Hydrostatic Testing of In-Situ Pipelines & Spike Testing

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6/27/18
Overall: GTS has designed hydrotests for over 1,000 miles of in-situ pipelines on over 500 projects. Pipeline diameters ranging from 2” to 42” on lines dating back to the 1920’s.
Agenda

• Hydrostatic Testing Overview
  • Why Hydrotect – NPRM Synthesis/Update
  • Essential Elements of a Hydrotect
  • In-Situ Testing Considerations

• Spike Testing
  • Why Include a Spike Test into your Hydrotect - NRPM
  • Flaw Growth Over Time
  • When is Spike Testing Appropriate
  • Test Pressure Determination

• Lessons Learned
  • Considerations for Value Add and Cost Savings
Revision to the code proposes to effectively eliminate the “grandfather” clause - used to establish MAOP on non-tested pre-1970 lines.

- Per GPAC March Meeting ~6,800 miles meet this criteria

**Timeline to establish MAOP**
- 15 Years from Effective Date of the Ruling

**Methods for Determining and Establishing MAOP**

1. **Hydrostatic Test**
2. Pressure Reduction commensurate with a test factor
3. Perform an Engineering Critical Assessment (fracture mechanics and material properties)
4. Pipe Replacement
5. Pressure Reduction for Lines <30% SMYS
6. Alternative Technology
Essential Elements - Hydrotest Overview

1. Prepare Test Ends
2. Identify water source
3. Ensure sufficient water flow or store
4. Fill line
5. Stabilize Temperature
6. Pressurize line for test
7. On Test and Monitor
8. Complete Test Documentation
9. Dewater, Dry and return to service
In-Situ Testing Considerations

Important to remember: Many other factors to account for when testing an in-situ line compared to a new line

Preliminary Engineering

- Validate physical properties of features
- Uncover unknown features (taps, PCFs, etc.)
- Other impediments to pigging
- Optimize test section
In-Situ Testing Considerations
In-Situ Testing Considerations

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**Outage Management**
- Up to 2 Week outage compared to 1-2 day outage
  - Services on the line being tested?
  - Radial feed line?
In-Situ Testing Considerations
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**Cleaning**
- Possibilities of residual contaminants in operational lines
  - Protrusions and debris can hinder cleaning/clearing
  - You don’t always know what may be in your line!
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- Possibilities of residual contaminants in operational lines
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**Water Handling**
- Possible contaminants, liquids, etc. compared to a clean brand new line
  - Filters
  - Water Sampling
  - BMPs and a response plan in the event of a rupture
In-Situ Testing Considerations
Spike Testing
1. Current GPAC stance is no Spike Test is required as part of a Hydrotest being used to establish MAOP

2. Rules out critical flaws including SCC and long seam defects.

3. Minimizing size of “just-surviving” flaws

4. Subsequent to Spike Hold period, relaxing the test pressure by 10% (minimum of 5% if 10% cannot be achieved due to test parameters) as research shows the reduction will generally stop or stabilizes crack growth and avoids continued subcritical crack growth
Sample Spike Test PvT Graph

Stabilization Period 1/2 Hour Spike Period

75% Min. Pressure
Min. Pressure (post spike)
Min. Pressure
Min. Pressure
100% SMYS (Weakest Segment)
100% SMYS (Weakest Segment)
Spike Pressure

Pressure (psig) vs. Time (min)

Spike Pressure
Min. Pressure
100% SMYS (Weakest Segment)
Stabilization Period 1/2 Hour Spike Period

On Test

911 psig

0 50 100 150 200 250 300 350 400 450 500 550 600

Time (min)
Flaw Growth Over Time

Sub Critical Flaw

Critical Flaw

Flaw Growth Line

Time

Pressure

MAOP

Operating Pressure Cycles

1.25 (TPM)

1.5 (TPM)
When is Spike Testing Appropriate?

