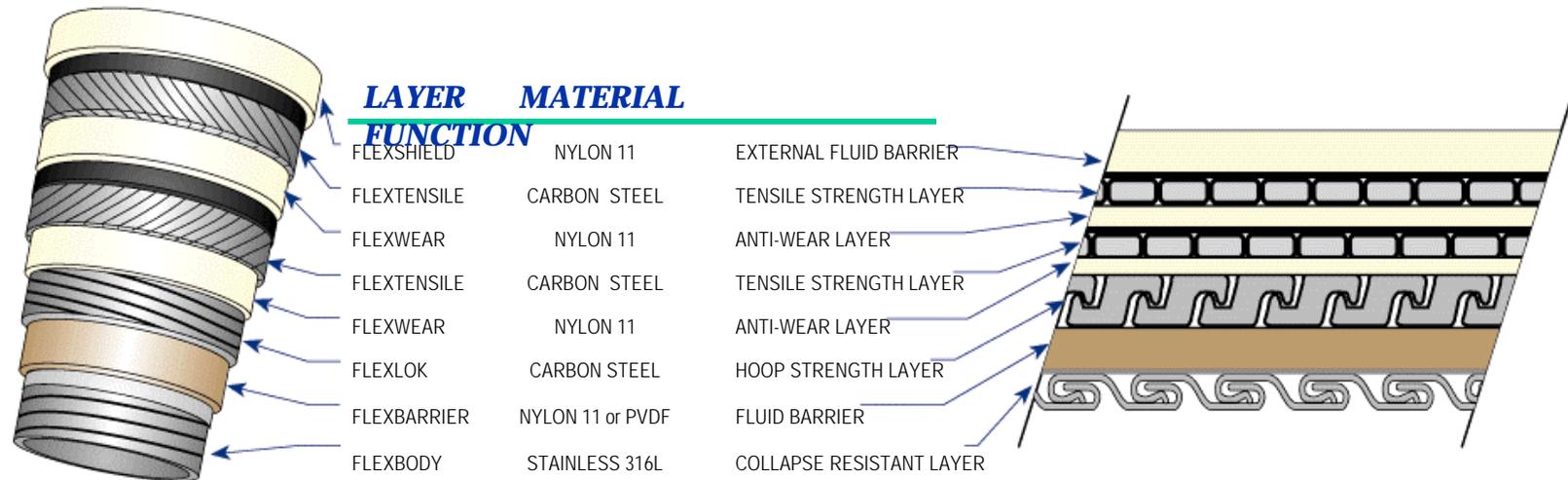


Unbonded Flexible Pipe Construction,  
Offshore and Onshore Arctic Applications  
and Qualification Testing

By: Cobie Loper

## Unbonded Flexible Pipe Construction

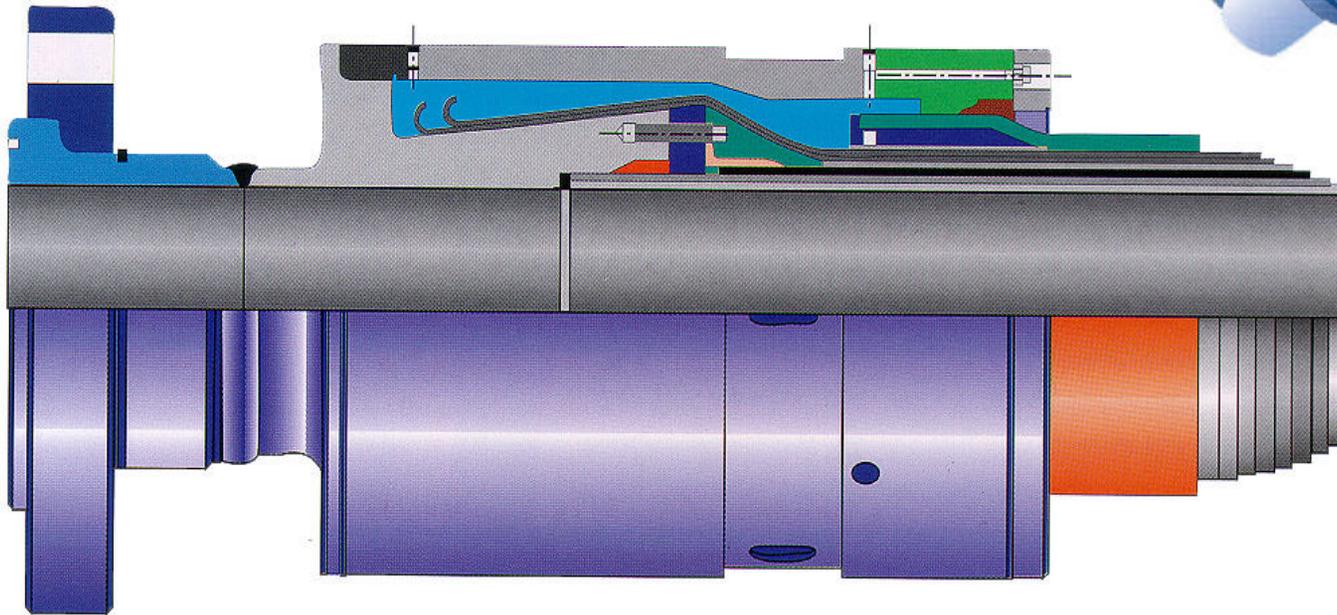
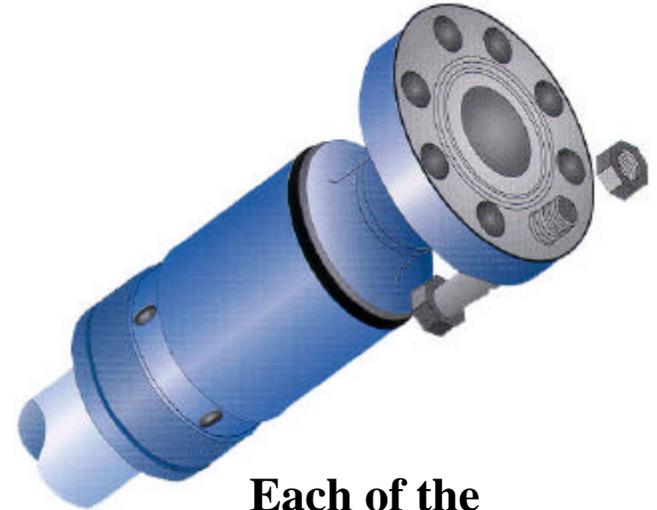


