Subsea And Deepwater Flow Assurance Insulation:
Challenges and New Developments

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Bredero Shaw

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Why Thermal Insulation?

- Subsea tiebacks with multiphase flow require flow assurance.
- Thermal insulation is a key tool to ensure reliable operation of subsea flowlines and risers.
- ’Dry’ and ’wet’ insulation systems available.
Insulation is required to maintain temperature of fluid under two conditions:

- **Transient Condition**
  - If a field or well is shut down for maintenance, either planned or un-planned.
  - The fluid must maintain temperature. If temperatures drop then blockages occur and start up is a problem.
    - Key properties are higher density and lower K values to reduce Thermal Diffusivity, store more heat and extend cool down time.

- **Steady State**
  - Controlled Thermal Loss over Flow System during Normal Production. Maintain temperatures to ensure design flowrates met.
    - Key property is U value
Flowlines – Thermal Insulation

- **Improved seabed stability**
  - Higher density and weight stabilizes the pipe on the seabed
  - Thinner insulation with equivalent U value also stabilizes the pipe as currents have less effect

- **Subsea Tie-backs**
  - Low U values are required for long tiebacks
  - Sometimes wet insulation cannot meet the requirement
Risers – Thermal Insulation

- Design to withstand continuous dynamic strain without failure
- Insulation may be needed to help “dampen” riser motion.
  - Key properties are a higher density and stiffer insulation material to add weight and stabilize the riser
  - Thinner insulation also reduces effect of subsea currents
  - Riser systems must be capable of accepting a degree of flexing over the lifetime of the field
  - The alternative is to hang weights on riser
Subsea Architecture- Thermal Insulation

- Concern with subsea manifolds, trees, jumpers, bends is cool down performance
  - Key properties are:
    - higher density and lower K values to reduce Thermal Diffusivity, store more heat and extend cool down time.
    - Low water ingress for terminations
‘Dry’ insulation (Pipe-in-Pipe or PiP)
- Achieving low ‘Overall Heat Transfer Coefficient’ (OHTC) / U values of 1.0 W/m²K or less
- The most commonly used insulation material is polyurethane foam
- It is important to ensure that the structural integrity is maintained for both installation and operational loads (thermal insulation, linepipe, centralisers, waterstop seals, and loadshares)
- Water ingress can cause corrosion and destroy the system
- Has higher S-lay & J-lay installation costs
- Limitations on pipe sizes and hence water depth capability:
  Outer pipe to resist hydrostatic pressure;
  Inner pipe to resist high pressures from deep-lying reservoirs

‘Wet insulation’ (Single pipe)
- Generally is more cost competitive than PiP
- The main workhorse has been polypropylenes
- Polypropylene is currently the standard steel catenary riser (SCR) insulation system
Challenges on Subsea and Deepwater Flow Assurance Insulation

**Industry Trends**
- Lower U-values
- Deeper water
- Higher temperatures (up to 150°C)
- Longer tie-backs
  - Maximize the number of satellites that can be tied back to a host
  - Encompass sufficient reserves to improve economic viability
  - Burial and electric heating are current solutions
- Tougher design and qualification requirements
  - Thermal performance
    - Heat loss coefficient (K-value)
    - Transient performance (K-value, Specific heat capacity, Density)
  - Mechanical performance – Response of system to hydrostatic load
    - Immediate (Stress-strain, Poisson's number)
    - Long term (Compaction and creep)
Challenges on Subsea and Deepwater Flow Assurance Insulation

Diagram:

- Design basis
- System Choice
  - Initial Geometry
  - Assign material thickness
  - Apply temperature profile
  - Calculate internal stresses
  - Calculate compression/creep
  - Re-apply temperature
  - Calculate performance
  - Produce report
- Compliant?
  - No
  - Yes

Temperature
- Water depth
- Life span
- U-value requirement
- Transient requirement
- Lay method
- Field joint system
- Other requirements

Thermal properties
- K-value
- Specific heat capacity

Mechanical properties
- Stress-strain
- Poisson's number
- Compaction and creep

Aging effects
- Water uptake
- Change in properties
- Chemical ageing
Examples of Difficult Insulation Projects

- Chevron Wheatstone - 110°C, 237 m, 30 yrs design life, tough spec
- Statoil Åsgard - 140°C, 350 m
- Statoil Kristin - 155°C, 350 m
- BP Thunder Horse - 132°C, 2,200 m multi-layer on very heavy pipe
- Chevron Blind Faith - 150°C, 2,000 m, complex composite multi-layer
- Woodside Pluto
- Shell Kizomba B SHR - Intricate PiP construction
- BP Block 31 - Extreme thickness on heavy wall pipe
- Total Pazflor - High thickness
- BP Skarv - Low U-value, multi-layer coating
Challenges on Subsea and Deepwater Flow Assurance Insulation

