

Linde Engineering

Linde

PHPK
TECHNOLOGIES

Vacuum Insulated Piping for LNG Service

Without a doubt the best performing insulated piping available, vacuum insulation has been used for decades in industries where the transfer of cryogenic liquefied gases is used. The LINDE PROCESS PLANTS and PHPK TECHNOLOGIES partnership now brings the LNG INDUSTRY the most reliable and proven method of transferring LNG with the minimum Boil-Off Gas. Vacuum Insulated Piping outperforms conventional mechanically insulated piping with 1/10th the steady state heat leak and other Pipe-in-Pipe “powder insulation” methods by 1/5th the steady state heat leak. Prefabricated in standard lengths up to 80’ (27m) and inner diameters up to 42” (1.06m), LINDE/PHPK vacuum insulated piping will save both time and money in the construction and operation of any LNG transfer and transport operation. LNG Export Terminals, Ships, Import Terminals and Peak Shaving Plants can all benefit from the advantages of Vacuum Insulated Piping (VIP).



LINDE/PHPK Experience

Prefabricated vacuum insulated piping has been used for nearly 50 years in critical applications for transferring liquid helium, liquid hydrogen, liquid nitrogen and many other cryogenic liquefied gases. Originally developed for its ultra low cool-down and steady-state heat leak values, VIP has evolved into a safe and economic solution for its dependability, ease of site installation, long term low maintenance insulation, reduced vapor recovery requirements, minimal outside diameter and overall versatility.

LINDE/PHPK vacuum insulated LNG piping is manufactured by LINDE Process Plants at the Port of Catoosa, Oklahoma, USA where direct barge access is available to major US Gulf seaports. LINDE is the world's leader in the Industrial Gas market and one of the largest manufacturer's of cryogenic equipment.

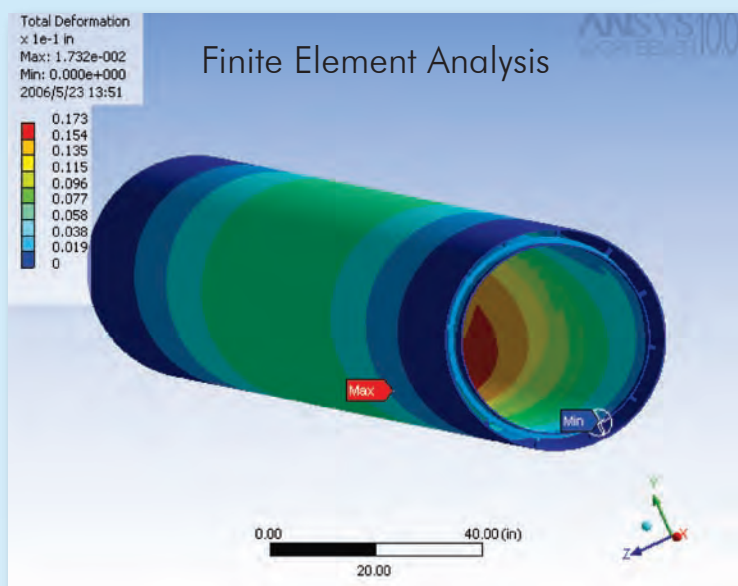
PHPK Technologies brings the partnership more than 15 years of experience designing and manufacturing complex VIP systems for a multitude of customers and industries including NASA launch complexes and test stands, US Navy aircraft carriers, US Government laboratories and test facilities, LNG Peak Shaving facilities and many more. PHPK's engineering and design staff averages over 20+ years experience in the cryogenic industry.

LINDE/PHPK VIP Design and Manufacturing

Starting with the overall system layout we will analyze system flexibility, stresses and loads based on inner and jacket piping materials and wall thicknesses, support structure locations, extreme environmental conditions, and normal and extreme operating conditions using Algor Pipe Plus which has been customized for pipe in pipe analysis. Once successful results are obtained each prefabricated pipe section will be analyzed using a Finite Element Analysis.

Piping system design, fabrication and inspection will be performed as a standard to ASME, ANSI B31.3, NFPA 59A, US Coast Guard and US DOT regulations where applicable. As the LINDE/PHPK partnership is part of a multi-national company, designing, fabricating and testing to other international codes and requirements is not a problem.