- ▲ As-installed cost
- ▲ Floating Production Units
- ▲ Corrosion resistance
- ▲ Re-usability
- ▲ Reduced abandonment costs and impact to environment
- ▲ Thermal loss resistance
- ▲ Flexibility to align with subsea structures

- ▲ 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.

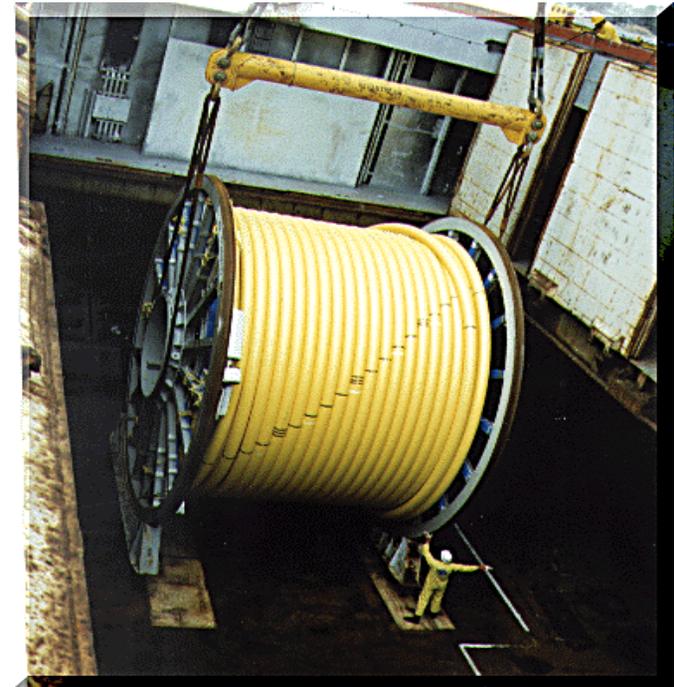
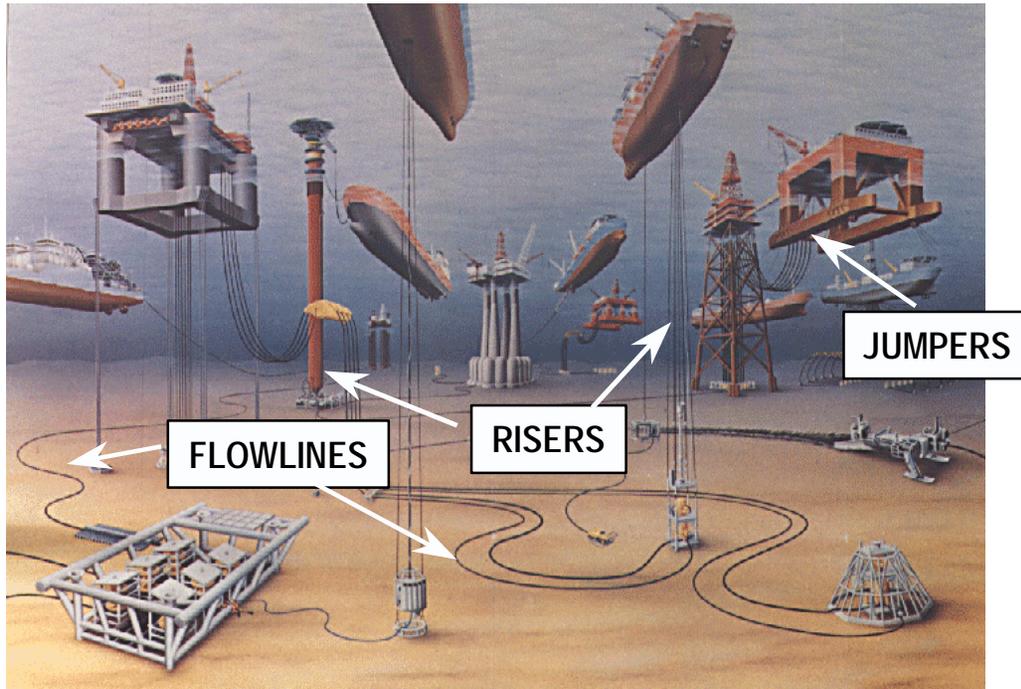
## Wellstream End Fittings