Various Kiefner & Associates reports on hydrostatic testing identify variations of three (3) categories for the suitability of a spike test:

**Spike testing is beneficial to:**
- Rule out time dependent and manufacturing threats and can extend not only re-assessment interval but life of pipe

**Spike testing is less necessary on:**
- Newer pipe, and lines operating at lower SMYS (<40%)

**Spike Testing can be inadvisable when:**
- Exceeding mill test pressures or to extremes that would cause plastic deformation
- Test pressures do not allow for significant enough reduction in pressure so as to restrain sub critical flaw growth
Test Pressure Determination

Ratings of Fitting and Max Shell Test Pressure
Test Pressure Determination

- Ratings of Fitting and Max Shell Test Pressure
- Elevation Changes Causing Static Head
Test Pressure Determination

- Ratings of Fitting and Max Shell Test Pressure
- Elevation Changes Causing Static Head
- Review Leak and CP History on the Line
Ratings of Fitting and Max Shell Test Pressure

Elevation Changes Causing Static Head

Review Leak and CP History on the Line

Mill Test Pressures and Documentation
Ratings of Fitting and Max Shell Test Pressure

Elevation Changes Causing Static Head

Review Leak and CP History on the Line

Mill Test Pressures and Documentation

Extend IM Reinspection Interval

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Table 3  Integrity Assessment Intervals:
Time-Dependent Threats, Prescriptive Integrity Management Plan

<table>
<thead>
<tr>
<th>Inspection Technique</th>
<th>Interval (Years) [Note (1)]</th>
<th>At or Above 50% SMYS</th>
<th>At or Above 30% up to 50% SMYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrostatic testing</td>
<td>5</td>
<td>TP to 1.25 times MAOP [Note (2)]</td>
<td>TP to 1.4 times MAOP [Note (2)]</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>TP to 1.39 times MAOP [Note (2)]</td>
<td>TP to 1.7 times MAOP [Note (2)]</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Not allowed</td>
<td>TP to 2.0 times MAOP [Note (2)]</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>Not allowed</td>
<td>Not allowed</td>
</tr>
</tbody>
</table>
Test Pressure Considerations

Ensure Proper Planning and **Communication** of Maximum and **Minimum** pressure control point

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>R STA.</th>
<th>ELEV.</th>
<th>SPIKE PRESSURE</th>
<th>MIN. PRESS</th>
<th>MAX. PRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN. PRESSURE CONTROL POINT</td>
<td>166+56</td>
<td>853’</td>
<td>690 PSIG</td>
<td>588 PSIG</td>
<td></td>
</tr>
<tr>
<td>MAX. PRESSURE CONTROL POINT</td>
<td>20+32</td>
<td>563’</td>
<td>816 PSIG</td>
<td></td>
<td>734 PSIG</td>
</tr>
<tr>
<td>LOCATION 1 (VERIFICATION STATION)</td>
<td>0+00</td>
<td>722’</td>
<td>747 PSIG</td>
<td>645 PSIG</td>
<td>665 PSIG</td>
</tr>
<tr>
<td>LOCATION 2 (TEST STATION)</td>
<td>190+42</td>
<td>820’</td>
<td>705 PSIG</td>
<td>603 PSIG</td>
<td>622 PSIG</td>
</tr>
</tbody>
</table>
Considerations and Lessons Learned

Methods and considerations for a cost effective hydrotest or hydrotest program:

Planning Lessons → Engineering Lessons → Execution Lessons
Planning Lessons Learned

Geographical Grouping
- Careful consideration of your program should be made to cluster project sites:
  - Environmental and Ministerial Permits
  - Public Convenience
  - Efficient Outage Management
  - Reduce Mobilization and improves access

Test Splitting
- Review elevations particularly in long stretches of untested line
- Can “leap frog” or “daisy Chain” tests utilizing water from tests on adjacent portions of the line
Planning Lessons Learned
Proper pipeline asset knowledge is critical to the successful design of a hydrotest

