Brian Cahill, Aspen Aerogels, USA, considers five performance areas critical to FLNG operations.

High five

The idea of putting a gas liquefaction plant on a boat – floating LNG (FLNG) – has opened up a whole new range of possibilities for fuelling the future. But actually fitting these plants on the boat is another thing entirely.

A number of mechanical clashes arise when attempting to shrink a major industrial facility down to one-quarter of its land-based footprint. As the thinnest cryogenic insulation material on Earth, Cryogel® Z is helping to resolve these issues, while also providing protections vital to the safe and efficient operation of an FLNG process.

Over the past decade, Cryogel® Z has been successfully installed across a range of demanding LNG applications, on and offshore, providing cold conservation, acoustic insulation,

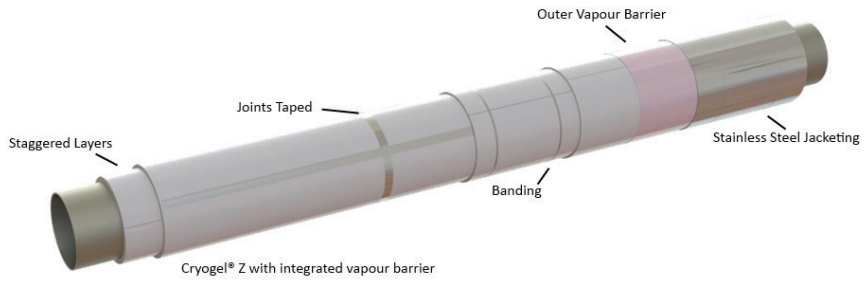

Figure 1. Cryogel® Z installation detail.

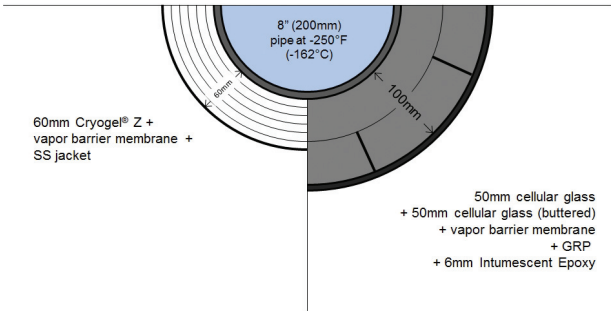

Figure 2. Cryogel® Z for cold conservation and passive fire protection.

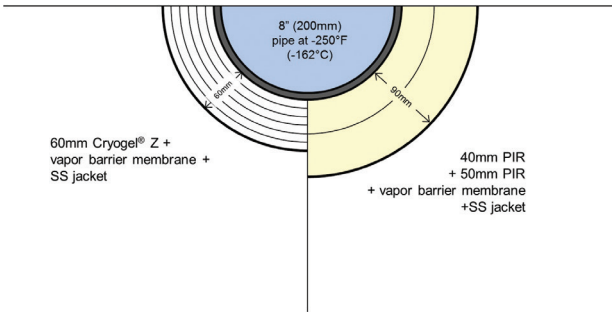

Figure 3. Cryogel® Z for cold conservation.

Table 1. Thickness of Cryogel®Z required for pool and jet fire protection (mm)

Duration (minutes)	Pool fire[1]	Jet fire[2]
15	20	60
30	20	60
45	30	60
60	30	60
75	40	60
90	50	100
120	60	100
150	70	n/a

Note: [1] Tested in accordance with the UL 1709 standard with a 1000°F (540°C) failure criteria.

[2] Tested in accordance with the OTI 95-634 standard with a 750°F (400°C) failure criteria.

and protection against pool fires, jet fires and cold-splash – five critical performance areas, traditionally requiring a range of insulations but now possible with only one.

Installation method

Cryogel® Z's 'cigarette' wrap installation ensures that each 5 mm or 10 mm layer has its own vapour protection. The insulation does not require costly or complicated contraction joints. Instead, alternate layers are simply staggered and can be supplemented with an acoustic barrier if required. The system is finished with commonly available GRP and stainless steel jacketing systems. This simplified installation technique translates into up to 75% quicker installation times than conventional insulations. A typical installation method is shown in Figure 1.

