# Bridging the modular GAP

**Neal Waaks, Aspen Aerogels, USA,** looks at how pre-insulated LNG piping can bridge the gap between stick built and modular construction methods.

The adoption of modular construction methods in LNG facilities, both for liquefaction and regasification terminals, has become increasingly common. The pace of adoption has intensified during the current construction boom of liquefaction terminals, spurred on by the number of projects in areas that are challenged by both higher labour costs, and more remote, sparsely populated locations with limited industrial infrastructure. Modular construction has additionally been embraced as a means to accelerate project delivery; overcome a limited skilled labour pool; improve health and safety; improve quality and reduce local environmental impact or community disruption. An equally important force driving increased modular construction has been risk management – the need to better predict project cost and scheduling. The growing modular construction trend has been particularly evident in the current terminal construction boom in Australia, where local labour cost and availability, infrastructure and environmental concerns have placed considerable constraints on traditional 'stick built' construction methods. Similar constraints have shaped how owners and contractors have approached project design and planning for proposed Canadian terminals.

Modular construction, however, is not a binary proposition. While the degree of modularisation has dramatically increased in LNG plant construction over time, the scope of modularisation on a given project is informed by variables that can be local in nature – such as local labour cost and skills, site footprint, and environmental and regulatory climate – and more global variables, including commodity prices, rising labour costs in emerging markets and transportation costs. A hybrid construction of stick built and modular content has consequently been the norm. Pre-insulation of piping bridges the gap between these two methods, and can be seen as a further step in maximising modular construction. Pre-insulation of the piping within the modular construction stream drives the modular concept deeper to include the module components before their arrival at the fabrication yard.

## Pre-insulated piping for LNG service

Pre-insulated piping is now a common element in LNG plant design. Applications are typically limited to large-bore, straight lines, such as jetty supply and return piping. Pre-insulated piping is commonly constructed in a pipe-in-pipe form. An inner, stainless steel carrier pipe is fitted with spacers and positioned within an outer casing pipe (or jacketing), commonly composed of high density polyethylene (HDPE) or other non-metallic materials. Polyurethane foam insulation is then injected into the annular space between the carrier pipe and casing. Alternate systems have been developed with direct foaming and shaping of the polyurethane or polyisocyanurate (PIR) foam on the carrier pipe, with a jacketing subsequently applied. Pre-insulated pipes are delivered to the jobsite with an uninsulated cut-back at each end of the pipe. Once fitted into position, the pipes are welded. Insulation of the field joints is completed following hydro testing. Manpower required on site is significantly reduced, with over 80% of the insulation work moved off site, reducing injuries, weather delays and on site traffic.

**Figure 1.** Pipe pre-insulated with aerogel insulation is delivered to a module yard, ready for placement in modules.

**Figure 2.** Pipe is insulated with aerogel in the workshop.

These systems are both robust and efficiently produced in an assembly-line process, in a manner that is impossible to achieve with traditional cryogenic insulations, such as cellular glass or pre-formed PIR foam. Traditional cryogenic insulations do not lend themselves well to pre-insulation. Their rigid, pre-formed sections cannot accommodate the stresses of pipe flexure when hoisted, or the common mechanical damage incurred in shipping, handling and installation of pipes on site. Where pre-insulated piping systems have been employed – typically on jetty lines – traditional insulation materials have remained in use inside the fence-line. There is, however, an alternative cryogenic insulation that can be practically and economically employed in both traditional in situ and pre-insulated LNG piping applications throughout the plant: flexible aerogel blanket.

