.7</td>
</tr>
<tr>
<td>Socket Coupling with Bend Radius of 100 Pipe Diameters</td>
<td>4.8</td>
</tr>
<tr>
<td>Socket Coupling with Bend Radius of 80 Pipe Diameters</td>
<td>5.8</td>
</tr>
<tr>
<td>Socket Coupling with Bend Radius of 50 Pipe Diameters</td>
<td>7.5</td>
</tr>
<tr>
<td>Squeeze-Off</td>
<td>8.5 – 10.5</td>
</tr>
</tbody>
</table>
Methodology: Combining FEM and RPM

> Detailed knowledge of the true stress states in the field application allow specific performance curves to be developed.

> These specific performance curves enable operators to develop the appropriate mitigation strategy for their application.
Comparing Current Lifetime Expectancies to Reference Data

> GTI has developed a 3, 2, 1 risk ranking methodology for Aldyl A pipe

> The method uses well conditioned historic data sets for material known to exhibit LDIW characteristics and pipe known to meet the design requirements of Aldyl A as defined by DuPont (non LDIW)

> High Risk

3 Performance < LPL of LDIW reference model

> Medium Risk

2 Performance > LPL of non LDIW reference model

> Low Risk

1 Performance > Mean of non LDIW reference model

LPL – Lower Prediction Limit

LDIW – Low Ductile Inner Wall
Correlating Risk Category to Vintage

1972 – High Risk Only
1973 – High and Medium Only
1974 – High Medium and Low
Unknown – High and Medium Only
Low risk – Less than 2% of samples
1974 vintage only
Correlating Risk to Pipe Surface Condition

- The core properties of Aldyl A pipe do not deteriorate over time
- Pipe that has been in service for >40 years has similar material properties to virgin pipe
- Degradation does occur at the pipe surfaces (both)
- Specifically the inner wall
- GTI is developing a set of key surface indicators that correlate to lifetime expectancy
Correlating Risk to Pipe Surface Condition – Ongoing Work

> Carry out targeted sampling of Aldyl A pipe
  – Specific geographic locations
  – Specific vintages
  – Specific sizes

> RPM models, Bi-directional Shift Factors and Surface Characterization are being carefully carried out to validate the current set of indicators

> The results will be incorporated into a hybrid causal model for risk ranking and lifetime prediction
Pipe Surface Condition Benefits

> Comprehensive understanding of:
  - Material characteristics
  - Influence of vintage of pipe
  - Influence of installation conditions

> Surface characterization methodology enables:
  - Less hydrostatic testing
  - More detailed risk ranking

> Historic data sets allow for better risk ranking and detailed mitigation strategies to be developed
Assessment of Frost Impact on CI Pipes

> Objective
  > To provide a relative risk-based approach and recommendations to enhance the criteria which operators use to identify the locations, durations, and frequencies for their surveillance of CI systems during winter operations.

> Initial findings...
  > Pipe size did not correlate to leaks.
  > Pipe size correlated to pipe breaks: Smaller diameters had more breaks.
  > No breaks were recorded for pipes > 18-inch diameter.
  > No correlation to age of pipes for pipes from 70-110 years.
  > Material assessment (microscopic and NDE) can assist in determining higher risk CI pipe segments.
Assessment of Frost Impact on CI Pipes

> Integrity of cast iron piping systems – BEM inspection technology
> Amount of graphitic corrosion is a factor related to breaks.

Region A entire wall cross section showing approximately 0.372” corrosion over 0.5” total wall thickness
Smart Leak Repair Forms

Objective of Smart Forms:

- To develop logic for a smart leak form to:
  - Improve the data collection process, and
  - Assist in identification of the root cause during the leak repair process,
- Provide “smart” questions and answer options to:
  - Guide the user through the process of determining the root cause,
  - Ensure that the correct root cause is identified and appropriate supporting information is provided.
Smart Forms - Current Need

> Integrity Management, PPDC, and other data/failure collection requirements:
  - Collect data as needed for mechanical fitting failures resulting in hazardous leaks
  - Data to assist in identifying threats

> PHMSA states: “High-quality data is core to an effective risk assessment”.

> PHMSA also states that the ability to identify existing and potential threats is an area of needed improvement.

> The use of “other” in leak forms is very problematic.

> Need for smarter leak forms to improve data quality.
Smart Forms - Current Need

> According to PHMSA current issues include:
  - Data quality - it is often outdated, incomplete, and has obvious errors.
  - OTHER as a leading cause in reporting

![Pie chart showing significant distribution system incidents by cause (2008-2010)]
Benefits of Proposed Smart Leak Form

> Well defined, consistent and coherent logic
> “Other” category avoided
> Potential for industry standard
> Readily implemented in electronic format
  – Integrate with mobile data apps
  – GIS integration possible
  – Tracking and Traceability integration possible
> Data collected can be fed directly into risk and consequence models (consistent structure)
Pipe Replacement Alternatives

> **PE Pipe Splitting**
  - Need alternative construction systems to replace vintage PE pipe. Splitting technologies is one alternative.
  - Issues:
    > The availability of standard commercial
    > Guidelines for applications and use of splitting equipment.
    > Best practices

Pipe splitting can offer cost savings while performing the operation more efficiently with less disruption to traffic and the general public.

![Average Pavement Restoration Required per Linear Foot of Pipe Replacement](chart.png)
Composite Materials Program

GTI’s Composite Materials (CM) program is facilitating the implementation of composite materials and technologies for the rehabilitation of distribution and transmission pipelines.

Need:

- Selection and design of composite pipe / structural liner pipe rehabilitation for distribution and transmission systems,
- Establishing and performing testing for long-term performance prediction of the various composite/structural liner systems,
- Establishing standards and design criteria necessary for the acceptance and allowable use by the natural gas industry, and
- Implementation and regulatory acceptance.
Benefits of the CM Program

> Will enable the safe and cost effective rehabilitation of distribution & transmission pipelines without large scale, open trench excavations.

> Composite piping / structural liner systems can provide natural gas operators with options to restore/replace their piping infrastructure.

> Composite materials have the potential to provide for a corrosion free, high strength, and damage resistant piping system.
Asset Tracking and Traceability Program

> Developed a unique identifier for gas components
  ─ 16 digit base-62 encoding system

> Developed technologies, processes, and standards to facilitate the tracking of assets throughout their lifecycle
  ─ Provide “Point and Click” GIS that attached operational data to assets

> Standardized PE fusion data capture and operator qualification

> Next Steps
  ─ Additional fusion data & Op qualification
  ─ Expand to transmission
Additional Research Needs

- More encompassing programs to identify existing and emerging threats to our industry (knowledge).
- Develop comprehensive library of pipeline material properties.
- Objective risk analysis and decision tool.
- Alternative pipe replacement options.
- Alternative replacement materials such as composite pipes and structural liners.
- Tracking and traceability for new systems being installed (transmission assets, assembly info, etc.).
Solving important problems facing the energy industry and its consumers ...

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