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

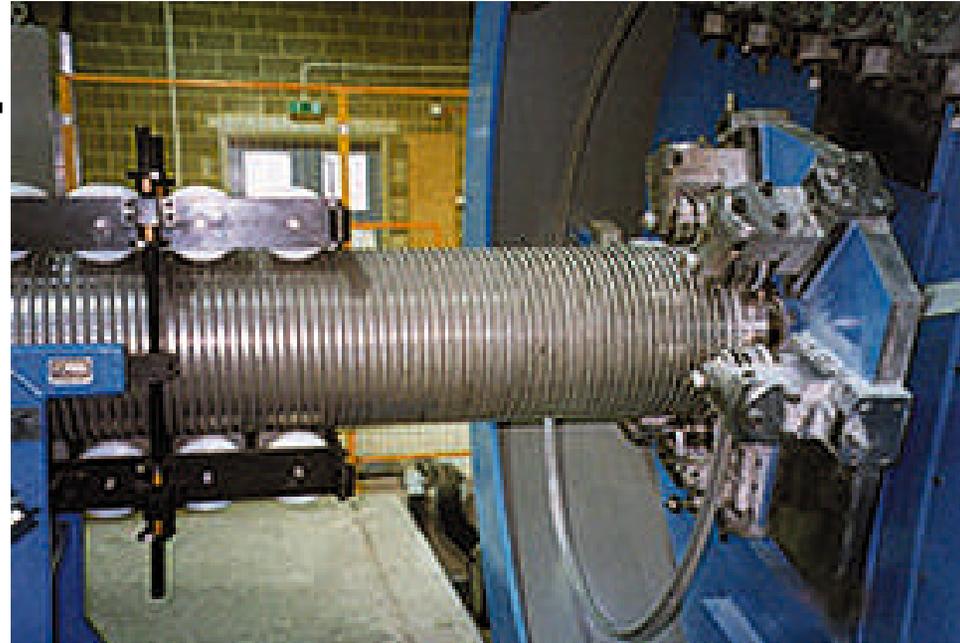
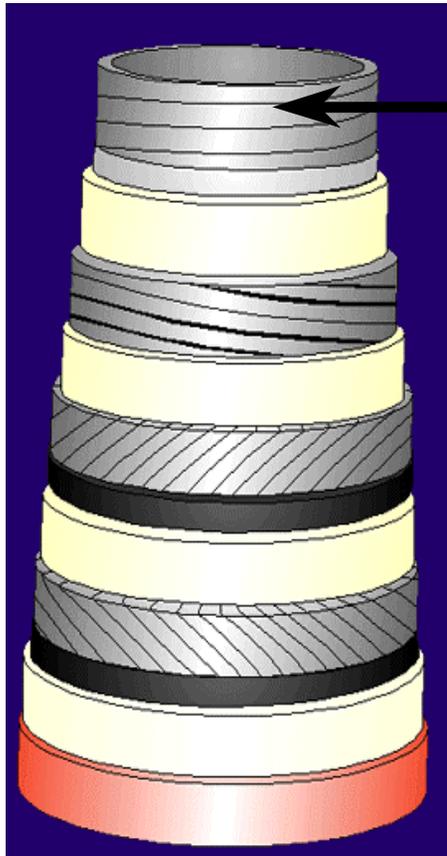
## Offshore Applications of Flexible Pipe