Case study 1: insulation comparison

Consider the task of insulating an 8 in. (200 mm) FLNG pipe[1] operating at -162°C (-260°F). The project specifier looks for significant space and economic advantages in the five critical areas of passive pool and jet fire protection, cold conservation, acoustic attenuation and cold splash protection.

Passive pool and jet fire protection

As safety is the primary consideration in the operation of any hydrocarbon process, it is critical that the selection of an insulation solution meets the most stringent criteria. Just 60 mm of Cryogel® Z provides 75 minute protection against jet fire impingement, while the same thickness provides up to 2 hours of pool fire protection. Table 1 details typical pool and jet fire protection requirements.

Figure 2 illustrates the thickness and complexity differences between a conventional insulation and a Cryogel® Z based solution for cold conservation and passive fire protection. The key benefits of the solution include the following:

- 43% thinner.
- 28% less weight.
- 19% less vapour barrier materials.
- 25% lower heat gain.
- 68% less labour.

Cold conservation

As an FLNG vessel can occupy as little as 25% of the footprint of its land-based equivalent, space will always be at a premium. Cryogel® Z has the lowest thermal conductivity ('k' value) of any conventional cryogenic insulation material, which corresponds to substantially reduced insulation thicknesses. As such, it can help free up real estate around flanges and valves. It can also improve pipe rack densities by shrinking the pipe-to-pipe spacing. Returning to the example of the 8 in. LNG pipe, the

benefits are again significant and are illustrated in Figure 3 and outlined below:

- 33% thinner.
- 13% less heat gain and boil-off gas (BOG).
- 15% less jacketing and vapour barrier materials.
- 59% less labour.

Acoustic attenuation to ISO 15665 standard

In addition to excellent thermal and passive fire protection, effective protection for operators and the environment against process and flow noise is essential on FLNG facilities. Cryogel® Z meets the requirements of ISO 15665 classes A, B and C, as well as Shell Class D. Other advantages include the following:

- 66% thinner.
- 23% less weight.
- 69% less jacketing.
- 66% less vapour barrier materials.
- 60% less labour.

Both of the systems illustrated in Figure 4 meet the stringent 'Shell D' insertion loss requirements, however Cryogel® Z does so with 130 mm (5 in.) less thickness requirement, which is highly advantageous in space-constrained FLNG processes.

Cold splash protection

The unique thermo-mechanical properties of Cryogel® Z means that it remains flexible at temperatures as low as -200°C while maintaining its thermal insulation properties. It does not suffer from brittle fracture, as demonstrated in Figure 5, which shows the material maintaining full flexibility post immersion in liquid nitrogen at -192°C.

This combination of thermal insulation and flexibility ensures that carbon steel piping and equipment can be easily protected from an adjacent rupture or spill of cryogenic fluids.

Case study 2: vessel-wide advantages

Another case study highlights direct and indirect benefits to the operator when Cryogel®, Cryogel® Z and Pyrogel® based solutions are added to a vessel-wide FLNG specification.[2]

Faster installations

Cryogel® Z facilitates improved labour utilisation through simplified installation methods and reduced sensitivity to workmanship. Increased space on racks and at fittings results in easier installation. Onboard, material utilisation is almost 100% on a range of complex pipe geometries, and pre-fabricated components such as pre-insulated supports, removable covers and accessories are readily available. A compact 'one size fits all' format streamlines logistics, dockside handling and slashes storage requirements, as detailed in Table 2.

An LNG gasification pipe project in Canada reported an 80% faster installation time using 20 mm of Cryogel® Z as the external protection in a composite assembly.

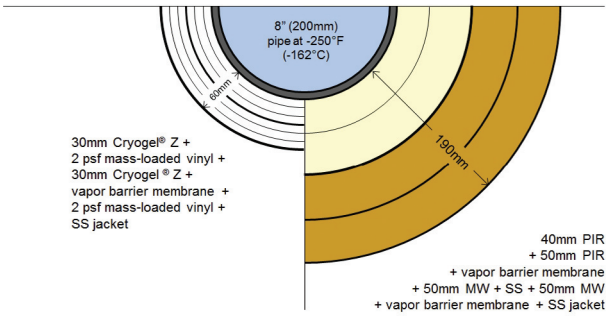

Figure 4. Cryogel® Z for cold conservation and acoustic attenuation.

