The Use of Reinforced Thermoplastic Pipe to Rehabilitate Pipelines to Restore Integrity and to Eliminate Ongoing Corrosion Concerns

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Agenda

• What are Reinforced Thermoplastic Pipes and Why Use them
• Rehab Example
• Critical Issues In Oilfield Environments
  • Overall
  • Liners
  • Reinforcement
  • Outer Jacket
• Test Criteria to Assess Polymers
  • Liners
  • Reinforcement
  • Outer Jacket
• Third Party Testing and Standards
• Questions
What are Reinforced Thermoplastic Pipes (RTP)?

- Three Layer Construction
  - Inner Barrier Layer
  - Reinforcement Strength Layer
  - Outer Protective Jacket
- Each Layer is Independent of One Another
  - Flexibility
  - Thermoplastic High Creep Properties Don’t Significantly add Strength when bonded together
Benefits of Reinforced Thermoplastic Pipes for Rehabilitation and New Installation

• Light Weight and Flexible Continuous Spools
  • Light Duty Equipment
  • Dramatically Reduces Installation Costs

• Corrosion Resistance
  • No Ongoing Corrosion Inhibitors
  • Must Select Correct Polymers

• Easy Pipeline and Tubing Integrity Management
Why Rehabilitation? Installation Example

- 6” 1.9 Mile Offshore Pipeline with Integrity Issues
- Hydrocarbons, Saltwater and 4,000PPM H2S
- RTP Design:
  - PPS Lined, Aramid Fiber Reinforced, PP Jacketed
  - 1600PSI Rated Pressure
  - Inconel 625 Unions
- In Line Test Spools
- 3 Day Install, 80% Less Capex vs. New Steel Line
- No ongoing Corrosion Inhibitors
Why is Material Selection Important?

• RTP was Originally Designed for Salt Water Flow Lines at Relatively Low Temperature (< 50°C)
• Acceptance in the Market Place has Increased the Applications for RTP
  • Oil/Condensate
  • H₂S
  • High Temperature
• Polymers Originally Used in RTP (HDPE) are not necessarily Acceptable for New Applications
• Operators need a Process to Evaluate Polymers and Reinforcements for RTP for Their Applications
Critical Issues for RTP in the Oilfield for Rehabilitation and New Installations

- Chemical Compatibility With Current Environment
  - Hydrocarbons . . . Oil, Gas, Condensate, Aromatics, Brine
  - Brine: 0 to 200,000PPM Salts
  - Wet CO₂ and H₂S
    - Up To 50% in Flow Lines
    - Up to 100% for Injection

- Permeation

- Temperature
  - Increasing with Horizontal Drilling
  - Secondary Recovery and Additional Water can Increase Temperature at Surface

- Abrasion . . . Sand, Coal Fines

- Flow Characteristics
  - Static vs. Cyclic
  - Pressure Spikes, Shut in Issues etc.

- Design Life

- Weight and Flexibility
Critical Issues Liners

- Material Selection is Very Important for Application
  - Temperature Dependent
  - Fluids Dependent
  - Interaction among Fluids
- Permeation of Product through Liner
- Abrasion Resistance
- Toughness
- Performance for a Range of Temperatures
  - Cold Temperature
  - Hot Temperature

Industry JIP Study Newcastle
Chemical Compatibility for Liners

• Looking for Stabilization of Properties Over Time
  • Polymers Can Increase or Decrease in Properties
  • Always Changes from Dry As Molded
• Polymer Properties Changes Generally
  • Soften and Swell
  • Hydrolyze and Get Brittle
  • Less Frequently Oxidize
• Elevated Temperature Accelerates Reaction Time
  • Some Polymers Have Limits of High Temperature Properties

Fortron (PPS) Change in Tensile Strength

Source: MERL Study of PPS in Norsok 710 Solution
Liner Chemical Compatibility – Importance of Fluid Interaction

- Plastic Manufacturers Generally Provide Data for Interaction with One Chemical
- A Mix of Chemicals Can Create a Negative Reaction to a Polymer
- Testing should be performed in a Representative Solution for a Proposed Environment

Lifespan Predictions for Nylon 11 in Water And Water/CO2 Mix

Source: Arkema
Liner Chemical Compatibility - Permeation

- Permeation Does not Necessarily Affect Liners
- Permeating Thru Liners Can:
  - Impact Reinforcement Material (Corrosion, Hydrolysis etc.)
  - Cause Pressure Build in Annulus and Impact Outer Jacket
- Highly Temperature Dependent
- Testing Requirements
  - Assure Saturation (Film not Bulk Weight Loss)
  - Compounds have Different Permeation Rates
- Test Entire Pipe Construction to See if Permeation Affects Outer Jacket