- ▲ **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**

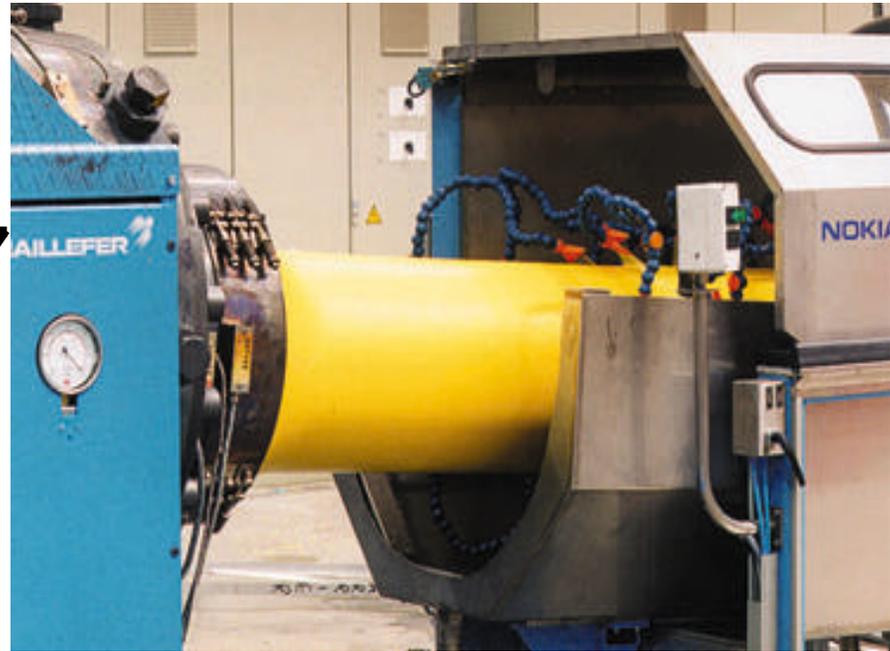
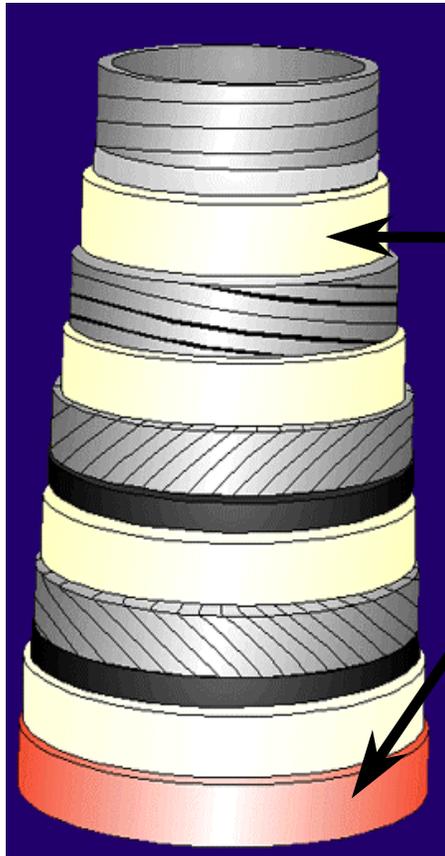


## The Flexbody layer



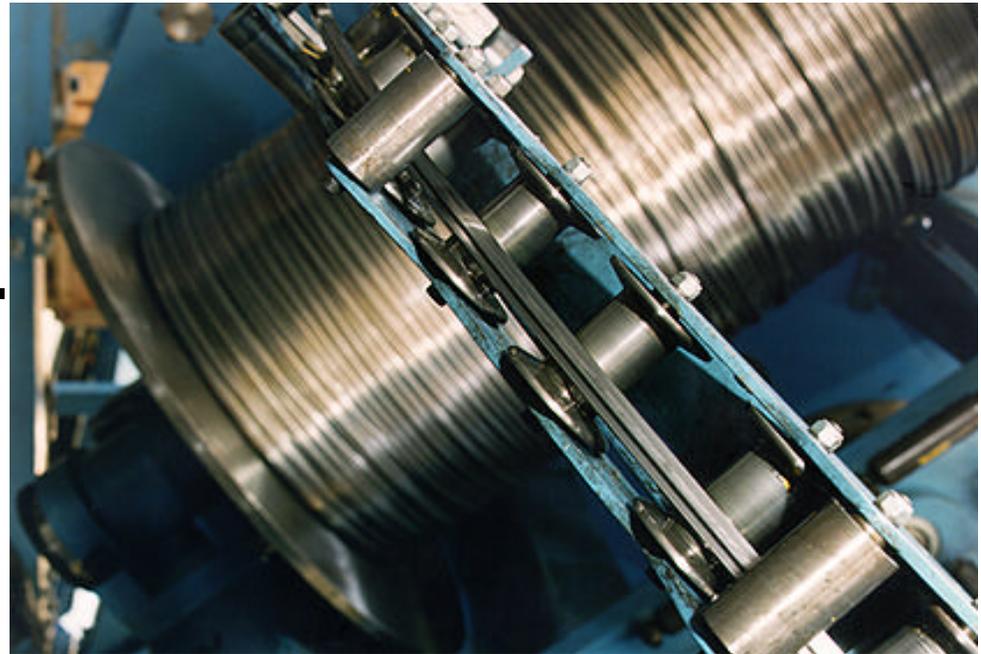
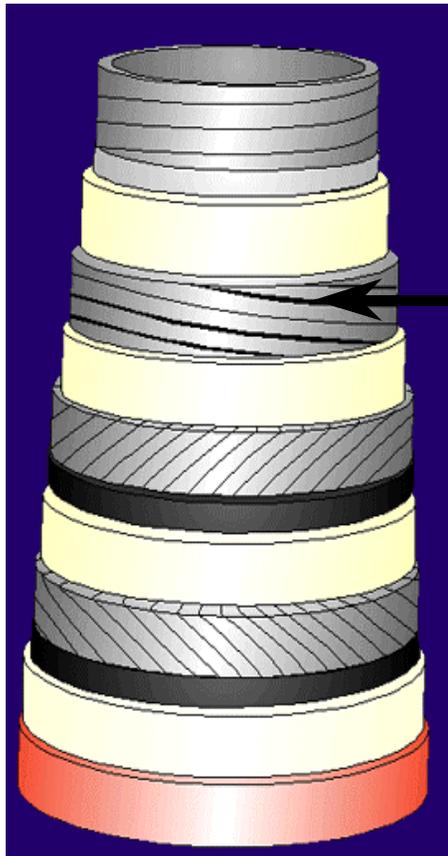
**Flexbody: corrugated metallic tube with specific internal diameter. A metallic strip is formed into an interlocking helical tube which allows flexibility.**

