

Vacuum insulated piping (VIP) has been widely used for over 40 years in cryogenic systems. Originally specified for only critical applications where maintaining a liquid state was absolutely imperative, the use of VIP has evolved into a long term economic means of transferring liquid cryogens in all related industries. Since vacuum insulation was first invented by Sir James Dewar in 1892 it has been used for insulating everything from sub-cooled liquid helium at near absolute zero to hot coffee in a Thermos bottle. The performance and economic advantages of vacuum insulation have been realised in many industries and applications for decades, yet the LNG industry has been very slow to embrace this 'new' technology. Extensive and unnecessary boil-off gas (BOG), pipeline insulation maintenance and repair, and running and maintaining large compressors and/or reliquefiers have been a common burden and expensive cost to LNG plant and terminal operation that has simply been accepted. Furthermore, when considering all aspects of the plant design and cost of using VIP versus

mechanically insulated piping, the initial capital investment can be lower with VIP.

### **Vacuum insulated piping**

So why is VIP not more widely used and accepted in the LNG industry? With all the LNG liquefaction facilities and regasification plants being built and planned only a very few are using VIP. Perhaps it is the perceived complexity of vacuum insulation or possibly that until recently there has been only one qualified supplier of large diameter, long length VIP with direct seaport access. Or maybe VIP is viewed as a 'new' technology reserved for laboratories or other controlled environments. Whatever the reason(s) for VIP not being used in all LNG transfer applications, the fact remains that manufacturing, installing and maintaining VIP for LNG industry applications is far simpler and more economical than many people realise.

A shop fabricated VIP pipe section or spool piece is simply constructed of an inner carrier pipe, normally stainless steel,



# Vacuum insulation

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Figure 1. Movement modelled for a vacuum insulated thermal compensation guide (TC guide).



Figure 2. A 42 in. diameter TC guide spool designed and manufactured by PHPK.

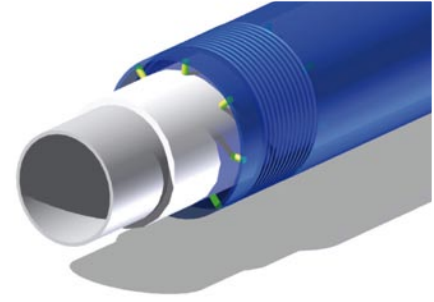


Figure 3. Section view of vacuum insulated piping (VIP) modelled.

which is wrapped with multiple, separated layers of a reflective material such as aluminised mylar to insulate from radiant heat transfer. A jacket pipe is centred over the carrier line, also stainless steel or a coated carbon steel material, using low heat conductive 'spacers' and sealed at each end with a low heat conductive end closure. The jacket pipe also contains a convoluted 'expansion joint' in each straight section to compensate for the contraction of the carrier pipe when LNG is being transferred. Each section has a chemical gettering system added to the vacuum space, and then is leak tested and evacuated to a level of 10-4 torr through an evacuation port on the jacket pipe. Although this may sound over simplified, for experienced manufacturers of vacuum insulated equipment and piping systems such as Linde and PHPK Technologies, this is an everyday process that has been performed and perfected over many years. As in any process piping system, additional considerations must be taken into account and therefore a thorough analysis must be performed by the manufacturer to assure the required extended life of the piping system.

### Installation

The installation of the VIP is also a simple process that can reduce construction time considerably. With prefabricated pipe sections, including elbows and tees coming in lengths of up to 30 m, the number of field welds can be reduced by more than 75% and each joint made in the field can either be mechanically insulated or vacuum jacketed in a matter of hours. The jacket pipe material is sufficient to support the weight of the spool so that supports, guides and anchors are also simple and easy to install. Additionally the outside diameter of VIP is approximately 150 mm less than the mechanically insulated pipe, which can reduce the size and/or number of piping supports throughout the plant. The Linde/PHPK team can also manufacture the VIP in prefabricated, self contained modules that include trusses, supports, expansion loops, and other process piping for spanning between jetty pilings.

### Heat leak performance

The heat leak performance of VIP is a minimum of 1/10<sup>th</sup> that of mechanically insulated piping. This not only significantly reduces the BOG in a steady state operating condition but also results in much faster cooldown time and allows transfer of LNG over much greater distances. Less BOG in the piping transfer system can reduce the number and size of compressors or reliquefiers needed to keep pace with loading or offloading operations at liquefaction and regasification facilities. This saves a tremendous amount of money in capital investment, maintenance costs and energy costs throughout the life of the plant.

### Maintenance

Maintenance of VIP is also a strong point when compared to mechanically insulated piping. Once a VIP system is installed and operational it can remain maintenance free for many years. Mechanically insulated pipe is prone to loss of its vapour barrier,

causing moisture and ice to build up and deteriorate the insulation resulting in an increased heat leak and more BOG. Maintaining a large mechanically insulated system sometimes requires a full time crew.

### Recent innovations

The Linde/PHPK partnership was formed specifically to design and manufacture VIP for the LNG industry, and it has recently introduced the vacuum insulated thermal compensation guide (TC guide). This is a durable and economical way to compensate for thermal contraction and cycling in any cryogenic piping system. Comprising two internal hinged joints in a single vacuum jacketed spool section, it is designed to allow up to 4.5° of deflection (9° when installed in a reverse deflection) with virtually no stress on the elbows. This technology has also been around for many years and has been used extensively with great success in the Aerospace Industry by NASA and other US government contractors.

The use of TC guide spools can greatly reduce or eliminate the need for costly expansion loops in any LNG piping system. In a typical large diameter LNG piping system the spool can allow for nearly four times the offset movement of a conventional rigid pipe expansion loop. This would allow for spacing of expansion loops on a straight piping run to be increased by more than three times the distance. Also, for configurations that have a natural change of direction and/or branches, the use of TC guides can allow for a simpler routing design and reduced nozzle stresses on connecting equipment. In addition to reducing the costs of expensive expansion loops, the TC guide will reduce the overall system pressure drop. This would allow for a lower initial loading or offloading pressure of the LNG, which will result in less flashing of LNG to gas due to the lower amount of pressure drop. In some systems the reduced pressure drop also allowed for a reduction in carrier line size.

In one particular sample case, use of TC guide spools in an actual LNG import terminal where two parallel 30 in. LNG transfer lines were running over 2 km each, the use of TC guide spools would eliminate 12 expansion loops with a total of 92 elbows and 850 m of piping. In addition to eliminating the piping materials, labour and associated supports, the overall pressure drop for each 30 in. line was reduced by over 25% at a transfer rate of 30 000 gpm.

While global demand and cost for natural gas continues to rise, proven technology for the most efficient design of transferring cryogenic fluids must be considered. VIP's short and long term advantages over the decades old conventional means of transferring LNG is one of the simplest ways to improve on the overall construction and operation costs of LNG terminals. When using vacuum insulated piping for export or import terminals, it is important to choose the most advanced and economical system available for the transfer of cryogenic fluids. ■