

New Options, Improved Economics from Aerogel Insulation

The challenges facing oil and gas operators seeking to develop new fields in hostile environments such as deep and ultradeep water are well documented and continue to increase. One important requirement for operators developing subsea fields is the ability to transport unprocessed hydrocarbons, which are frequently at high pressure and high temperature, over longer distances along the ocean floor. Without sufficient insulation, the hydrocarbons will cool and create hydrates/wax buildup that can eventually clog flowlines at significant cost to operators. Cabot Corp. has developed Nanogel aerogel, a nanoporous insulation product, to address associated economic and efficiency issues.

Sometimes called "frozen smoke," aerogels are light insulating solids. Nanogel is a hydrophobic aerogel produced as particles, each of which consists largely of air ($\approx 95\%$) trapped in nanosized pores that severely inhibit heat transfer through the material.

A proprietary manufacturing method imparts mechanical benefits (NanoSprings) to the aerogel particles in addition to characteristics that make them useful for thermal insulation. The aerogel performs across a range of temperatures (from -200 to $+250^\circ\text{C}$) making it applicable in systems ranging from liquefied natural gas (LNG) to high-pressure/high-temperature settings.

Four products have been developed for the oil and gas market—the Expansion Pack, Compression Pack, Particle Pack, and Thermal Wrap systems. The first two are pipe-in-pipe products and use half-shells made with Nanogel aerogel particles compressed and packed under vacuum. In field application, a series of half-shells is positioned in a pipe-in-pipe or other assembly and activated (vacuum is breached), resulting in form fitting of compressed particles into a desired shape, either filling the entire annular space (Expansion Pack) or, under higher compression, filling a predetermined portion of the annular space (Compression Pack).

Operating Economics

There are two ways in which improved economic impact is created during development of subsea fields—by allowing the use of smaller jacket pipes and by enabling the construction of longer tieback lines.

In the case of smaller jacket pipes, substituting Nanogel for other insulation forms (such as polyurethane [PU] foam/rock wool) allows operators to reduce the size of outer pipes without compromising system performance (U -value), resulting in:

- Material savings on pipe steel.
- The ability to fit more pipe sections on a barge or reel, thereby reducing the number of barge trips.
- The ability to use smaller lay barges that have lower day rates.

For example, to achieve a target U -value of $0.7 \text{ W/m}^2\text{-K}$ with an 8-in. flowline, an outer pipe of approximately 14 in. would be required if the insulation were PU foam. With the Expansion Pack system, the size of the outer pipe could be reduced to approximately 11 in. (Table 1).

In the case of longer tiebacks, aerogel performance enables operators to reduce the number of needed production platforms or to develop marginal fields. In an 8×12-in. pipeline, where the longest

TABLE 1—SAMPLE U -VALUES ATTAINABLE FOR TYPICAL PIPE-IN-PIPE CONFIGURATIONS* WITH NANOGEL

U -value ($\text{W/m}^2\text{-K}$)	Pipe Configuration		
	6×10 in./ 8×12 in.	8×14 in.	24×32 in.
Oil ($\approx 70^\circ\text{C}$)	0.65–0.80	0.50–0.55	
Hot Oil ($\approx 175^\circ\text{C}$)	0.75–0.85	0.55–0.60	
LNG ($\approx -165^\circ\text{C}$)			0.12–0.14

*Assumes nylon centralizers every 2–6 m.

possible run with PU foam is ≈ 25 km, the Expansion Pack system can increase maximum distance by approximately 70% to ≈ 40 km.

In addition, the growth of LNG has resulted in significant interest in developing new designs for LNG pipelines, tankers, and storage vessels. The use of aerogel in these systems offers numerous financial benefits, including

- Reduced costs associated with pipeline trestles/expansion loops.
- Increased flexibility with regard to materials of construction for subsea LNG pipelines.
- Increased capacity, efficiency for LNG tankers-storage vessels.

Combining Mechanical and Thermal Benefits

The Expansion Pack system expands after insertion to fill the annular space; a mechanical bond is created that transfers both axial and radial load between inner and outer pipes during laying and operation. Mechanical benefits aid in installation and allows for the reduction and potential elimination of heat-bridging centralizers. This combination gives engineers new options for improving pipeline design, particularly for systems with large temperature differences between inner and outer pipes.

Compression Pack system users can "dial in" required U -values by varying the thickness of the aerogel half-shells. The result is a system with constrained half-shells and a residual air gap between the insulation layer and the outer pipe. Installation of the Compression Pack system is similar to that of the Expansion Pack, except that the insulation material is constrained by a metal sheath. With the sheath in place, the half-shells are activated (vacuum is breached), allowing particles to fill any spaces between half-shell packs without allowing radial expansion. Once the operation is performed, the entire assembly is inserted into the outer pipe and secured. The final system consists of a layer of highly compressed aerogel and a residual air gap that acts as a secondary insulation zone.

While the Compression Pack system affords more flexibility in some dimensions, it does not deliver the same level of mechanical support as the Expansion Pack system, particularly in axial-load transfer.

K -values for both systems range from 14 to 17 mW/m-K (0.008 to $0.010 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$) at ambient conditions, and are $\approx 9 \text{ mW/m-K}$ ($0.005 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$) at cryogenic conditions.

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