Each factory evacuated pipe section will be helium leak tested at a sensitivity of 1×10^{-9} cc/sec before undergoing a two week bake-out, evacuation and retention process to ensure the vacuum insulation integrity.



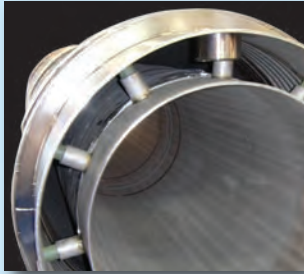
Calculated Steady-State Heat Leak Per Foot for LNG Service

6x8 Spool	1.800 Btu/hr-ft
8x10 Spool	2.898 Btu/hr-ft
16x20 Spool	5.494 Btu/hr-ft
24x30 Spool	8.466 Btu/hr-ft
30x36 Spool	10.047 Btu/hr-ft
36x42 Spool	11.979 Btu/hr-ft
42x48 Spool	13.975 Btu/hr-ft

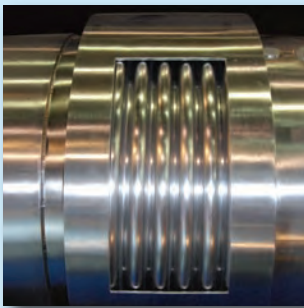
LINDE/PHPK VIP Standard Features and Options



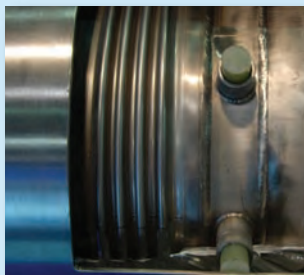
Standard flush mount combination evacuation port/annular relief port and vacuum test gauge. The flush mount design feature enables easy handling, storage and installation of prefabricated pipe sections with minimal risk of damage. Feature also allows for easy factory or field application of corrosion resistant HDPE or paint coatings and/or optional redundant foam insulation to jacket pipe in case of inaccessible installations.



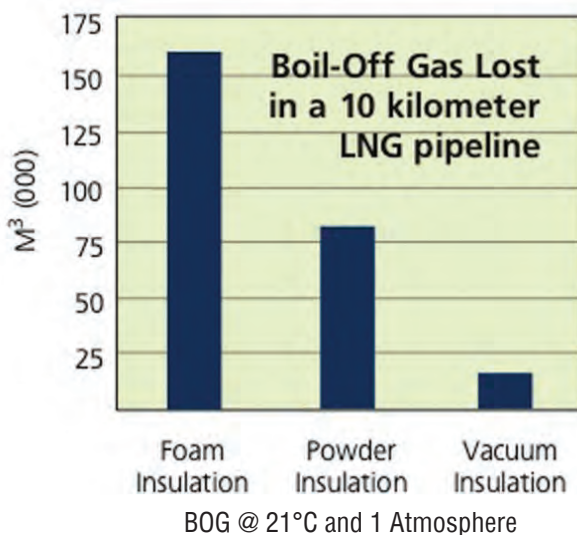
Our standard spacer support design provides high G-load integrity and low heat conduction which is critical to maintaining piping structural integrity while providing the lowest boil-off gas rate during cool down and steady state operations. Field piping supports used for this piping are standard slide plates, guides and anchors. Multi-layer laminar radiation shielding wrapped around carrier line provides the highest degree of radiant heat transfer reduction available.



External expansion bellows are used in our standard above ground piping design to compensate for thermal contraction and expansion between the inner and jacket pipes. Bellows are made of 321 stainless steel for corrosion resistance and designed for a 5,000 cycle life to assure against metal fatigue. A stainless steel cover can also be added for protection. The jacket pipe would be designed and fabricated with a painted or HDPE coated carbon steel material as a standard. Stainless steel jacket can also be supplied for additional corrosion resistance and/or secondary containment.