Flexible aerogel blanket has been installed on dozens of LNG terminals around the world, in many cases resolving issues with other, traditional insulation systems after construction has been effectively completed. Well known for its extremely low thermal conductivity – allowing significantly reduced insulation thickness – aerogel blanket features technical properties that are of particular utility in cryogenic services on LNG plants. An aerogel cryogenic insulation system can provide combined classes of protection within a single applied insulation system, joining thermal and condensation control with pool fire, jet fire, acoustic and cryogenic splash protection, often with only minor changes to the accessories package. Importantly, these technical advantages are achieved whether installed in situ, in pre-insulated piping delivered to the site, or integrated within modular construction. However, pre-insulation – whether ultimately destined for stick built construction, or for integration within a module at an off-site yard – enjoys the same advantages of modular construction in general, including lower off-site labour costs, more rigorous quality control, reduced safety incidents, and a shortened construction schedule. For stick built sites, pre-insulation of piping can provide an additional, vital benefit: it reduces project delivery risk by removing the final stage of plant construction from the critical path of the project schedule. Pre-insulation virtually eliminates dependency on weather conditions and lighting, and mitigates potential bottlenecks during construction as insulation work is no longer dependent on pipe releases. Indirect costs are reduced as scaffolding, equipment rentals, security, construction debris, temporary office space, and housing are either eliminated or reduced in scope or utilisation.

Pre-insulated piping utilising aerogel blanket insulation has been used extensively on piping and equipment in above-ambient service. Thousands of kilometers of deep sea pipe-in-pipe are in operation, insulated within the annular space with aerogel blanket. Steam assisted gravity drainage (SAGD) steam lines have been pre-insulated on an equal scale, and equipment and piping pre-insulated with aerogel blanket have been successfully installed on refineries and petrochemical plants around the world. Aerogel blanket easily and routinely accommodates the physical rigours of these applications. However, LNG piping presents particular challenges not seen in above-ambient applications; principally, the maintenance of the critical vapour seal of the cryogenic system. In recent trials, an aerogel pre-insulated pipe and support system was put through the paces in rigorous real-world conditions to test its suitability for use in LNG service.

## A trial case study

In planning for the construction of a North American LNG liquefaction facility, the engineering procurement and construction (EPC) contractor confronted several key challenges. A limited site footprint severely constrained the available lay down area for materials storage and staging during construction, while an accelerated construction schedule had also been imposed. Modular construction was not considered an option. During the Front End Engineering and Design (FEED) stage, it had been determined that in the absence of a modular option an alternative solution would be required to meet the schedule and cost constraints. Prior research had identified aerogel blanket as a possible answer. However, this solution would need to be fully validated to the actual project conditions. The contractor consequently undertook a trial of the proposed system. The trial was conducted with aerogel blanket insulation (Cryogel Z) on 6 in. and 18 in. pipes, duplicated with a control group of equal sized pipes insulated with preformed PIR insulation. The trial would mimic actual conditions for the project, with the construction of the pipe insulation systems in accordance with project specifications for materials, accessories, and thicknesses.

Test pipes in 80 ft lengths were fitted with an internal system to deliver and sustain even dispersion of cold gaseous nitrogen within the pipes, allowing the pipe interior to be maintained at a steady LNG temperature of -162°C. Thermocouples were installed on all four test pipes at multiple locations. Insulated pipe supports were installed on both groups, with vapour stops. The test pipes were mounted on raised dollies, and stationed in adjoining workspaces. All necessary materials were positioned at hand. The insulation work would be conducted in ideal shop conditions, providing productivity data for the pre-insulated production.

Installation started simultaneously on the two test groups. Installation crews were equally composed of eight installers and one foreman. For the aerogel insulation system, thicknesses of 70 mm and 90 mm of Cryogel Z were applied, respectively, on the 6 in. and 18 in. pipes. The PIR control set was insulated with 100 mm in a double-layer system on the 6 in. pipe, and 140 mm in a triple-layer system on the larger 18 in. pipe. These thicknesses were calculated to provide necessary condensation control in accordance with actual site conditions. The results were not unexpected, reflecting similar in situ productivity advantages: installation of the aerogel blanket system on the combined 6 in. and 18 in. pipes was completed 31% faster than on the similar PIR pipe control group.