![CO2 Transmission Data cc/M²-day](chart.png)
Abrasion Resistance of Liner

• Sand and Coal Fines Can Create Severe Abrasion to Piping Systems

• Plastics are Generally Better than Steel (Not PTFE)

• Taber Abrasion can Give a Good Comparison of Materials

• Flow Tests with Sand Solutions at Maximum Design Velocities is a Better Test

<table>
<thead>
<tr>
<th>Material</th>
<th>Mg/1,000 Cycles</th>
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<tbody>
<tr>
<td>Nylon</td>
<td>5mg</td>
</tr>
<tr>
<td>PVDF</td>
<td>5-10mg</td>
</tr>
<tr>
<td>UHMW PE</td>
<td>5 mg</td>
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<tr>
<td>PTFE</td>
<td>500 mg</td>
</tr>
<tr>
<td>304 Stainless</td>
<td>50 mg</td>
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</tbody>
</table>

Source: George Fischer DIN S53754 ASTM D1242 C-10 Wheel 1Kg Load
Liners - Other Considerations

- Toughness in Cold Temperature
- Impact Strength
  - Withstand Impacts During Installation
  - Drop Tests on Pipe not Just Coupons
- Creep of Polymers From Under Couplings
- Fatigue Properties for Cyclic Loading Applications
Critical Issues for Reinforcements

• Strength
  • Static
  • Cyclic

• Resistance to Environment
  • Permeation of Compounds
  • Damage to Outer Jacket

• Impact of Bending Upon Reinforcements

• Impact and Bending Resistance
Reinforcements – Static Strength

• Steel Is not Impacted by Creep Stress Rupture (Barlow Equation for Strength)
• All other Reinforcements’ Long Term Strength Determined by Stress Rupture Testing
  • ASTM D-2992 Proc B
  • Impacted by Temperature
  • Well Established in Industry
  • Test on Pipe as well as Raw Reinforcement
    • Some Reinforcements have no Construction Effect

"Long Term Creep and Stress Rupture of Aramid Fibers" Fallatah, Dodds, Gibson
Reinforcements - Cyclic Strength

- ASTM D2992 Proc. A is too Difficult
  - Requires Predicting Cycles to Failure
- Alternative Method
  - Cycle Pipe Samples over Customers Cyclic Range
  - Run Cycles equivalent to life span of Product
  - Compare Un Cycled Samples to Cycled Samples for Burst Strength
- Required for Cyclic Application - Rod Pumps, PD Pumps etc
Reinforcements – Chemical Resistance

Hydrolysis of Aramid Fibers in Acidic Environments

- Resistance to:
  - Permeation of Fluids Including Hydrocarbons, CO₂, H₂S
  - Temperature Dependent
- Assume Breach in Outer Jacket:
  - Resistance to Exterior Environment
  - Well or Ground
- Data Should be Vendor Specific

Source: Teijin

Aramid fiber type

Aramid A (100%)
Aramid B (88%)
Aramid C (31%)

56 days at 90°C, pH=4

Retained breaking strength [%]
Reinforcements – Other Considerations

• Pressure Hold at MAOP at Minimum Prescribed Bend Radius
  • Does Reinforcement Spread during Bending
  • Uneven Load of Reinforcement
• Drop Test on Finished Pipe to See if Reinforcement may be Damaged from Impact
Outer Jacket – Critical Issues

• UV Resistance
  • Buried, In Well or Surface Application
  • Storage Life Requirements
  • UV Inhibitor can have an Impact on Temperature (Carbon Black, TiO₂ White)
  • Testing of UV based Upon Weatherometer Data

• Abrasion Resistance
  • Dragging on Ground
  • Dragging in Casing
  • Same testing as Liner

• Material Selection for Outer Environment
  • Ground or Surface
  • In Well Same as Liner Requirements
  • Same Testing as Liner
Test Criteria Available in the Market

• API 15S
  • Focus on Strength
  • API 17J Provides Good Test Criteria for Material Selection (Exclude Dynamic Loading)
  • API 17E Similar to 17J but for Hoses for Umbilicals
  • Cyclic Loading is Optional but should be Required by Operators with Such Environment

• Non-Lab Tests Can Enhance the Comfort with Material Selection for an Application
  • Abrasive Flow Tests
  • High Temperature Gas Pressure Tests for Permeation Impact on Finished Pipe System
  • Coupling Retention Tests
Conclusion

• The Marketplace is Familiar with Steel and its Strength vs. Corrosion Characteristics
• Polymers React Differently than Steel and need to be Tested to Determine Proper Performance
• Critical Issues for Polymers:
  • Chemical Compatibility with Environment (As a Whole)
  • Temperature
  • Permeation
• Performance of One layer can Impact another layer of the RTP System
  • Permeation of the liner Affect on Reinforcement and Outer Jackets
• Metallic Coupling Material Selection Not Addressed