Unbonded Flexible Pipe Construction, Offshore and Onshore Arctic Applications and Qualification Testing

By: Cobie Loper
Unbonded Flexible Pipe Construction

**Layer**  | **Material**  | **Function**
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FLEXSHIELD | NYLON 11 | EXTERNAL FLUID BARRIER
FLEXTENSILE | CARBON STEEL | TENSILE STRENGTH LAYER
FLEXWEAR | NYLON 11 | ANTI-WEAR LAYER
FLEXTENSILE | CARBON STEEL | TENSILE STRENGTH LAYER
FLEXWEAR | NYLON 11 | ANTI-WEAR LAYER
FLEXLOK | CARBON STEEL | HOOP STRENGTH LAYER
FLEXBARRIER | NYLON 11 or PVDF | FLUID BARRIER
FLEXBODY | STAINLESS 316L | COLLAPSE RESISTANT LAYER

▲ As-installed cost
▲ Floating Production Units
▲ Corrosion resistance
▲ Re-usability
▲ Reduced abandonment costs and impact to environment
▲ Thermal loss resistance
▲ Flexibility to align with subsea structures

▲ Diameter range: 1” to 20”
▲ Pressure capabilities: 15,000psi
▲ Depth capability: 10,000ft
▲ Thermoplastic materials: HDPE, PA11 or PVDF
▲ Reinforcement materials: Carbon steel (NACE compliant steels) and composite armor wires.
Wellstream End Fittings

The end fittings are designed to terminate the ends of each flexible pipe layer and provide the required connection to mate with the customer’s production facilities.

Each of the flexible pipe layers is individually terminated and sealed to sustain the imposed loads and maintain fluid-tight integrity.
Offshore Applications of Flexible Pipe

- Dynamic Risers from Floating Production Facilities
- Static Flowlines where installed cost is competitive with rigid pipe
- Water, gas and chemical injection
- Oil and gas export
Norsk Hydro - Troll Olje Gas Province

▲ Water depth 340 meter
▲ EPCI for Flowlines and Risers including:
  ▲ 140km off 10” Flexible Flowlines
  ▲ 20 off 10” Flexible Risers
  ▲ 2 off 15” Flexible Export Risers
  ▲ Static and Dynamic Umbilicals
  ▲ 7 km off Dynamic Service Umbilical (DSU)
▲ Fabrication of 2 riser Arch Jackets
▲ 25 subsea structures at Troll B & C
▲ All Subsea work performed diverless
The Flexbody layer

Flexbody: corrugated metallic tube with specific internal diameter. A metallic strip is formed into an interlocking helical tube which allows flexibility.
The Barrier and Flexshield layers

Flexbarrier/shield: are applied by the extrusion process and are polymer layers extruded over either the carcass or on the exterior and form a boundary for fluid.
Flexlok: steel, hoop strength layer consisting of circumferentially wound profiled wire. The Flexpress layer uses the same machinery but uses a rectangular wire.
The Flextensile layers

Flextensile: helical steel armor layer that resists internal pressure and axial tension. The flat wire can be of various sizes and tensile strengths depending on the pipe design.
Qualification Test Facilities

Static Qualification

Dynamic Test Rigs to simulate riser top loading
## End Fitting and Pipe Service Totals

<table>
<thead>
<tr>
<th>Installation Year</th>
<th>Number of Lines</th>
<th>Total Length Installed (km)</th>
<th>Assumed Service Time (years)</th>
<th>Number of End Fittings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>90</td>
<td>165</td>
<td>0.5</td>
<td>180</td>
</tr>
<tr>
<td>1997</td>
<td>59</td>
<td>102</td>
<td>1.5</td>
<td>118</td>
</tr>
<tr>
<td>1996</td>
<td>66</td>
<td>47</td>
<td>2.5</td>
<td>132</td>
</tr>
<tr>
<td>1995</td>
<td>36</td>
<td>20</td>
<td>3.5</td>
<td>72</td>
</tr>
<tr>
<td>1994</td>
<td>22</td>
<td>41</td>
<td>4.5</td>
<td>44</td>
</tr>
<tr>
<td>1993</td>
<td>73</td>
<td>65</td>
<td>5.5</td>
<td>146</td>
</tr>
<tr>
<td>1992</td>
<td>51</td>
<td>29</td>
<td>6.5</td>
<td>102</td>
</tr>
<tr>
<td>1991</td>
<td>28</td>
<td>27</td>
<td>7.5</td>
<td>56</td>
</tr>
<tr>
<td>1990</td>
<td>5</td>
<td>7</td>
<td>8.5</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>430</strong></td>
<td><strong>503</strong></td>
<td><strong>40.5</strong></td>
<td><strong>860</strong></td>
</tr>
</tbody>
</table>
On-land Applications of Flexible Pipe