## The Barrier and Flexshield layers



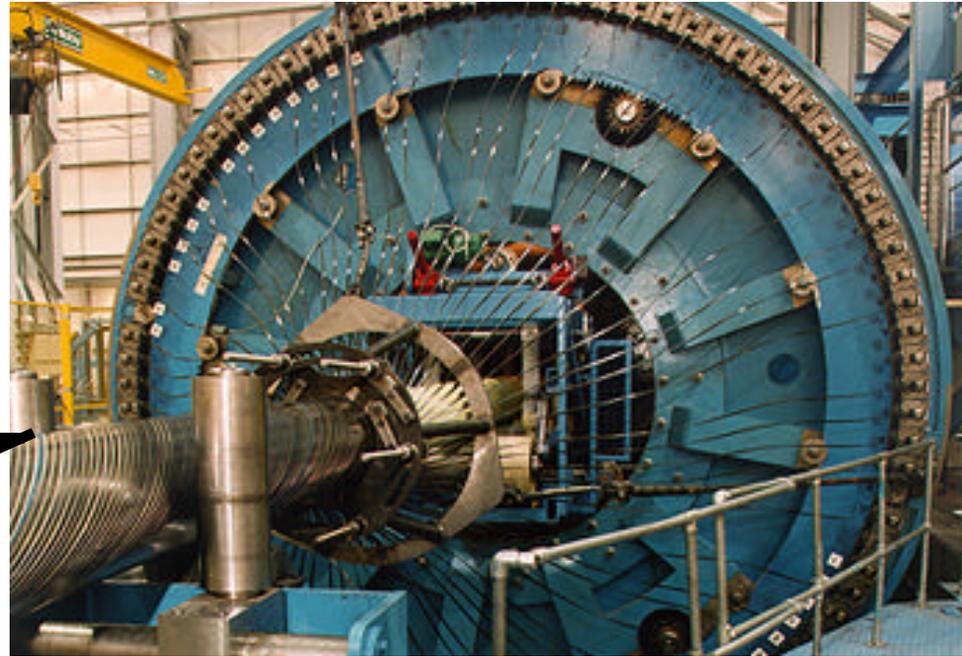
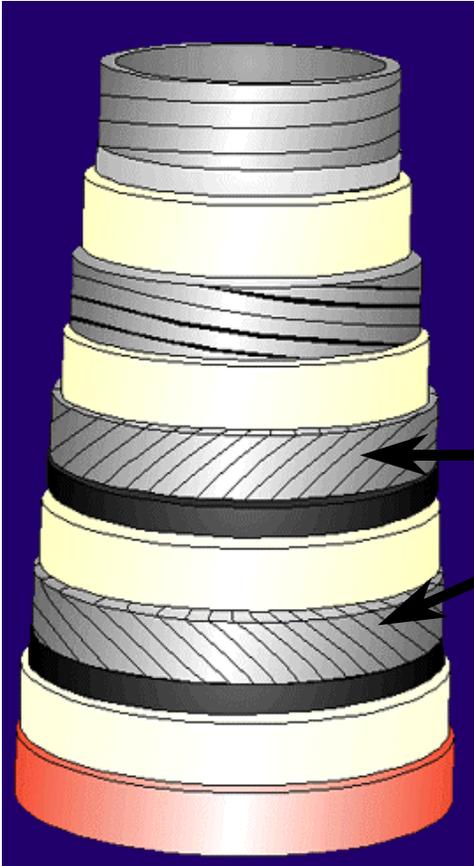
**Flexbarrier/shield:** are applied by the extrusion process and are polymer layers extruded over either the carcass or on the exterior and form a boundary for fluid.

## The Flexlok and Flexpress layers



**Flexlok: steel, hoop strength layer consisting of circumferentially wound profiled wire. The Flexpress layer uses the same machinery but uses a rectangular wire.**

