Characterization of Pipeline Defects

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NG’s current service territory covers 4,500 square miles and serves 549,300 customers.

**Infrastructure**

- 22 Gate stations (delivery points)
- 278 Miles Transmission main (pipeline)
- 387 Gas regulating stations (pressure reducing)
- 7,948 Miles distribution main
- 490,790 Services
- 562,711 Meters
- 314,271 Service regulators
National Grid Gas Transmission In Upstate N.Y.

- 278 miles transmission pipe
  - 170 miles > 30% SMYS
  - 108 miles 20% - 30% SMYS
  - 190 miles constructed prior to 1970
  - 58 miles in HCAs
  - Most one way feed
Stress and Flaw Depth Relationship

\[
\% \text{ SMYS} = \frac{100 \cdot \left( \frac{P \cdot D}{2t} \right)}{\text{Material Strength}}
\]

Where:
- \( P \) = Pressure (psig)
- \( D \) = Outside Diameter (inches)
- \( t \) = Pipe Wall Thickness (inches)

Material Strength = Specified Strength of the Material

Allowable Flaw Depths ("FD") for:
- 30% SMYS
- 72% SMYS
- 100% SMYS
Low Stress vs High Stress

Low-stress lines are inherently less risky than high-stress lines, specifically:

- Consequences of failure are reduced (“potential impact area” is reduced).
- Likelihood of failure is reduced for third party damage, internal and external corrosion (larger and deeper defects are required to cause failure).
- Failure modes pose less risk (leak vs. rupture).
Classification of Defects

is dependent upon the following ratio:

\[ P_f \text{ ratio} = \frac{P_f}{MAOP} \]

where

- \( P_f \text{ ratio} \) = Predicted failure pressure ratio of a defect
- \( P_f \) = Predicted failure pressure of a defect (determined by B31.G or equivalent)
- \( MAOP \) = Maximum Allowable Operating Pressure of the Pipeline
Figure 7-1 contains three plots of the allowed time to respond to an indication. The figure is applicable to the prescriptive-based program. The intervals may be extended for the performance-based program, as provided in Section 7.2.5.
Corrosion Defect

1931, 18” diameter, .312” wall, seamless, Grade B pipe, operating pressure - 300 psi, stress - approximately 25%.
Mechanical damage

1951, 12” diameter, .312” wall, seamless, Grade B pipe, operating pressure - 237 psi, stress - approximately 13%.
## Characterization by Threat

<table>
<thead>
<tr>
<th>Time Dependent</th>
<th>Stable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. External corrosion</td>
<td>4. Manufacturing Related Defects:</td>
</tr>
<tr>
<td>2. Internal corrosion</td>
<td>• Defective pipe seam</td>
</tr>
<tr>
<td>3. Stress corrosion cracking</td>
<td>• Defective pipe</td>
</tr>
<tr>
<td>4. Manufacturing Related Defects:</td>
<td>5. Welding/Fabrication Related:</td>
</tr>
<tr>
<td>• Defective pipe seam</td>
<td>• Defective pipe girth weld</td>
</tr>
<tr>
<td>• Defective pipe</td>
<td>• Defective fabrication weld</td>
</tr>
<tr>
<td></td>
<td>• Wrinkle, bend or buckle</td>
</tr>
<tr>
<td></td>
<td>• Stripped threads/broken pipe/coupling failure</td>
</tr>
<tr>
<td>• Gasket o-ring failure</td>
<td>• Gasket o-ring failure</td>
</tr>
<tr>
<td>• Control/relief equipment malfunction</td>
<td>• Control/relief equipment malfunction</td>
</tr>
<tr>
<td>• Seal/pump packing failure</td>
<td>• Seal/pump packing failure</td>
</tr>
<tr>
<td>• Miscellaneous</td>
<td>• Miscellaneous</td>
</tr>
</tbody>
</table>
### Characterization by Threat (cont.)