Internal expansion bellows are used in our standard design where overall system thermal contraction cannot be accommodated. Bellows are made of multi-ply 304 stainless steel and are provided with a stainless steel liner to prevent squirting, reduce pressure drop and fluid turbulence. The length of the bellows and number of plies is dependent on the designed operating pressure, amount of contraction to be accommodated and desired cycle life. The use of inner bellows will allow the inner pipe to contract without movement of the outer jacket pipe thus eliminating the need for expansion loops.



Comparison of Boil-Off Gas (BOG) generated based on two (2) 10 Kilometer long 24" pipelines transferring 130,000 M³ of LNG at a rate of 228 M³ per minute.

Heat Leak Values:

Foam: 0.26 w/m²k

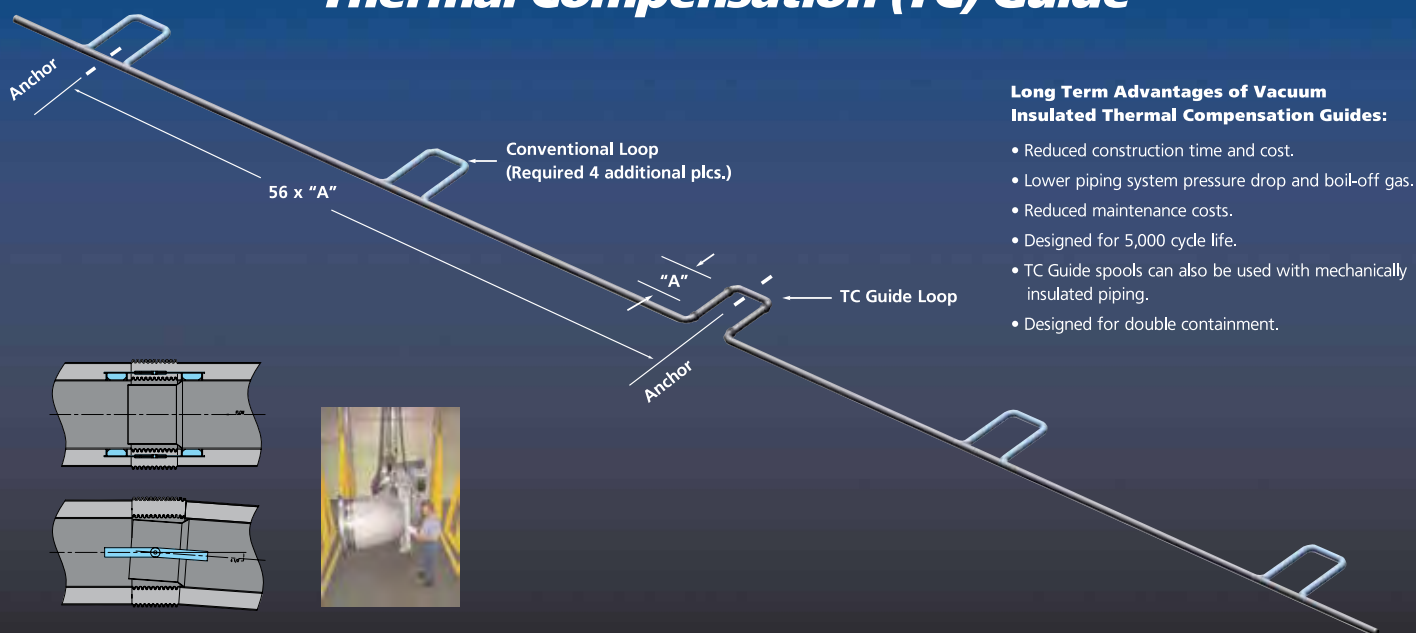
Powder: 0.13 w/m²k

Vacuum: 0.026 w/m²k

Why Choose Vacuum Insulated LNG Piping?

- Reduced installation time and labor costs
- Reduced maintenance costs and down time
- Faster cool down with lower BOG
- Fewer expansion loops required with TC Guide spools
- Prefabricated expansion loop skirts and riser modules available
- Remote vacuum and/or temperature monitoring available
- Lower heat leak resulting in:
 - Less boil off gas (BOG)
 - Less reliquefier usage
 - Less compressor usage
 - Longer transfer distances
 - Smaller pipe diameters possible

Thermal Compensation (TC) Guide



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