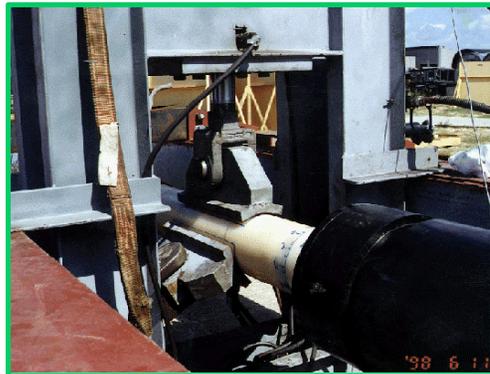
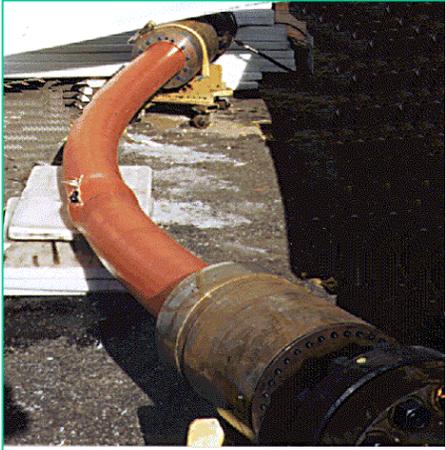
## The Flextensile layers



**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



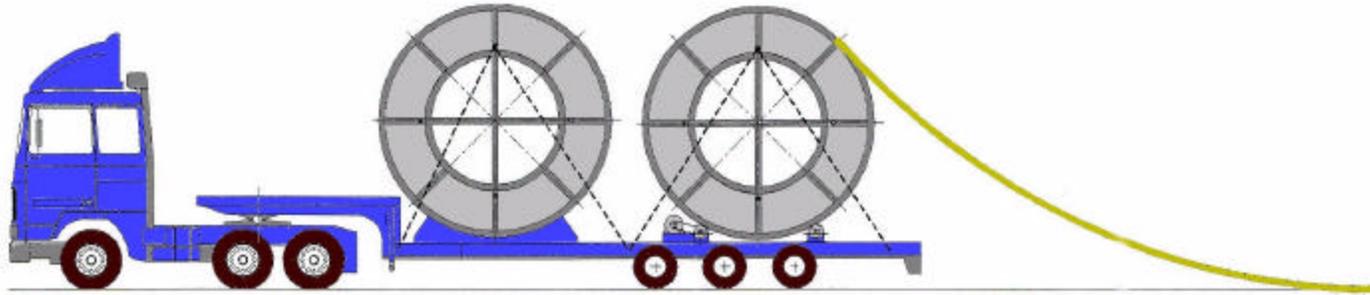
### Dynamic Test Rigs to simulate riser top loading



## End Fitting and Pipe Service Totals

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

## On-land Applications of Flexible Pipe



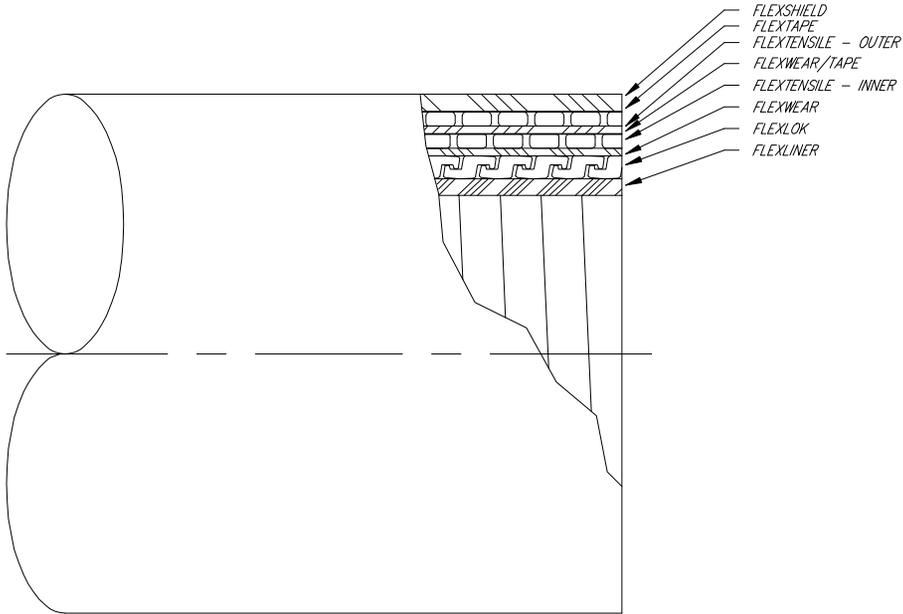
- ▲ **Arctic operating environments.**
- ▲ **Mining**
- ▲ **Water injection service in hostile environments (i.e., desert areas)**
- ▲ **Gas transmission lines**
- ▲ **Rehabilitation of existing sewer, water and transmission lines.**

## Material and Full Scale Qualification Testing for Arctic Applications

Activity	Scope	Results	Comments
Material Qualification	<ul style="list-style-type: none"> <li>• Tg for HDPE and Nylon 11</li>   <li>• Brittleness Temperature Testing</li>   <li>• Tensile Testing</li>   <li>• Low temperature tensile testing on metallic layers</li> </ul>	<p>HDPE -127°C Nylon 11 -13.3°C</p> <p>No failures to -90°C</p> <p>7.6% Yield elongation at -50°C</p>	<p>HDPE material is acceptable for arctic applications.</p> <p>Nylon 11 subsequently determined to be suitable.</p>
Full Scale Qualification	<ul style="list-style-type: none"> <li>• Freeze Thaw Test</li>   <li>• Installation Bend Test</li>   <li>• Impact Test</li>   <li>• Cold Hydrostatic Pressure Test</li> </ul>	<p>-40°C, No damage.</p> <p>-40°C, No Damage.</p> <p>-40°C, 3.18cm impact rod. No damage.</p> <p>  Successfully passed hydrotest.</p>	<p>Installation bend test confirmed ability to install at low temperatures. Bending stiffness is within acceptable levels.</p> <p>Structural integrity at low temperatures confirmed.</p>

