OUT IN THE COLD

Sally Zhou and Rick Lowery, Norplex-Micarta, USA, examine the effectiveness of glass-based insulation material in cryogenic applications.

It may not be a high-profile part of the LNG infrastructure, but insulation is essential when natural gas is in its cryogenic liquid form. LNG applications need special insulation material to handle the extreme temperatures, stresses, and environments found along LNG supply routes.

Why is insulation vital to the LNG industry? Consider a conversion plant where a number of components are attached to LNG-carrying tanks and pipes. These components can transfer ambient heat into the tanks and pipes, thereby reducing the efficiency of the systems that chill and compress the gas. To block this heat transfer, insulating layers are placed between vessels containing LNG and attached components. The result is higher chilling and compression efficiency, which lowers the plant's energy consumption and costs.

The operating costs and efficiency of LNG facilities are also directly related to the quality of insulation systems. For example, better insulation translates into reduced amounts of boil-off gas (BOG), which is the result of heat leakage through insulation into the LNG.

In addition to stopping heat transfer, insulation shields plant components from the extreme cold temperatures of LNG vessels. This prevents problems such as icing of the ladders encircling LNG storage tanks, which can endanger plant personnel climbing the ladders. It also prevents extreme temperature fluctuations that can cause damaging expansion and contraction of metal components such as bolts and pipe supports.

Furthermore, LNG insulation serves as an electrical barrier. Electric current flows between metal parts in contact with each other, causing the parts to corrode. By blocking the flow of electric current, insulating layers prevent this phenomenon, known as galvanic corrosion.

Figure 1. LNG pipe insulated from super structure I-beam with NP500CR.

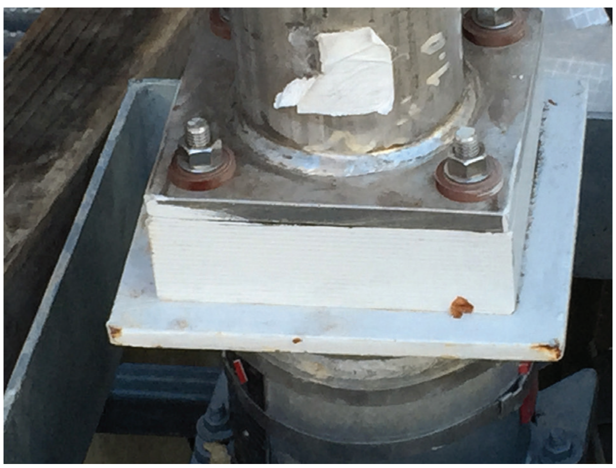

Figure 2. Pillar base insulated with NP500CR cryogenic glass-epoxy insulation.

Figure 3. NP500CR insulates an LNG pipe hanging from an adjustable hanger.

Insulation options

There are many different insulation types and materials available to the designers of conversion plants, receiving ports, pipelines, ships, tanks, and other components of LNG transportation and storage systems. Some of these fall into a category known as thermoset composites, which consist of a polymeric matrix and a reinforcing material. Thermosetting resins set when heated and cannot be remoulded. Uncured and at room temperature, they are in a liquid state, which facilitates the addition of reinforcing fibres.

Some types of thermoset composite insulation combine wood or paper with epoxy or phenolic resin formulations. These inexpensive cellulose-based composites provide adequate insulation in some cases. However, components exposed to extremely low temperatures require more robust insulating layers with a substrate made of woven fibreglass fabric.

The most capable thermoset composites combine a woven glass fabric with an epoxy resin system. One type of glass-epoxy composite, manufactured to comply with the National Institute of Standards and Technology (NIST) G-10CR process specification for cryogenic applications, is also specially formulated to maintain its physical properties at temperatures approaching absolute zero. This distinguishes it from most thermoplastics, which retain relatively little strength at extremely low temperatures, such as those near LNG.

Ceramics are also able to provide adequate thermal isolation at very low temperatures. However, ceramics are usually more expensive than glass-epoxy composites. Moreover, extreme cold makes ceramic components more brittle than they are at normal temperatures, and therefore even more prone to fracture on impact with another object. By contrast, cryogenic glass-epoxy composite insulation will not become brittle or fracture-prone in the vicinity of LNG.

Carrying the load

Cryogenic glass-epoxy material offers higher mechanical strength than its cellulose counterparts, and also retains that strength at low temperatures. This is crucial, for example, when the material is used to insulate the steel supports placed along the length of an LNG pipe. These supports carry both the weight of the pipe and the LNG flowing through it. In order to economise, plant designers try to minimise the number of supports under long pipes. The result is wider spaces between supports, which increases the load on each support. When supports for a steel pipe are placed at 100 ft intervals, for example, a single support has to carry the weight of a 100 ft length of that pipe, as well as the LNG in that section.

Loads placed on the pipe supports are also placed on the support insulation. In this case, the insulation prevents temperature migration between the pipeline and support structure, allowing for more efficient temperature control of the LNG being transported.