▲ Arctic operating environments.
▲ Mining
▲ Water injection service in hostile environments (i.e., dessert areas)
▲ Gas transmission lines
▲ Rehabilitation of existing sewer, water and transmission lines.
# Material and Full Scale Qualification Testing for Arctic Applications

<table>
<thead>
<tr>
<th>Activity</th>
<th>Scope</th>
<th>Results</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Qualification</td>
<td>● Tg for HDPE and Nylon 11</td>
<td>HDPE -127°C</td>
<td>HDPE material is acceptable for arctic applications.</td>
</tr>
<tr>
<td></td>
<td>● Brittleness Temperature Testing</td>
<td>Nylon 11 -13.3°C</td>
<td>Nylon 11 subsequently determined to be suitable.</td>
</tr>
<tr>
<td></td>
<td>● Tensile Testing</td>
<td>No failures to -90°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Low temperature tensile testing on metallic layers</td>
<td>7.6% Yeild elongation at -50°C</td>
<td></td>
</tr>
<tr>
<td>Full Scale Qualification</td>
<td>● Freeze Thaw Test</td>
<td>-40°C, No damage.</td>
<td>Installation bend test confirmed ability to install at low temperatures. Bending stiffness is within acceptable levels.</td>
</tr>
<tr>
<td></td>
<td>● Installation Bend Test</td>
<td>-40°C, No Damage.</td>
<td>Structural integrity at low temperatures confirmed.</td>
</tr>
<tr>
<td></td>
<td>● Impact Test</td>
<td>-40°C. 3.18cm impact rod. No damage.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Cold Hydrostatic Pressure Test</td>
<td></td>
<td>Successfully passed hydrotest.</td>
</tr>
</tbody>
</table>


## Arctic Supply Experience

<table>
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<tr>
<th>Activity</th>
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<th>Results</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype Supply</td>
<td>• Eighteen (18) 4-inch ID jumpers supplied in 1996.</td>
<td>Successful operation for 3 years.</td>
<td>Fixed flange hampered installation process. Stiffness, weight and handling difficult due to complex design beyond functional requirements.</td>
</tr>
<tr>
<td></td>
<td>• Incorporated a stainless steel carcass, heat trace, excessive insulation and external impact proectedion.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Diagram of Arctic Supply Experience](#)
Optimization of Pipe Structure for Arctic Applications

▲ Reduce excessive conservatism in pipe design from subsea applications.
▲ Customize end fitting design and materials to optimize costs.
▲ Develop cost effective shipping methods.
▲ Limit capital equipment costs.
▲ Maintain basic pipe design, properties and capabilities.
Low Cost Product Development

Product L (Onshore)

▲ Advantages
   ▲ Collapse dependent on Hoop Pressure Armor
   ▲ Removes cost associated with stainless steel carcass
   ▲ Improved flow characteristics

Product K (Offshore)

▲ Advantages
   ▲ Low cost product
   ▲ Utilizes steel tape in lieu of hoop pressure armor
   ▲ Round armor wire
   ▲ Low cost end fitting components
Pete’s Wicked Development Plans

▲ 4.52 miles of 6-inch flexible pipe running from wellhead to existing infrastructure.

▲ Smooth bore structure with reduced insulation. No heat trace or external carcass.

▲ Installed from lowboys in winter on ice road. Laid directly on tundra with wood or plastic timbers in some locations for fowl migration and VSM between two lakes for Caribou movements.

▲ Reels shipped to Corpus Christi to be combined with module shipment to the slope.
Reinforced Thermoplastic Pipe (RTP)

- Thermoplastic external shield
- Carbon steel wrap to give on bottom stability (specific gravity > 1.2)
- Thermoplastic composite reinforcement to resist internal pressure
- Thermoplastic liner

▲ Low material/installation cost
▲ Light Weight
▲ No sour service corrosion issues
▲ Improved flow efficiency

▲ Diameter range: 4” to 12”
▲ Pressure range: 20 bar to 200 bar
▲ Liner / shield materials: HDPE, PA11 or PVDF
▲ Reinforcement materials: E-Glass or Aramid fibre