- A lack of widely acceptable industrial testing methods and standards for pipeline coatings and insulation materials for the new applications
  - High temperature cathodic disbondment (CD) testing for temperature of 95°C or above, when high temperature FBE coating raw material is also relatively new to the industry
  - Hot water soak testing for insulation system
  - Thermal shock testing for insulation system
  - Increased demands for simulated service testing to validate thermal and mechanical properties of insulation system
Can it be Both an Insulation and a Weight Coating?

- **Pluto LNG project:**
  - Consists of subsea wells tied into one subsea manifold and one pigging manifold in approximately 830 m water depth.
  - Two 27 km long, 20” (508 mm) flowlines transport the gas to a riser platform.

- **A 7 layer coating for Insulation & Weight:**
  - 3LPP + 1 layer of Thermotite® Deep Foam (TDF) polypropylene insulation + 2 layers of a heavy aggregates-polypropylene blend + 1 layer of solid polypropylene
  - The material was successfully extruded to a density of 2000 kg/m3
Pipe End Preservation for Long-term Storage

- Coated pipe can be stored in a tropical and marine environment for over 2 years.
- Application of a temporary preservation paint/product is common but the removal process brings concerns on schedule, safety, performance and cost.
Challenges on Subsea and Deepwater Flow Assurance Insulation

- Base insulation materials have changed little and are still focused on polyurethane, polypropylene and epoxy foams and syntactics

- Limitations of the existing materials
  - High installation cost
  - High thickness
  - Hydrostatic pressure limitations
  - Subsea stability
  - Temperature limitations
<table>
<thead>
<tr>
<th>Material</th>
<th>Insulation Type</th>
<th>K-value (W/m.K)</th>
<th>Max. temp. (°C)</th>
<th>Max depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipe-in-Pipe (Dry insulation)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PUF (Polyurethane foam)</td>
<td>Foam</td>
<td>0.03-0.04</td>
<td>80 / 144</td>
<td>&lt;200 (PE) / 3050 (steel)</td>
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<tr>
<td>Mineral wool</td>
<td>Rock fiber</td>
<td>0.04</td>
<td>700</td>
<td>3050 (steel)</td>
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<tr>
<td>Fibreglass</td>
<td>Spun mineral fibers</td>
<td>0.032</td>
<td>&gt;150 (Steel PIP)</td>
<td>3050 (steel)</td>
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<tr>
<td>Micro-porous silica</td>
<td>Micro-porous ceramic</td>
<td>0.006-0.023</td>
<td>&gt;150</td>
<td>3050 (steel)</td>
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<tr>
<td>Aerogel</td>
<td>Nano size silica</td>
<td>0.014-0.021</td>
<td>650</td>
<td>3050 (steel)</td>
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<tr>
<td><strong>Single pipe (Wet insulation)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber (Neoprene / HNBR)</td>
<td>Solid</td>
<td>0.26 – 0.28</td>
<td>90 /140</td>
<td>&gt;3000</td>
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<tr>
<td>Filled (Neoprene / HNBR)</td>
<td>Solid</td>
<td>0.12 – 0.14</td>
<td>90 /140</td>
<td>&gt;3000</td>
</tr>
<tr>
<td>Syntactic epoxies</td>
<td>Syntactic</td>
<td>0.12-0.17</td>
<td>110</td>
<td>2800</td>
</tr>
<tr>
<td>Solid PU (Polyurethane)</td>
<td>Solid</td>
<td>0.19-0.20</td>
<td>90 wet /115 dry</td>
<td>&gt;3000</td>
</tr>
<tr>
<td>sPU (Polyurethane)</td>
<td>Polymeric syntactic</td>
<td>0.13</td>
<td>90 wet /115 dry</td>
<td>250</td>
</tr>
<tr>
<td>GsPU (Polyurethane)</td>
<td>Glass syntactic</td>
<td>0.14 – 0.17</td>
<td>90 wet /115 dry</td>
<td>2800</td>
</tr>
<tr>
<td>PP (Polypropylene)</td>
<td>Solid</td>
<td>0.21 – 0.24</td>
<td>140</td>
<td>&gt;3000</td>
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<tr>
<td>PPF (Polypropylene foam)</td>
<td>Foam</td>
<td>0.13 – 0.2</td>
<td>140</td>
<td>600 (2000 special formulation)</td>
</tr>
<tr>
<td>GsPP (Polypropylene)</td>
<td>Glass syntactic</td>
<td>0.17</td>
<td>140</td>
<td>2800</td>
</tr>
</tbody>
</table>
Thermotite® ULTRA™
—Next Generation Subsea Insulation