When wood and paper-based insulation cannot carry the required loads, designers use cryogenic glass-epoxy material, which is strong enough to handle the highest compressive loads along LNG pipelines. In addition, this material has ample strength to withstand stresses caused by pipe movement during LNG transport. The length of a 5-mile LNG pipeline can change by several feet due to temperature and pressure changes inside and outside the pipe. This expansion and contraction of the pipeline can place considerable amounts of shear stress on pipe supports, as well as their insulation. Cryogenic glass-epoxy material can handle these high shear stresses, which in many cases would cause cellulose-based composite insulation to fail.

This specially formulated material weighs approximately a quarter of the weight of steel, but is just as strong. Despite the high glass content that gives it such great strength, the material can be machined with commonly used tools. Norplex-Micarta's cryogenic glass-epoxy insulation material, Micarta Block NP500CR, is generally supplied in thicknesses from 2 – 6 in. to meet different design targets for 'hot side' temperature. The 'hot side' of the insulation is opposite the 'cold side' nearer the LNG. Lower 'hot-side' temperature means there is less heat transfer through the insulation, which translates into lower costs to keep the 'cold side' at the design temperature in a particular operating environment.

Its strength also makes cryogenic glass-epoxy material a good choice for thermally insulating gaskets, washers, and bolts. During LNG pipeline installation, gaskets and washers must withstand compressive forces as high as 5000 psi as pipe sections are joined together. Shear forces also come into play as metal pipeline components expand and contract with temperature changes, though cryogenic glass-epoxy gaskets prevent some of this temperature-related deformation.

Gaskets fabricated with NP500CR range from 0.25 in. – 16 ft in inside diameter, and from 0.01 – 0.25 in. thickness. Besides serving as thermal insulators, these gaskets help prevent galvanic corrosion of metal pipeline sections.

As bolt insulation, cryogenic glass-epoxy material can withstand the high stresses common at connection points. Wood composite materials are a less expensive option for insulating bolts, however these low strength materials are more likely to fail when subjected to connection loads, causing downtime and necessitating costly repairs.

Cryogenic glass-epoxy insulation also carries heavy loads at LNG storage facilities, where it is placed under storage tanks to minimise heat transfer. For this application, NP500CR is usually supplied in 3 – 4 in. thicknesses and custom fabricated to meet the designer's needs. Once in place, it is secured with a two-part cryogenic-rated epoxy to the concrete foundation.

Minimal water absorption

Additional insulation challenges are posed by LNG plants and pipelines located in coastal areas. These structures are exposed to both salt water and high humidity. In this type of environment, wood and paper-based materials absorb large amounts of water, which accelerates their deterioration and adversely affects their thermal and electrical insulation properties. Cryogenic glass-epoxy insulation, however, absorbs relatively little water, so it lasts much longer and performs more consistently than wood and paper alternatives. As a result, the glass-based composite reduces replacement costs and downtime for repairs.

Glass-epoxy material also fares better than cellulose-based products against caustic substances in cleaning solutions used at LNG facilities. This further reduces deterioration and extends the life of plant insulation.

Similar to coastal LNG plants, vessels that liquefy and transport natural gas operate in salt water and high humidity environments. In these harsh settings, cryogenic glass-epoxy material maintains its physical and insulation properties, giving it an advantage over wood and paper-based alternatives. On transport ships, NP500CR measuring 2 – 3 in. thick serves as thermal insulation at points where strength is critical. Shipboard applications include platforms, ladders, and areas where people work.

Storage tanks and piping on board LNG carriers are often supported by cryogenic glass-epoxy insulation, like their land-based counterparts. With a wide operating temperature range, the material can withstand the cryogenic-to-ambient temperature swings that occur when LNG-carrying vessels are emptied or filled.

For ships that use LNG as a source of power, glass-based materials are also a good choice for engine-room insulation. Their minimal water absorption in high-humidity ship environments makes them much less likely to fail than cellulose-based materials, as temperatures change during repeated engine startup/operation/shutdown cycles.

LNG on the road

Though currently on a smaller scale than ship and pipeline transportation, LNG transport by truck is becoming increasingly common. Trucks transport LNG from ports to vehicle fuelling stations equipped with cryogenic tanks and LNG-handling equipment. In the future, trucks may also transport LNG to mines and other remote industrial sites, where it will be used to generate power.

In this emerging part of the LNG industry, cryogenic glass-epoxy insulation provides the same benefits as it does in conventional LNG transport. Applications related to truck transport of LNG include tank supports, isolation plates on loading structures, and washer and bolt insulation.

Conclusion

In a variety of settings, specially formulated glass-epoxy material is meeting the LNG industry's insulation challenges. The material keeps heat out of LNG vessels and protects plant components from temperatures near absolute zero. It also offers the strength to handle a variety of loading conditions, as well as corrosion resistance that ensures long life and minimal replacement and maintenance costs. These benefits should boost demand for the material, as more designers around the world face the cold realities of handling cryogenic LNG. **LNG**