The jacketing was subsequently painted matte black on both groups to enable more reliable thermal imaging. The insulated pipes were lifted from the dollies in order to assess the physical integrity of the two systems. Returned to the dollies, the pipes were then filled with nitrogen gas and monitored until a steady state had been achieved at a temperature of -162°C to emulate LNG operating

**Figure 3.** Pre-insulated piping is stacked and ready for loading onto a truck. The aerogel insulation is resistant to mechanical damage.

**Figure 4.** Cryogel blanket is installed during a cryogenic pre-insulation trial. Cryowrap insulated pipe support can be seen on the pipe with vapour stop.

conditions. Infrared thermography was conducted on all pipes to establish the base performance of the respective systems. Following this assessment, the liquid nitrogen was exhausted and the pipes were returned to ambient temperature in anticipation of the next, and most critical, trial stage.

The project site was located approximately 1000 miles from the contracted pipe fabrication facility. In order to reproduce real world conditions, the four test pipes would be transported by road for an equivalent distance. The pipes were loaded on the truck and secured for standard transport. Accelerometers were installed on the spools to monitor both the shock loading (g) and excitation frequency (Hz). The pipe sets were then transported for 1000 miles, matching the actual distance and transport conditions expected during project deliveries. Pre-insulated piping spools can be expected to see vertical shock loads as high as 7 g. While the pipe and supports can easily handle these loads, rigid insulation materials cannot sustain such dynamic loading. Oscillation of the pre-insulated pipe will lead to a 'diving board' effect, with large tensile and compressive loads concentrating where the insulation meets the supports.

**Figure 5.** During the trial, the insulated system is tested at LNG temperature, both before and after truck transport. The surface of the pipes has been painted black to ensure the most accurate thermography.

**Figure 6.** Pre-insulated piping is loaded onto a truck for its 1000 mile test journey. Pipes would be monitored with accelerometers during their journey.

Following transport by road, the pipes were removed from the trailer and again filled with nitrogen. Once stabilised at a steady-state LNG temperature, infrared thermography was conducted to assess the post handling and transport condition of both the Cryogel Z and PIR test groups. The Cryogel Z pre-insulated system showed no failures or cold spots. Thermography of the PIR test group showed the predicted effects of the stresses of handling and transport.

A destructive, post-trial inspection of the systems revealed compression damage to the PIR test group, and multiple failures of the vapour barrier, leading to the identified cold spots and icing.

Analysis of the trial data revealed substantial productivity gains. Pre-insulated piping can reduce on-site construction time and indirect costs by 84% when compared to in situ applications. This gain is accompanied by an estimated 92% fewer on-site man-hours, with a similar reduction of on-site truck traffic and waste. More importantly, the Cryogel Z system can capture all of the construction, schedule, and cost benefits of pre-insulation, and do so with the same insulation system design as is used in the field-fabricated and modular portions of the project.

## Conclusion

LNG plant construction has increasingly adopted modular construction techniques. In parallel, pre-insulated piping on these plants has become widespread where most practical – on large-bore, straight lines. Where there are constraints on implementing modular construction, pre-insulated piping provides many of the same advantages, and can bridge the gap between stick built and modular construction, or further augment the modular process. To test the viability of pre-insulated piping plant-wide, an EPC contractor commissioned a trial of pre-insulated piping utilising flexible aerogel blanket insulation.

The results of the trial revealed rapid shop installation times for the pipe spools that were pre-insulated with Cryogel Z aerogel blanket, and excellent resistance to the mechanical forces during fabrication, handling and transportation to site. Pre-insulation with Cryogel Z aerogel blanket provides a viable alternative to existing pre-insulated pipe solutions. It also allows the design engineer to capture the value of closer pipe spacing and combined classes of thermal, passive fire, acoustic, and cryogenic splash protection with a single plant-wide insulation system. Applying the right insulation technology to the evolving construction paradigm in the LNG sector is a step best taken in early design. For plants insulated with traditional insulation systems that have experienced issues during start-up or operations, Cryogel insulation has frequently provided the solution, even after construction. **LNG**