

## AND READY FOR HIGHER CAPACITY

**Austin Szatkowski and Christopher Butler, Air Products and Chemicals Inc., USA**, discuss advances in coil-wound heat exchanger technology and applications.

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**A**s the LNG industry has evolved, technological advances have been essential in meeting new requirements. One of these has been the desire for more production from a single train, which has been achieved through both design improvements leading to more efficient exchangers, and also by building physically larger exchangers. LNG production in new geographies presents its own challenges: from the sub-zero conditions of an Arctic plant, to the hurricane prone plants on the US Gulf Coast, to the blast and wave loading for floating LNG (FLNG) units. Air Products has introduced solutions to address all of these challenges, and this article will discuss how these solutions have been developed.

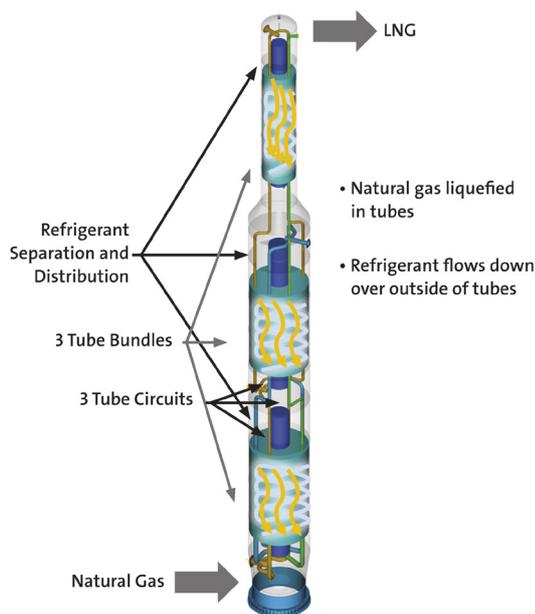
## Heart of the plant

All LNG liquefaction cycles require large heat exchangers in which the natural gas is liquefied. Coil-wound heat exchangers (CWHEs) have long been accepted for LNG service for single trains processing more than 5 million tpy down to relatively small and mid sized plants of 0.25 million tpy, and more recently for FLNG plants as well.

CWHEs have a long track record of proven performance, providing excellent heat transfer in a mechanically robust assembly. They are proven to have very high availability and require no periodic maintenance.

The CWHE is where natural gas is cooled, liquefied and subcooled. Some liquefaction cycles require only a single

### Main Cryogenic Heat Exchanger



**Figure 1.** Typical three bundle main cryogenic heat exchanger (MCHE) where natural gas enters the bottom of the unit and flows up where it is cooled and eventually leaves at approximately  $-160^{\circ}\text{C}$ .

main cryogenic heat exchanger (MCHE) per train, while others may utilise separate CWHEs to perform precooling or subcooling duty. Figure 1 shows a typical three bundle MCHE where natural gas enters at the bottom of the heat exchanger and flows up where it is cooled and eventually leaves the heat exchanger at approximately  $-160^{\circ}\text{C}$ . Refrigerant flows down the outside of the bundles in the downwards direction.

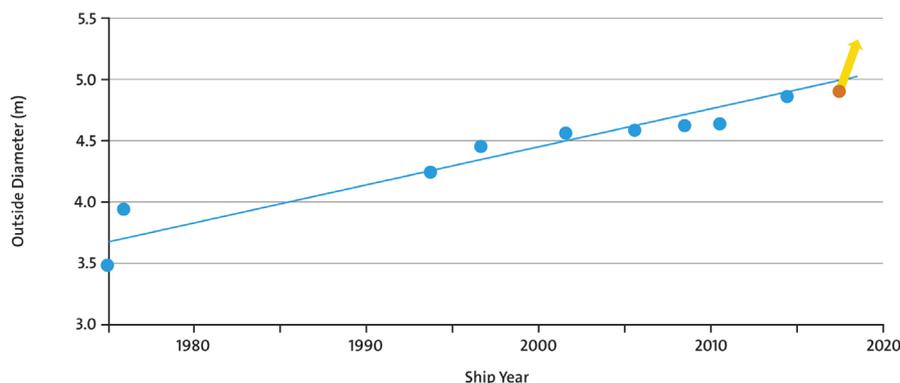
Air Products' CWHEs contain coil-wound tube bundles housed within an aluminium or stainless steel pressure vessel shell also designed to retain refrigerants in the event of a shutdown. For LNG service, the heat exchangers may consist of one or more tube bundles, each made up of several tube circuits. With this type of exchanger, the different tube circuit areas can be matched to the process requirements resulting in an efficient and compact design.

The tube bundles are made up of small bore aluminium tubing, which provides a large amount of heat transfer surface area in a relatively compact package. Tube circuits can be designed for feed pressures in excess of 100 barg for greater process efficiency. In a coil-wound tube bundle, aluminium tubes are wound helically around a central mandrel or support tube. Successive layers are spaced apart from one another to provide uniform shell side refrigerant flow. A single tube bundle may contain hundreds of kilometres of tubing.