## Arctic Supply Experience

Activity	Scope	Results	Comments
<b>Prototype Supply</b>	<ul style="list-style-type: none"> <li>• <b>Eighteen (18) 4-inch ID jumpers supplied in 1996.</b></li> <li>• <b>Incorporated a stainless steel carcass, heat trace, excessive insulation and external impact protection.</b></li> </ul>	<b>Successful operation for 3 years.</b>	<b>Fixed flange hampered installation process.</b>  <b>Stiffness, weight and handling difficult due to complex design beyond functional requirements.</b>



## **Optimization of Pipe Structure for Arctic Applications**

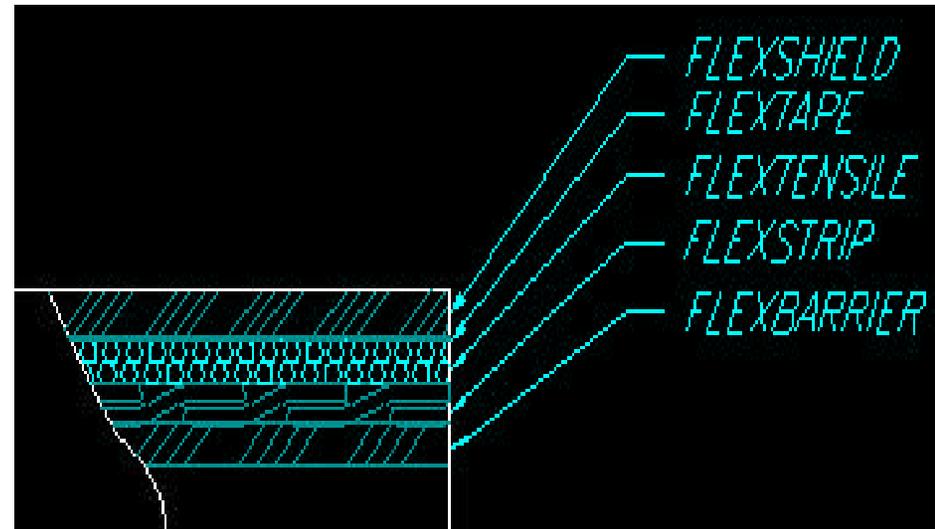
- ▲ Reduce excessive conservatism in pipe design from subsea applications.**
- ▲ Customize end fitting design and materials to optimize costs.**
- ▲ Develop cost effective shipping methods.**
- ▲ Limit capital equipment costs.**
- ▲ Maintain basic pipe design, properties and capabilities.**

## Low Cost Product Development

### Product L (Onshore)

#### ▲ Advantages

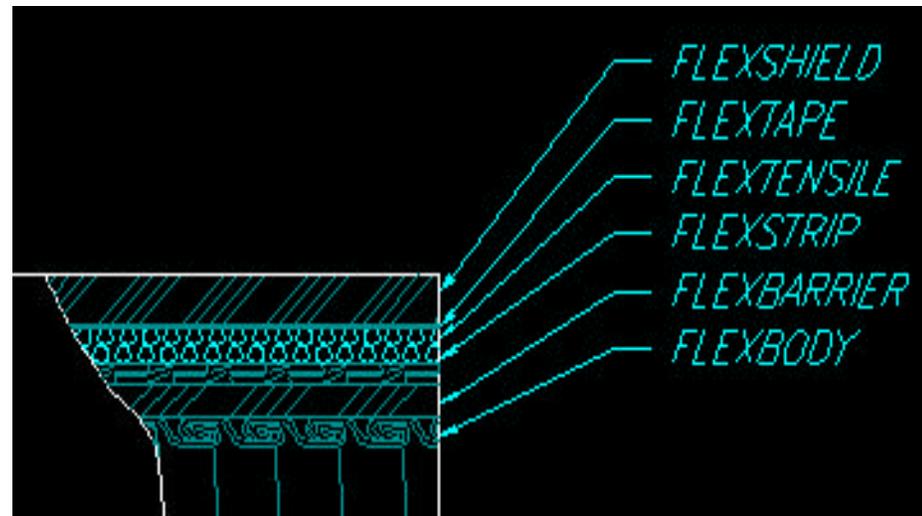
- ▲ Collapse dependent on Hoop Pressure Armor
- ▲ Removes cost associated with stainless steel carcass
- ▲ Improved flow characteristics



