PE 2708 Medium Density Bi-Modal PE Materials

2011 OGA Technical Seminar

Brian Moidel
Principal Engineer
Dominion East Ohio Gas
• DEO Pipeline Replacement Program
• What is Being Replaced
• Key Safety Performance Requirements
• Why Bimodal PE2708
• Installation
• PolyPipe 1” cts tubing Issue
• Summary
Dominion East Ohio (DEO)

1,200,000 Customers
Dominion East Ohio

- 1,200 Miles of Intrastate Gas Transmission and Storage Pipelines
- 2,100 Miles of Gas Gathering Pipeline
- 19,600 Miles of Gas Distribution Mains
- 1.2 Million Customers
DEO Pipeline Infrastructure Replacement Program

- Includes replacement of 4,100 miles of bare steel, cast iron, wrought iron, and copper pipe.
- Represents approximately 20% of DEO’s 21,000-mile pipeline system.
- Covers a 25-year, total-project timeframe, with the first five years approved by PUCO.

Effective October 16, 2008, the PUCO granted Dominion East Ohio (DEO) a revenue increase to recover expenses associated with the pipeline infrastructure replacement (PIR) program.
What is being replaced?

Bare Distribution and Transmission Pipe

- Target Pipe: Bare Steel, Cast & Wrought Iron
- Total Pipe: All DEO Pipe in System

Total Pipe in DEO System: 21,263 Miles
Replacement Program
25 Year Projection

• Total Miles of Mains & Services Replaced
  – Approx. 4,122 miles @ $2.1 Billion

• Miles of Main replaced with Plastic Pipe
  – Approx. 2,600 miles (6” and less)
  – Approx. 600 miles (8” – 12”)
  – Total = approx. 3,200 miles

• 25 Year Proposed Expenditure on Plastic Pipe mains ($2007 dollars):
  – $1.5 Billion
What is it being replaced with?

Dominion’s Plastic Design Standard

<table>
<thead>
<tr>
<th></th>
<th>60 psi &amp; below</th>
<th>61 – 100psi</th>
<th>101-125psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>2”</td>
<td>SDR 11 PE2708</td>
<td>SDR 11 PE4710</td>
<td>SDR 9 PE4710</td>
</tr>
<tr>
<td>3”</td>
<td>SDR 11.5 PE2708</td>
<td>SDR 11 PE4710</td>
<td>SDR 9 PE4710</td>
</tr>
<tr>
<td>4” – 12”</td>
<td>SDR 13.5 PE2708</td>
<td>SDR 11 PE4710</td>
<td>SDR 9 PE4710</td>
</tr>
</tbody>
</table>

And Steel…..but you don’t want to hear about that!
Bimodal Reactor Configuration

Higher MW
- toughness
- mechanical properties
- crack resistance
- melt strength

Lower MW
- stiffness
- tensile strength
- flex modulus
- processability

Result: The final product has excellent burst strength, SCG, RCP & chemical resistance
**Key Requirements**

- **Maximum Operation Pressure** – One of the key components in RCP failures.

**Slow Crack Growth** – Major field failure mode. Stress formed at tip of defect or scratches & initiates small crack, which grows slowly until penetrating through the pipe wall.

**Rapid Crack Propagation** – Rare but catastrophic. Upon impact, crack can initiate along pipe wall. Under the driving force of the internal pressure, the crack can rapidly propagate along the pipeline.
**New PE Pipe Material Designation Codes (ASTM D3350)**

<table>
<thead>
<tr>
<th>Pipe Material Designation Code</th>
<th>1st Digit (Density)</th>
<th>2nd Digit SCG (PENT)</th>
<th>3&amp;4 Digit (HDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical</td>
<td>Current</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE 2406</td>
<td>PE2406</td>
<td>&gt;.925 - .940</td>
<td>10 hrs min.</td>
</tr>
<tr>
<td><strong>PE2708</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE3408</td>
<td>PE3408</td>
<td>&gt;.940 - .947</td>
<td>10 hrs min.</td>
</tr>
<tr>
<td><strong>PE4710</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>500 hrs min.</td>
</tr>
</tbody>
</table>
Environmental Challenge
And ...... RCP!
• RCP resistance decreases with:
  – Larger sizes
  – Thicker wall
  – Lower Temperatures
  – Higher Pressures
## Critical Pressure

<table>
<thead>
<tr>
<th>PE Material</th>
<th>S-4 Critical Pressure, bar (psi)</th>
<th>Full Scale Critical Pressure, bar (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unimodal PE2708</td>
<td>1 (14.5 psi)</td>
<td>6 (87 psi)</td>
</tr>
<tr>
<td>Bimodal PE2708</td>
<td>10 (145 psi)</td>
<td>38* (551 psi*)</td>
</tr>
</tbody>
</table>

* Determined by ISO 4437 equation based on S-4 data
Uni-Modal PE2708

$P_{c(S-4)} = 15\text{psig} \Rightarrow P_{c,FS} = 90\text{psig}$ (Leak Test pressure for 60psig MOP operating system) \@ 0^\circ\text{C}