<table>
<thead>
<tr>
<th>Time Independent</th>
<th>7. Third Party/Mechanical Damage:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Damage inflicted by first, second or third parties (instantaneous/immediate failure)</td>
</tr>
<tr>
<td></td>
<td>• Previously damaged pipe (delayed failure mode)</td>
</tr>
<tr>
<td></td>
<td>• Vandalism</td>
</tr>
</tbody>
</table>

8. Incorrect Operations:

- Incorrect operational procedure

9. Weather Related and Outside Force:

- Cold weather
- Lightening
- Heavy rain or floods
- **Earth movements**
Three Sections of the Federal Code that address Pipeline Defects

- 192.307 & 309 Construction
- 192.711 & 713 & 717 Operation
- 192.933 Integrity Management
Construction (192.307 & 309) (>20% SMYS)

- Each imperfection that could impair serviceability must be removed or repaired
  - Grinding repairs are permitted provided min. wall is maintained
- Dents must be removed as follows
  - with stress risers, effect longitudinal or seam welds
  - >40% SMYS ¼” deep or larger for <12” diameter
  - >40% SMYS 2% or larger for 12” diameter or greater
Operation (192.711-717)  
(>40% SMYS)

• Each imperfection that could impair serviceability must be removed or repaired
  – “Repair by a method that reliable engineering tests and analysis show can permanently restore the serviceability of the pipe”

• Each leak must be repaired by
  – Removing and replacing a cylinder containing the defect
  – Clamp or welded patch over corrosion
  – Other method that can permanently restore serviceability
Integrity Management (192.933) (>20% SMYS)

“An operator must take prompt action to address all anomalous conditions…” as follows

• Immediate repair condition
  – Defects with a failure pressure ratio of 1.1 or less
  – Dents that contain stress risers
  – Any defect the operator deems necessary

• One year condition
  – Plain dent >6% (.5” for <12” dia.) in upper 2/3
  – Plain dent >2% (.25 for <12” dia.) effecting a girth or seam weld

• Monitored conditions
  – Plain dent >6% (.5” for <12” dia.) in lower 1/3
  – Plain dent >6% (.5” for <12” dia.) in upper 2/3 w/critical strain levels not exceeded
  – Plain dent >2% (.25” for <12” dia.) effecting a girth or seam weld w/critical strain not exceeded
Characterization of Defects

1. **Immediate** - Defect is at or near failure point.
   
   operators to make prompt repairs.

2. **Scheduled** - Defect is significant but not at failure point.
   
   operator to schedule repairs based on the severity of the defect.

3. **Monitored** - Defect will not fail before next inspection.
   
   operator to monitor the indication’s growth at scheduled intervals.
Boils Down to Four Types of Defects

- Cracks
- Plain Dents
- Corrosion- Metal Loss
- Mechanical damage- Dents w/gouges
Cracks

Occur due to:

- Poor material properties- Manufacturing
- Poor welding- Construction
- SCC- Condition specific

Controlling the process and environment can limit the existence of these type of defects
Plain Dents

Occur due to:

- Installation/Construction
- Ground movement/settling
  - Buckling
- Some rock impingement

Plain Dents are normally not harmful provided they are not extremely large
Corrosion

- We know the most about
- Understand and can model:
  - Behavior – leak vs. rupture
  - Growth Rates
  - Failure mechanisms
  - Mitigation/prevention

Our challenge is finding and sizing defects prior to failure
Mechanical Damage

- To effectively manage requires prevention
- Difficult to mitigate due to random/time independent nature of the defect
- Almost all fail immediately
- Those that do not can remain latent for years
- Most complex failure mechanism
- Tendency to rupture rather than leak

Detection and sizing are key to analysis of latent defects
Failure from Mechanical Damage

1964, 16” diameter, .250” wall, ERW, X-42 pipe, operating pressure - 490 psi, stress - approximately 40% SMYS
Failure Mode - Latent Third Party Damage
What have we done

• B31.8S and IMP Regulations
• Develop Direct Assessment ICDA&ECDA
• ILI advancements
What have we done

• Robotics & Sensors for Autonomous inspections

• Advance Development of Guided Wave
What have we done

- Third Party Monitoring / Listening devices
- Advancements in leak detection
What have we done

- Ground probing radar and other locating devices
- Implement GIS and GPS mapping techniques
What have we done

- Constructed pipe beds to test new technology
What are we doing

- Long Term Monitoring using Guided Wave (MsS)
- Mini-Camera for Inspection of Cased Crossings
What are we doing

- Acoustic Stand-off Technique for Internal/External Inspection
What Remains to be done?

- New sensors for detecting defects
- Non intrusive inspections
- Further engineering evaluation of defects and failure mechanisms
- Reconcile %CSA to % thru wall
- Improve locating methods/ devices
- Education
- Damage Prevention technology