Table 2. Logistics comparison

Properties	Cryogel® Z vs. traditional design
Insulation part numbers	99% fewer
40 ft. high-cube ISO containers	87% fewer
Number of dock-to-ship crane lifts	80% fewer
40 yd^3 waste containers	87% fewer

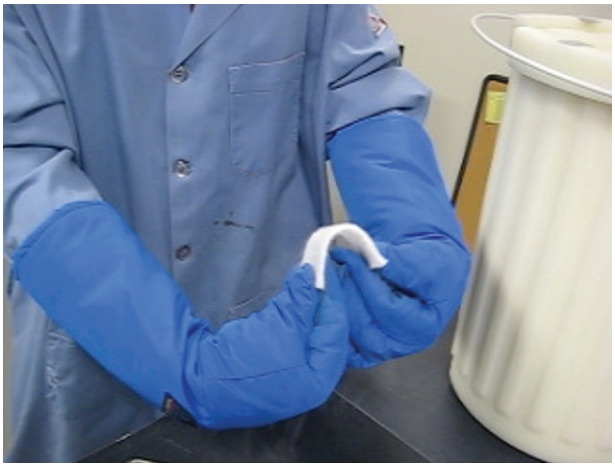

Figure 5. Cryogel retains full flexibility at -192°C (©Aspen Aerogels).

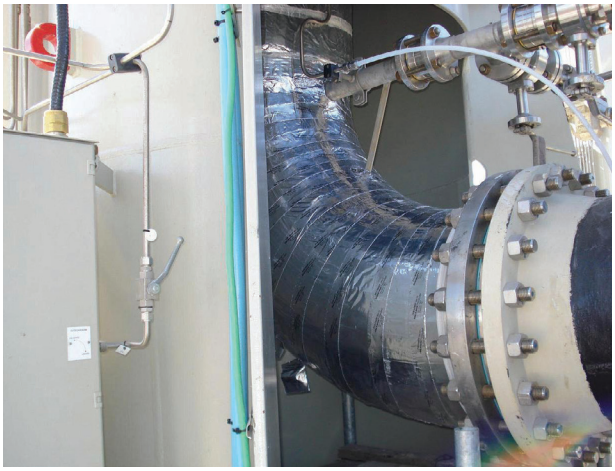

Figure 6. Loading arm elbow.

Durability

Cryogel® Z is extremely durable against mechanical damage and impervious to cryogenic cycling, making it suitable for use on risers, bellows, field joints, loading lines and arms.

At an LNG facillty in Chile, Cryogel® Z was installed at the base of a loading arm subject to cryogenic cycling. The installation, shown in Figure 6, is thin and light enough so as not to impede the swing mechanism. In a conventional installation this joint would remain uninsulated due to the severely challenging operating conditions.

Stiffer support of jacketing results in fewer dents and buckles, and helps reduce the potential for damage to the vapour control protection. This natural toughness and absence of a brittle fracture mechanism means that offsite installation for economic or geographical reasons and subsequent module transportation by road or sea is now possible without compromising the protective layer.

The bottom line

In the example referenced in the second case study, the Cryogel® Z solution represents significant savings through lower labour and accessory costs. This does not include any additional savings associated with shaving a critical path activity by more than 10 weeks, nor does it reflect the indirect contribution of proportionally fewer accidents, stoppages and work disruptions.

Conclusion

With a projected US$ 700 billion investment to 2035, the future for LNG projects is unquestionably bright.[3] This clean and economic fuel will help consumers across the globe to sustain economic growth while meeting increasingly stringent environmental challenges. FLNG has been described as a game-changing innovation in the delivery of energy to consumers. Projects of this magnitude require material suppliers to match this innovation and bring forward next generation solutions. With the development of Cryogel® Z, Aspen Aerogels has established a leading position in the delivery of mission critical cryogenic protections. **LNG**

Notes

1. Ambient temperature = 35°C, wind speed = 2 m/s, emissivity = 0.9.
2. Pyrogel® XT-E, Pyrogel® XT F, high temperature aerogel blanket insulations.
3. World Energy Investment Outlook 2014, *International Energy Agency*.