Pipe Diameter

Operating Pressure

- Red = RCP "possible" zone
- Yellow = RCP "caution" zone
- Green = RCP "safe" zone
Bi-Modal PE2708

\[ P_{c(S-4)} = 145 \text{psig} \Rightarrow P_{c,FS} = 560 \text{psig} @ 0 \degree C \]
### Critical Temperature Values

<table>
<thead>
<tr>
<th>PE Material</th>
<th>S-4 Critical Temperature at 5 bar (73 psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unimodal PE2708</td>
<td>60°F (15°C)</td>
</tr>
<tr>
<td>Bimodal PE2708</td>
<td>28°F (-2°C)</td>
</tr>
</tbody>
</table>
Uni-Modal PE2708

$T_c = 60^\circ F (15^\circ C) @ 73$ psig (5 bar)

- **Red** = RCP “possible” zone
- **Yellow** = RCP “caution” zone
- **Green** = RCP “safe” zone
Bi-Modal PE2708

$T_C = 28^\circ F (-2^\circ C) \text{ at } 75\text{psig} (5 \text{ bar})$

- Red = RCP “possible” zone
- Yellow = RCP “caution” zone
- Green = RCP “safe” zone

Pipe Diameter

Operating Temperature

- 2" - 12"
Slow Crack Growth

- PE gas pipe does not fail in ductile manner due to the lower operation pressure.

- SCG failure is observed in the field on older PE gas pipe due to stress concentration.

- PENT test, ASTM F1473, is the standard test to measure the resistance to SCG failure.

- SCG requirement has increased from 192h ESCR/Cell class 3 (3hr PENT), to 600h ESCR/Cell Class 4 (10h PENT), to 100h PENT/Cell Class 6, to 500h PENT/Cell Class 7.

- The longer the PENT hours, the better the resistance to SCG failure.
SCG Improvement

Data is from Polymer Eng. And Sci., May 1991, Vol. 31. No. 10 and Dow Chemical Product Data Sheet
SCG of Bi-Modal PE2708

- Bi-modal PE2708 has outstanding SCG resistance with PENT hours
  - 150 times higher than ASTM D 2513 requirement.
  - 30 times higher than PE2708 requirement
  - 15 times of a typical uni-modal PE2708
  - 10,000 times higher than the first generation PE gas pipe resin
Joining Methodology

Generic Butt Fusion
Joining Procedure for
Field Joining of
Polyethylene Pipe

TR-33/2006

LETTERS OF COMPLIANCE FROM PPI
MEMBER COMPANIES FOR 49CFR
§192.283 FOR PIPE INTENDED FOR GAS
DISTRIBUTION APPLICATIONS
February 1, 2009

Subject: PPI TR-33 GENERIC BUTT FUSION PROCEDURE / LETTER OF APPROVAL

This letter is to verify that PolyPipe, Inc. has conducted butt fusion testing using the PPI Generic Butt Fusion Joining procedure as shown in Appendix A of PPI Technical Report TR-33. This testing was conducted in accordance with DOT 49 CFR 192.283 and consisted of visual inspection, tensile tests (ASTM D638), hydrostatic quick burst tests (ASTM D2513) and sustained pressure 80C testing. Initial testing and qualification was performed by a PPI task group and requalified 5 years later as reflected in the TR-33/2006 report. PolyPipe Inc has completed additional qualification to these same procedures and test protocol for its bi-modal PE2708 and PE4710 products for gas distribution. PolyPipe Inc approves the use of the PPI Generic Butt Fusion procedures for the joining of these bimodal products to each other and to the products previously tested in earlier qualifications.
Qualification Testing
Butt Fusion Joints
8” PE New Construction
12” PE New Construction
Handling PE Pipe
Storing PE Pipe
Storing PE Pipe
PolyPipe 1” cts Issue

**Issue:** 1” cts PE2708 (Bi-modal) tubing out of specification; resulting in low wall:

- **Cause of problem** – Water System
- **Affected timetable Jan 18 – 21, 2010**
- **Corrective Action** – Installed water conditioning system to eliminate hard water
- **Lab testing** – Accelerated life testing of PE gas tubing at JANA Labs
Accelerated Life Testing

• **Purpose of testing** was to perform dimensional analysis and accelerated simulated service condition testing on tubing with below spec wall pipe (0.030” wall).

• **Results of testing** conclude that this 0.030” **bi-modal** wall tubing can be expected to operate without failure with internal pressure of 60psig or less at service temperature of 73 deg F or lower for a period exceeding 100 years.
Summary

- RCP failure is a major safety concern at DEO due to the low ambient temperatures
- Bimodal PE2708 offers excellent RCP resistance
- DEO specifies bimodal PE2708 in end use specification
- Bimodal PE2708 has been installed at DEO for the past 3 years and it is in safe operation
• Bimodal PE2708 plastic is flexible for purposes of installation and squeeze off.
• Fusion of bimodal PE2708 meets the same parameters as unimodal PE pipes.
THE END

Thank you for your attention!

Questions?