by Abbe Miller, editor-in-chief

Shipping news

To transport liquefied natural gas around the world, large vessels are specifically designed with a strong attention to liquid tightness and temperature control

Photo credit: Excelerate

Although you can't see or smell natural gas, it's about as ubiquitous as sliced bread and cell phones. It's used in heating, cooking and power generation and is a key ingredient for various chemicals, plastics and fertilizers. About 30 percent of electricity consumed in the United States in 2016 was generated from natural gas.

Despite its widespread use in society, transporting natural gas is tricky. To keep it safe and stable during shipping, it's stored in liquefied natural gas (LNG) tanks installed in LNG carriers (LNGCs), in a semi-slushy state at minus 260° F. The incredibly cold (or cryogenic) temperatures allow it to be transported at atmospheric pressures and also reduce its volume by about 600 times compared to its gaseous state.

As natural gas consumption grew, a need for specially built ships to carry the natural gas came into light. In 1963, the engineering company Technigaz designed an experimental ship, the Pythagore, as the first gas tanker built on an applied membrane principle. Successful tests conducted with liquid azote provided the green light that was needed for the transport of natural gas, ethylene, methane and other gases.

Three decades later, Technigaz merged with Gaztransport to become Gaztransport & Technigaz (GTT), an engineering company that is an expert in the design of containment systems with cryogenic membranes to transport and store liquefied gas. To date, more than 400 LNGCs have been deployed, due in part to the pioneering work delivered by Technigaz and Gaztransport.

CRYOGENIC CONTRACTS

The challenges surrounding the shipment of natural gas go beyond the actual shipping; the slushy, liquefied product must also be converted back to gas once it arrives on shore. Often, the conversion process takes place on a floating storage and regasification unit (FSRU). These FSRU vessels can be classified in two ways: as ships that handle both the transport and the conversion of the natural gas and as offshore installations that remain

Photo credit: Roland Mouron

Workers use welding technology developed in-house at GTT to produce the company's NO96 LNG tanks.

stationary while converting the cargo back to gas. After being converted back to its gaseous state, the natural gas can be pumped into smaller storage tanks to be delivered further inland.

Recently, GTT announced a new order from Hyundai Heavy Industries (HHI) for the design of LNG tanks for a new FSRU. Initially, the FSRU will be an anchored vessel, although it has the capacity to navigate, if necessary in the future. HHI is a South Korean company that builds tankers and containerships, shuttle tanks, LNGCs and FSRUs. The contract is part of 12 FSRUs currently in the GTT order book.

The end goal of the welding equipment design was to make the welding process easier irrespective of the position in which it is carried out.

While the overall construction of an FSRU is a substantial process – the delivery date for HHI's latest unit is set for 2020 – the production of the LNG tanks is an especially critical part of the process. Welds must be liquid tight to avoid the cold liquid from damaging the ship's hull and to maintain the cargo's overall temperature.

