3M™ Glass Bubbles
For Syntactic Foam Wet Pipe Insulation

Go Deep.

Proven, cost-effective technology for insulating deepwater flowlines.
Today’s more challenging conditions call for higher-performance materials

Kilometers of Global Offshore Pipelines

Source: Infield Systems Ltd.
It’s all about “U”

**U-Value**: measures the ability to conduct heat

- Expressed as Watts/meter$^2$ K
- Lower U-values are better insulators
- For U-values between 2 and 10 W/m$^2$ K, wet pipe insulation can be a cost-effective solution
Flow assurance options

**Passive (Insulative) Systems**
- Glass Syntactic Foams
- Pipe in Pipe (PiP)
- Solid Polymer
- Foamed Polymer
- Buried Pipe

**Active Systems**
- Heated Pipe
- Chemical Treatment
- Pigging
- Combinations
## Comparison of pipeline insulation technologies

<table>
<thead>
<tr>
<th>System</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe in Pipe</td>
<td>Oldest technology, lowest U Value</td>
<td>Higher installed cost</td>
</tr>
<tr>
<td>Glass Syntactic Polypropylene</td>
<td>Existing technology, depth capability</td>
<td>Thermal conductivity constrained by pipe coating process and depth requirements</td>
</tr>
<tr>
<td>Glass Syntactic Epoxy</td>
<td>Existing technology, ultra deepwater capability</td>
<td>Pipe lay inflexibility</td>
</tr>
<tr>
<td>Glass Syntactic Epoxy + Macrospheres</td>
<td>Existing technology, depth capability</td>
<td>Pipe lay inflexibility</td>
</tr>
<tr>
<td>Glass Syntactic Polyurethane</td>
<td>Existing Technology, thermal conductivity less constrained by coating process, depth capability</td>
<td>Maximum operating temperatures $&lt; 115^\circ C$</td>
</tr>
<tr>
<td>Solid PP</td>
<td>Existing technology, no depth limit</td>
<td>Limited U value</td>
</tr>
<tr>
<td>Glass Syntactic Phenolic</td>
<td>High temperature</td>
<td>Emerging technology, pipe lay flexibility</td>
</tr>
<tr>
<td>Glass Syntactic Silicone</td>
<td>High temperature, flexibility</td>
<td>Higher cost binder system</td>
</tr>
</tbody>
</table>
Out of their depth:

The limitations of pipe-in-pipe

- Heavy and bulky
- Difficult and costly to reel and lay
- Impractical in deep/ultra-deep waters due to current weight limitations
- Certain pipe-in-pipe situations exceed the capabilities of most pipe-lay ships
Growing need for alternatives to pipe-in-pipe

Tie-Back Distance for a 10" Pipe
Syntactic foams made with 3M™ Glass Bubbles

A practical alternative to pipe-in-pipe for deepwater applications

- Wet insulated pipe about 1/2 the weight of PIP
- Smaller diameter, more pipe per spool
- 20 - 40% reduction in installed cost over PIP
- Faster installation

Deep Blue on the Dalia project, Offshore Angola
Photo Courtesy of Technip.
3M Oil and Gas

Proven syntactic foams made with 3M™ Glass Bubbles

- Glass Syntactic Epoxy
- GSPU - Glass Syntactic Polyurethane
- GSPP - Glass Syntactic Polypropylene
  - Layered, Tape, Profile Extrusion
- Glass Syntactic Silicone
- Glass Syntactic Phenolic
## The science behind 3M™ Glass Bubbles

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shape</strong></td>
<td>Hollow, thin walled, unicellular spheres</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>Soda-lime borosilicate glass</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>White</td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>0.12 - 0.60 g/cc</td>
</tr>
<tr>
<td><strong>Crush Strength</strong></td>
<td>250 – 28,000 psi</td>
</tr>
<tr>
<td><strong>Hardness</strong></td>
<td>Mohs scale 5</td>
</tr>
<tr>
<td><strong>Softening Temp</strong></td>
<td>600°C</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>15 - 135 microns</td>
</tr>
</tbody>
</table>

- Avg: 40 µm
- ~ 1 - 2 µm
3M™ Glass Bubbles for thermal insulation

- Low thermal conductivity
- Compatible with foam resins
- Insoluble in water
- Can be surface-treated
- Better heat, pressure and chemical resistance than solid glass beads
- High resin loading

This chart represents a sampling of the 3M glass bubbles portfolio of products.

Typical K value of base resin is approx. 0.22 (W/m K)
A long history in the oil and gas industry
The continuing evolution of 3M Glass Bubble technology

3M™ Glass Bubble Product Portfolio (by relative strengths and densities)
Typical syntactic foam insulation applications
3M Oil and Gas

Precision-engineered products with global capabilities

- Broad portfolio of products
- Continual investment in new product offerings
- High-capacity manufacturing
- Global manufacturing & availability
- Reputable product consistency & quality
Recent sampling of wet insulation projects incorporating 3M™ Glass Bubble-filled syntactic foams

Stars indicate recent wet insulation projects that incorporate 3M glass bubbles.
Design considerations
Thermal conductivity of 3M™ Glass Bubbles

Select from 3M’s product portfolio to obtain desired U Value.
Performance characteristics used in selecting insulation

- Exceed WAT at platform
- Longer cool-down period
- Survive ocean depth
- 20-year life
- Reliability
- Meet installation schedule
- Low fully-installed cost
Where do 3M™ Glass Bubbles play?

Glass Syntactic Wet Insulated Flowlines are:
- operating today between 1 and 35 km.
- At depths between 500 to 2800 m
- Capable of U-values < 2 w/m²K

There is growing confidence and acceptance with more systems in place.
Additional values of 3M™ Glass Bubble-filled insulation

- Thinner pipe insulation coatings at constant U value:
  - More pipe on a reel
  - Fewer days of barge time (~ $500K/day)
- Lower U value for same thickness
- Enables longer tieback distances
- Given U value at a deeper depth
- Lower U value at a given depth
- Faster/ Lower Cost Field Joint Application
- Narrower particle size distribution
The latest advancements in glass bubble technology

Higher Strength-to-Density Glass Bubbles for Lower Thermal Conductivity

- S42XHS
- XLD series

Better bonding

Surface treated glass bubbles

<Rob Hunter – help>

Floated series
Voyage to the bottom of the sea

Wet Pipe Insulation Performance – Ocean Depth

- Syntactic Foam with first generation glass microspheres
- Syntactic Foam with second generation glass microspheres
- Syntactic Foam with third generation glass microspheres
- Syntactic Foam with latest generation glass microspheres
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For Wet Pipe Syntactic Foam Insulation

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