### Product K (Offshore)

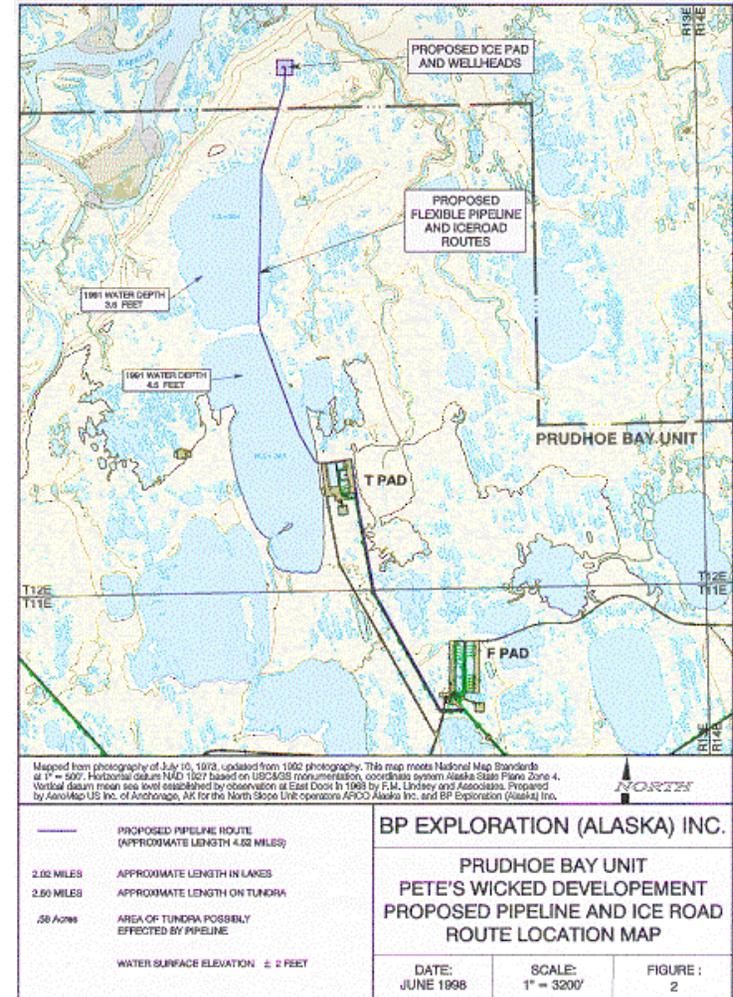
#### ▲ Advantages

- ▲ Low cost product
- ▲ Utilizes steel tape in lieu of hoop pressure armor
- ▲ Round armor wire
- ▲ Low cost end fitting components

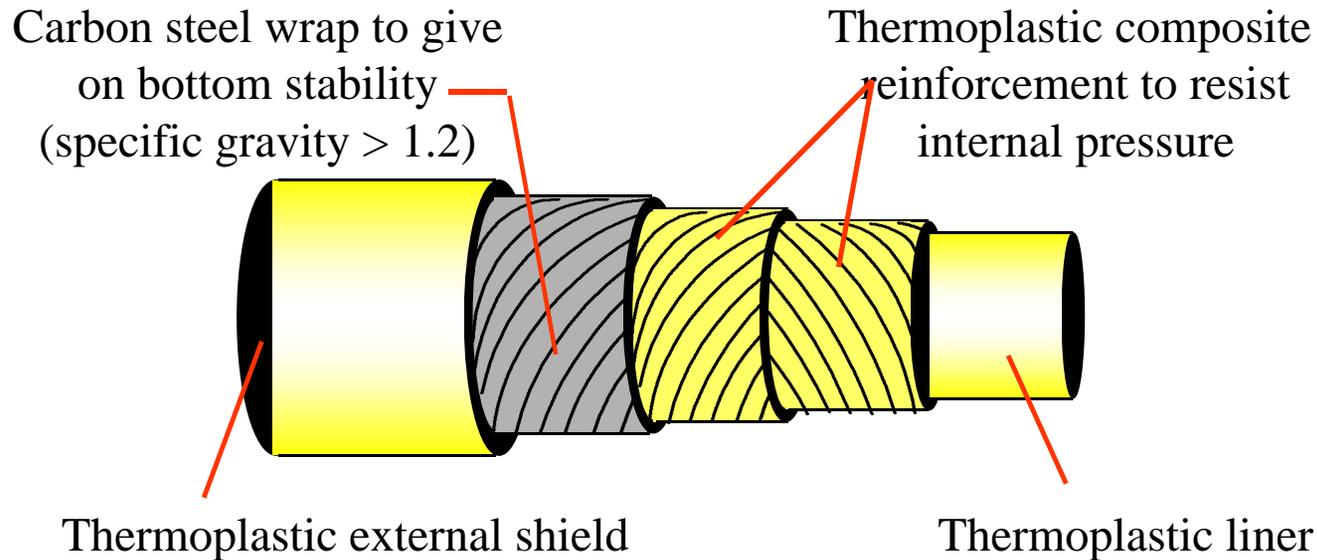


## Pete's Wicked Development Plans

- ▲ **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)



- ▲ 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