The pressure vessel shells may be manufactured from aluminium or stainless steel depending on design pressure requirements and specific application. The shell also houses the interconnecting piping between the bundles and internal vapour and liquid management systems. The outside of the shell is designed to support the platforms and ladders, the piping, valves and insulation. This modularised approach is designed to minimise field work and in response to industry demands. Air Products has worked with customers and engineering, procurement and construction (EPC) contractors to successfully implement several alternative types of modularisation strategies.

A typical MCHE may be as large as 5.0 m in diameter, 55 m high, and weigh 500 t.

### Growth of LNG Heat Exchangers Since 1975



**Figure 2.** The graph shows heat exchanger diameter growth of over 40% since 1975.

## Industry desire for higher capacity

The LNG market has pushed larger production plants in order to realise economies of scale. Air Products has been able to meet this need by both increasing exchanger size and optimising designs to increase the production for a given size exchanger.

The company has developed manufacturing and shipping methods to support market demand for larger CWHEs.





**Figure 5.** An MCHE being moved to the field site in the Arctic Circle.

open-shop radiography for assemblies that are too large to fit into a specialised radiographic enclosure.

### Higher tubeside design pressure

Another factor that affects both the process efficiency and production capacity for a CWHE is the natural gas feed pressure. Since natural gas feed is carried through the heat exchanger tubes, a higher tubeside design pressure is required in order to achieve these improvements. As the design pressure increases, both efficiency and production will increase up to a certain point. Even though there is not a process efficiency benefit with increasing pressure after this threshold, there is still the benefit of increased production from the same size exchanger.

In order to ensure the satisfactory design and fabrication of CWHEs with higher tubeside pressures, Air Products has completed a significant amount of development addressing the integrity and design of all components, such as the tubing, tubesheets, internal piping, and associated process nozzles.

### Challenging design locations

As the LNG industry has expanded into new geographies, challenges associated with each of these new locations need to be addressed. This includes designing for Arctic conditions with snow, ice and sub-zero temperatures, to US locations, where the equipment needs to withstand a Category 4 hurricane, to FLNG, which includes blast and cyclic fatigue due to wave motion.

In Arctic design, Air Products takes into account the snow and ice that could build up on the exchangers and associated platforms during the long winters. Additionally, the sub-zero temperatures present the challenge of designing the shipping saddles and lifting equipment to not be susceptible to low temperature embrittlement and the resulting fracturing that could occur.

The shale gas boom has driven the development of new liquefaction projects in the US. The US-based plants presented their own challenges, including high design wind speeds. A number of projects are located along the Gulf of Mexico where it is not uncommon for hurricanes to make landfall. Therefore, the CWHEs used were designed to withstand a wind speed equivalent to a Category 4

hurricane. This requirement resulted in increasing pressure vessel shell thicknesses substantially, and the need to develop more robust base designs. Air Products does not only design the heat exchanger, but also the piping and platforms that attach to it. The attachment of the platforms to the pressure vessel required the development of a new design due to the higher wind speeds to allow a better transfer of the loads into the shell without overstressing the

components. This new design went through testing within the fabrication facility to make sure that the tight tolerances required to make it work as designed could be met.

FLNG applications presented a number of requirements that did not have to be considered before. The most significant were designing for significant blast load due to the compact layout and for cyclic fatigue caused by the rocking of the vessel due to wave motion. Both of these design criteria were drivers in the utilisation of stainless steel pressure vessel shells. While the shell was changed to a stainless steel alloy, the internal components, such as the bundles and piping, were able to remain aluminium. This led to the need to develop a means of transitioning between the two materials, which include the impact of the differential thermal expansion that would occur when the exchanger was operating.

The blast and fatigue conditions for FLNG which helped drive the need for a stainless pressure vessel also required the inclusion of an upper guide as a way to reduce loads on the base support and keep it from being overstressed or impractical in size for integration. The upper guide is a crucial component because not only does it need to interface with the steelwork of the surrounding process module, but has to do so with tight tolerances in order for the benefits in reducing fatigue to be achieved. On the other end of the exchanger, Air Products has developed several new alternative base designs. The different designs were developed to enable seamless integration with the particular module/deck designs for each of the three FLNG projects in which the company has been involved to date.

### Conclusion

The ability to integrate the liquefaction process design, the mechanical design and the fabrication, shipment and start-up of the CWHEs leads to an optimisation of performance and reliability. The improvements achieved over the decades in manufacturing exchangers have been steady and significant. [LNG](#)

### Bibliography

1. MCKEEVER, J., PILLARELLA, M. and BOWER, R., 'An ever evolving technology', *LNG Industry*, (Spring 2008).