- Comprehensive Pipeline Features List (PFL)
  - Identifies all unpiggable features
  - Provides pipeline specifications to determine test pressures
  - Identifies underrated features
### Engineering Lessons Learned

<table>
<thead>
<tr>
<th>Feature Number</th>
<th>Start Station</th>
<th>End Station</th>
<th>Line ID</th>
<th>Class Location</th>
<th>Install Date</th>
<th>Feature</th>
<th>Type</th>
<th>Feature by Feature Length (ft.)</th>
<th>Current MAOP (psig)</th>
<th>Normal Operating Pressure (psig)</th>
<th>O.D. 1</th>
<th>W.T. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>570</td>
<td>0+08.5</td>
<td>0+09.2</td>
<td>8002</td>
<td>3</td>
<td>5/24/2011</td>
<td>Tee</td>
<td>Straight Tee</td>
<td>0.7</td>
<td>500</td>
<td>500</td>
<td>4.5</td>
<td>Unknown</td>
</tr>
<tr>
<td>571</td>
<td>0+09.2</td>
<td>0+11.5</td>
<td>8002</td>
<td>3</td>
<td>5/24/2011</td>
<td>Pipe</td>
<td>No Casing</td>
<td>2.3</td>
<td>500</td>
<td>500</td>
<td>4.5</td>
<td>Unknown</td>
</tr>
<tr>
<td>574</td>
<td>194+32.5</td>
<td>194+05.5</td>
<td>L001</td>
<td>3</td>
<td>5/24/2011</td>
<td>Pipe</td>
<td>No Casing</td>
<td>63.0</td>
<td>500</td>
<td>500</td>
<td>12.75</td>
<td>0.250</td>
</tr>
<tr>
<td>575</td>
<td>194+95.5</td>
<td>194+98.0</td>
<td>L001</td>
<td>3</td>
<td>5/24/2011</td>
<td>Valve</td>
<td>Plug</td>
<td>2.5</td>
<td>500</td>
<td>500</td>
<td>12.75</td>
<td>0.250</td>
</tr>
<tr>
<td>576</td>
<td>194+98.0</td>
<td>195+03.0</td>
<td>L001</td>
<td>3</td>
<td>5/24/2011</td>
<td>Pipe</td>
<td>No Casing</td>
<td>5.0</td>
<td>500</td>
<td>500</td>
<td>12.75</td>
<td>0.250</td>
</tr>
<tr>
<td>577</td>
<td>195+03.0</td>
<td>195+06.0</td>
<td>L001</td>
<td>3</td>
<td>5/24/2011</td>
<td>Elbow</td>
<td>Unknown</td>
<td>3.0</td>
<td>500</td>
<td>500</td>
<td>12.75</td>
<td>0.250</td>
</tr>
</tbody>
</table>
Proper pipeline asset knowledge is critical to the successful design of a hydrotest

- Comprehensive Pipeline Features List (PFL)
  - Identifies all unpiggable features
  - Provides pipeline specifications to determine test pressures
  - Identifies underrated features

Future Planning

- Prep line to accommodate smart pigs?
- Test for Other factors (IM)
  - Casing with an IM assessment requirement
  - Pipeline requires future DA? Increase test factor from 1.5 to 1.7 to extend assessment to 7 years

Contingency Material
Engineering Lessons Learned
Execution Lessons Learned

Test Monitoring
- Test certification tool to monitor real-time pressure fluctuations
  - Will provide information on if pressure drop is on account of a leak or temperature change

Leak Contingency Planning
- Prepare and identify most likely locations for leaks
  - Seam Type, pipe vintage, low points
- Have an isolation plan
- Have BMP Equipment on standby during test
Questions?

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Additional Information
GTS will be providing Part II of a webinar series with additional hydrotest information on TBD
Test Steps

• Temperature Stabilization
• Pre-Test Leak Identification
  • Monitor Fill pump pressure
  • 1 Hr P Stabilization @ 75% Min TP
• Spike Test for 30 min (max) Hold Period - 7.5 Hrs
• De-pressure and Dewater
Test Duration Determination

Longer test duration does not necessarily mean safer pipeline upon completion!