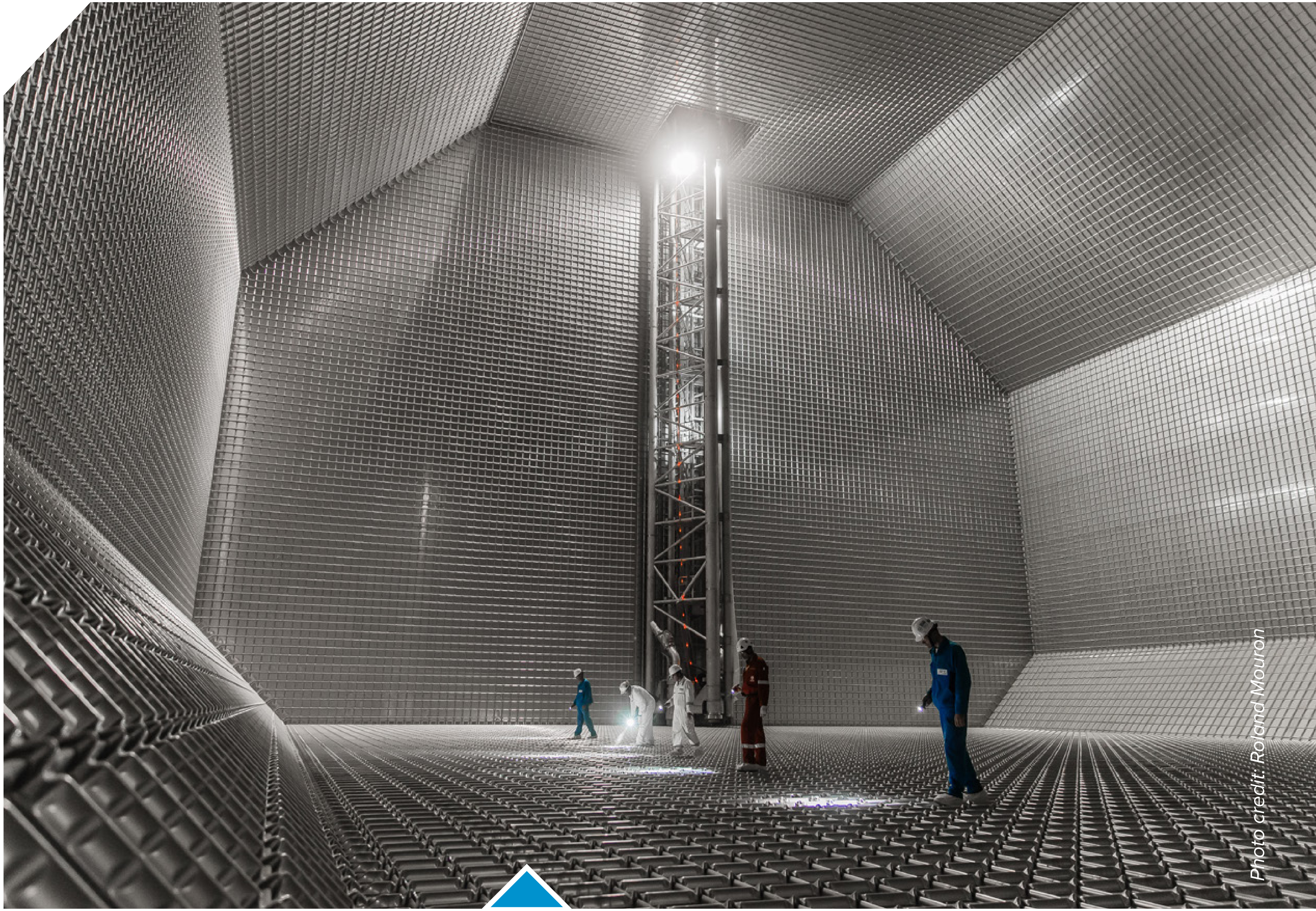
GTT's LNG tank types are divided into two main families: MARK III and NO96. Both consist of two insulating spaces and one or two metallic membranes. The insulating materials are used to keep the natural gas in its liquid state while the membranes are to contain the cargo and ensure a complete tightness of GTT's tank systems.

The unit being designed for HHI will fall under the Mark III family of tanks.

For the NO96 family of tanks, insulating spaces are made of structural plywood boxes filled with perlite, mineral glass wool and/or foam. The tanks' metallic membranes are made of 0.7-mm-thick iron nickel alloy (Fe-36%Ni) that boasts an extremely low coefficient of thermal expansion – even at the cryogenic temperatures required for the transport of LNG.

Similarly, the Mark III family of tanks features insulating spaces that are predominantly made of bonded plywood and reinforced polyurethane foam. The primary membrane, which is in contact with the LNG, is made of corrugated 1.2-mm-thick 304L stainless steel. The corrugated material allows the membrane to remain flexible as the ship is in transit while also absorbing variations in length in the case of changes in temperature.

The Mark III tanks also feature a secondary membrane made of a



The inside of a GTT Mark III LNG tank where liquid natural gas will be kept at cryogenic temperatures.

composite material – aluminum foil sandwiched and bonded between two layers of fiberglass cloth. The airtight requirements are achieved by sophisticated bonding techniques designed specifically for the triplex composite.

NO SMALL TASK

The Mark III unit that GTT is designing for HHI offers a capacity of more than 47 million gallons (170,000 m^3). The fabrication and installation of such units is no small undertaking.