- Lower k factor than PP
- Lower film thickness for same insulation value
- No glass spheres
- Infinite water depth
Thermotite® ULTRA™ — Next Generation Subsea Insulation

- Thermal insulation and corrosion protection system based on FBE and styrenic alloys.
  - Multi-layer ULTRA system comprised of a base 3 layer:
    - FBE
    - ULTRABond adhesive to bond FBE to ”ULTRA”
    - Solid ULTRA
  - One or more insulation layers of solid or foamed ULTRA
  - ULTRASHield high ductility outer shield

Solids
- Density 1030 kg/m³
- K-value 0.156 W/m.K

Foams
- Density 740 – 850 kg/m³
- K-value 0.115 – 0.145 W/m.K
Thermotite® ULTRA™
—Next Generation Subsea Insulation

- Winner of the Spotlight on New Technology Award at the Offshore Technology Conference 2010

- Balboa subsea tieback project in GOM: Mariner Energy and Ocean Flow International (“OFI”)
  - 10 km flowline in 975m WD
  - 47.6 mm foam system on 5.5625”X0.500” line pipe
  - Coating completed at Bredero Shaw in Pearland, TX in Q2 2010
  - Reel lay with Ultra Field Joint

- ENI Goliat: Technip, OD 12” and 40 mm Ultra Foam, 2011
ULTRA™ 120 Development

Qualification trials successfully conducted in August 2012 in Bredero Shaw Kuantan Malaysia, witnessed by DnV

Increase in operation temperature through inclusion of heat barrier between ULTRA foam and FBE, using the extensively tested materials

Development included:

• Development of high temperature styrenic adhesive / topcoat
• Development of higher temperature styrenic FJ infill
• Development of application processes
The Industry’s Largest Simulated Service Vessel (SSV):
Winner of 2012 OTC Spotlight on New Technology Award

<table>
<thead>
<tr>
<th>Capability/Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Test Pressure</td>
<td>25 bar (± 2)</td>
</tr>
<tr>
<td>Maximum Test Pressure</td>
<td>300 bar (± 5)</td>
</tr>
<tr>
<td>Chilled Water Temperature</td>
<td>4°C (40°F) (± 2)</td>
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<tr>
<td>Inside Pressure Vessel</td>
<td></td>
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<tr>
<td>Internal Temperature</td>
<td>20°C – 180°C (68°F – 356°F)</td>
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<tr>
<td>Sample Length</td>
<td>6 m (18”) max</td>
</tr>
<tr>
<td>Vessel ID</td>
<td>1.2m (48””)</td>
</tr>
<tr>
<td>Number of Pipe Samples</td>
<td>one pipe</td>
</tr>
<tr>
<td>Pipe Inside Diameter</td>
<td>95 mm - 660 mm (4” - 26”)</td>
</tr>
<tr>
<td>Pipe Outside Diameter (includes insulation)</td>
<td>145 mm - 810 mm (6” - 32”)</td>
</tr>
<tr>
<td>Coating Thermal Conductivity</td>
<td>0.1 - 0.3 W/m K</td>
</tr>
<tr>
<td></td>
<td>(0.06 – 0.17 BTU / ft hr F)</td>
</tr>
<tr>
<td>Overall Heat Transfer Coefficient (U)</td>
<td>1.5 - 6 W/m² K</td>
</tr>
<tr>
<td></td>
<td>(0.3 – 1.1 BTU / ft² hr F)</td>
</tr>
</tbody>
</table>

Creep
Cool Down
k factor
End Seal Tape for Coated Pipe End Preservation

An easily removable and durable plasticized tape, featuring a modified pressure-sensitive adhesive and a highly flexible backing with excellent abrasion and chemical resistance.

Before and after application

Removal after six months external exposure
End-to-End Solution including Field Joint Coatings Available in APAC
Closing Remarks

- As offshore pipeline installation in deepwater and ultra deepwater applications increases, technical requirements for subsea flow assurance insulation will continue along the following directions: longer tie-back, lower U value, deeper water depth, and higher operating temperatures.

- The challenges to the pipeline industry are to improve the conventional systems or to develop new insulation materials/technologies to address the new requirements, and to establish meaningful testing standards and capability to validate the performance of these improved/new insulation systems.

- To meet these challenges and requirements is not an easy task, but has been and will be possible through the joint efforts of all interested parties.