**DEFECTS UNDERGOING UNSTABLE CRACK GROWTH, HYDROTEST**

These cracks would survive 30 minute and 2 hour test, but after 2 hour test they would be in worse condition (i.e. larger crack opening).

Reprinted with Comments added - Harvey Haines, John Kiefner & Mike Rosenfeld, “Study questions specified hydrotest hold time’s value”, Oil & Gas Journal, March 5, 2012.
Approx. 90% of flaw failure pressure

Approx. 95% of flaw failure pressure

X = point of irreversible strain

If loading (pressurization) stops or held constant, defect continues to failure

If loading (pressurization) stops or held constant, defect continues to grow slowly and stabilizes

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Defects Held at a Stress Near Failure

Flaw growth from pressure cycling near the failure stress level, from PRC/AGA NG-18 Report No. 111, Kiefner, J.F., Maxey, W.A., and Eiber, R.J., “A study of the Causes of Failure of Defects That Have Survived a Prior Hydrostatic Test”, 11-3-80
<table>
<thead>
<tr>
<th>Diameter</th>
<th>Wall Thickness</th>
<th>Grade, psi</th>
<th>MAOP, psig</th>
<th>Test Pressure, psig</th>
<th>Ratio of Test Pressure to MAOP</th>
<th>Minimum Time to Failure, years</th>
</tr>
</thead>
<tbody>
<tr>
<td>30&quot;</td>
<td>0.375&quot;</td>
<td>52,000</td>
<td>400</td>
<td>790 (60.77%)</td>
<td>1.975</td>
<td>438</td>
</tr>
<tr>
<td>30&quot;</td>
<td>0.375&quot;</td>
<td>52,000</td>
<td>400</td>
<td>680 (52.31%)</td>
<td>1.7</td>
<td>221</td>
</tr>
<tr>
<td>30&quot;</td>
<td>0.375&quot;</td>
<td>52,000</td>
<td>400</td>
<td>600 (50.00%)</td>
<td>1.5</td>
<td>126</td>
</tr>
<tr>
<td>30&quot;</td>
<td>0.375&quot;</td>
<td>52,000</td>
<td>400</td>
<td>500 (level below minimum allowed)</td>
<td>1.25</td>
<td>46.3</td>
</tr>
<tr>
<td>30&quot;</td>
<td>0.375&quot;</td>
<td>52,000</td>
<td>400</td>
<td>440 (level below minimum allowed)</td>
<td>1.1</td>
<td>21.4</td>
</tr>
</tbody>
</table>

Effects of Test Pressure-to-MAOP Ratio on Times to Failure Caused by Pressure-Cycle-Induced Fatigue Crack Growth of an Initial Flaw (for a Class 3 Segment)
<table>
<thead>
<tr>
<th>Diameter</th>
<th>Wall Thickness</th>
<th>Grade, psi</th>
<th>MAOP, psig</th>
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<tbody>
<tr>
<td>30”</td>
<td>0.375”</td>
<td>52,000</td>
<td>890</td>
<td>1237 (95.2%)</td>
<td>1.39</td>
<td>216</td>
</tr>
<tr>
<td>30”</td>
<td>0.375”</td>
<td>52,000</td>
<td>890</td>
<td>1113 (85.6%)</td>
<td>1.25</td>
<td>110</td>
</tr>
<tr>
<td>30”</td>
<td>0.375”</td>
<td>52,000</td>
<td>890</td>
<td>979 (75.3%)</td>
<td>1.1 (not allowed in a test with water)</td>
<td>43</td>
</tr>
</tbody>
</table>

Effects of Test-Pressure-to-MAOP Ratio on Times to Failure Caused by Pressure-Cycle-Induced Fatigue Crack Growth of an Initial Flaw (for a Class 1 Segment)

Lower test ratio provides longer minimum time to failure because testing to higher % of SMYS