As is the case with most large ships, FSRU vessels are built at a shipyard. Due to the nature of on-site shipyard assembly, engineering companies like GTT must specifically design their LNG units in a way in which they can be installed directly into a ship's hull. Once the hull's fabrication has been completed, GTT's prefabricated components are positioned directly onto predefined positions.

To fabricate its NO96 family of tanks, GTT chooses the iron nickel alloy in large coil formats, which is used to cover the length of the tanks. A list of approved material suppliers is given to the shipyards. A typical tank measures approximately 50 m in length, 40 m in width and 30 m in height. To join the large pieces of material, the edges of the coils are welded to iron nickel alloy tongues that run the length of the tank.

Because of the large size of the tanks as well as the on-site assembly requirements, GTT had to develop specific welding equipment for the various joining aspects of the tanks' production. Unsurprisingly, that equipment has evolved and improved over GTT's past 50 years of LNG containment system development. The focus for designing the welding machines was to ensure the positioning of the membrane to limit fatigue stress.

The main welding operation consists of the assembly of three iron nickel alloy sheets: two that measure 0.7 mm thick and another that measures 0.5 mm thick, which serves as a tongue for the joining process. This welding operation anchors the membrane to the insulation while providing full ▸

Because of the large size of the tanks as well as the on-site assembly requirements, GTT had to develop specific welding equipment for the various joining aspects of the tanks' production.

tightness. The welding process used is resistance seam welding. Traditional spot welding is also used in some areas, as needed.

For the Mark III family, 3-m-by-1-m sheets of corrugated stainless steel are positioned on top of the modular sandwich panel elements and then welded into place. Primarily, plasma arc welding is used, which is a process similar to GTAW where a smooth and enlarged plasma jet allows the welding of thin material. Most of the welds are filet welds, which allows GTT to guarantee a latitude in the positioning of membranes.

Other metallic elements exist in GTT's technologies, and these are welded with GTAW or GMAW. GTT also uses studs to secure elements to the inner hull. These studs are welded by a gun.

As was the case with the NO96 units, GTT needed specialized welding equipment for its Mark III units, as well. Therefore, the company worked with international partners to develop specialized tools.

The end goal of the welding equipment design was to make the welding process easier irrespective of the position in which it is carried out. GTT takes advantage of pressure rollers, following rollers, and optical and mechanical gauges to deliver the best welds possible. The main challenge the company faces is in the welding of relatively thin materials. In such cases, the welding is very sensitive and depends highly on heat evacuation.

Depending on the presence of a metallic support under the membranes, parameters have to be adapted, especially on the corrugated material found within the Mark III technologies. A solution is to set up programs for the different areas of corrugation allowing for a very smooth transition during changes in the torch's angle. As mentioned tools like pressure rollers are also helping to reduce gaps between sheets and provide constant heat evacuation.

AMBITIOUS R&D

Producing LNG containment systems requires ongoing R&D for various technologies, including welding and other joining technologies. ▸

The Mark III LNG tank technology uses 3-m-by-1-m sheets of corrugated stainless steel that are welded into place to form the primary tank membrane.

That R&D also entails intensive testing, including rupture, impact and fatigue testing.

At GTT, engineers test materials and bonding procedures by simulating conditions encountered in shipyards through sea swell simulators that mimic the movement of the liquid in the tanks using models that are one eighth the size of the actual ships. Research engineers also look at how materials and bonding procedures age over time to ensure a long and robust lifespan.

While longevity and safety are at the forefront of GTT's R&D efforts, limiting the loss of cargo is also a major focus. With LNG shipping, the goal is to reduce what's called a boil-off rate, which is the amount of liquid that evaporates due to heat leakage.

For its recent contract with HHI, GTT is leveraging its Mark III Flex+ technology, which increases a tank's insulation thickness and adds a reinforced secondary barrier. The Mark III Flex+ technology enables an improved daily boil-off rate of 0.07 percent of tank volume per day, which the company describes as "unequalled" in its field. For more information about the company's tank technologies and specialized welding processes, contact Nicolas Laurain, GTT's metallic material and welding team manager. ■

GAZTRANSPORT & TECHNIGAZ