

THE MARCH OF THE GTT MEMBRANE

GTT has been developing its established Mark III and NO96 membrane tank technologies to accommodate the changes sweeping through the LNG shipping industry

GTT membrane tanks – whether of the Mark III or NO96 types – represent the most popular choice of cargo containment system for LNG vessels.

Of the approximately 500 conventional LNG carriers (LNGCs) and floating storage and regasification units (FSRUs) currently in service, 75% are equipped with GTT membrane technology. Of this total there is a fairly even split between Mark III and NO96 ships.

The orderbook for such ships presently stands at around 110 vessels, and GTT membranes have been specified for 80% of these. While the NO96 system will be fitted on about 60% of the current slate of GTT newbuildings, the actual percentage split between the NO96 and Mark III options for new ships at any one time is more to do with the choice of shipbuilder, rather than any advantages one system may have over the other.

Dealing with change

Over the past 15 years the LNG shipping industry has been characterised by change. Global LNG trade and the fleet serving it have expanded rapidly, supporting a growing community of LNG terminal and ship operators.

At the same time, gas buyers and sellers have adopted a more flexible approach to their sales negotiations, engendering more spot and short-term cargoes and opening up possibilities as to where shipments might be discharged.

The LNG supply chain has also been extended dramatically. Floating LNG production and regasification vessels have opened up new gas export and import opportunities, while the fleet of coastal distribution tankers continues to grow. In addition, the first purpose-built LNG bunker vessels are now in service and more shipowners outside the gas carrier sector are choosing to



The distinctive waffled stainless steel primary barrier of a GTT Mark III membrane tank

order LNG-fuelled ships.

For a designer of ship systems like GTT, advances in LNG carrier technology have been as important as the commercial changes impacting the industry. In addition to the 40% increase in the size of an average conventional LNG carrier, new ship propulsion systems have underpinned important gains in fuel efficiency.

The introduction of four-stroke dual-fuel diesel-electric (DFDE) propulsion systems early in the new millennium marked an important advance on traditional steam turbine power units. More recently, two-stroke dual-fuel engines have enabled further reductions in fuel bills and have become the most popular propulsion system for LNG carrier newbuildings.

The lower fuel requirements of these new propulsion systems have allowed GTT to improve the thermal performance of its traditional Mark III and NO96 systems, using new versions of the technologies yielding lower cargo boil-off rates.

“With more efficient propulsion systems, less natural boil-off is required to feed the engines,” explained GTT commercial vice president David Colson. “At lower ship speeds, say less than 16 knots, our established containment systems may yield too much boil-off gas. We have developed new versions of our Mark III and NO96 systems which allow operation with no lost boil-off at lower speeds, thereby increasing the vessel’s operational flexibility.”

Mark III and NO96 step changes

GTT’s original Mark III membrane tank design, with its characteristic waffled stainless steel primary barrier, has been further developed in recent years through the introduction of the Mark III Flex and the Mark III Flex+ versions.

Table 1 shows the evolution of the Mark III membrane and highlights the difference in thermal performance between the three versions of the design. With the Mark III Flex+ system, the guaranteed daily natural cargo boil-off rate (BOR) is down to 0.07% of the tank volume per day.

The reduced BOG rate achieved by the Mark III Flex+ is obtained by increasing the insulation thickness to 480 mm, from the Mark III Flex’s 400 mm. Also, the assembly of the secondary barrier below the top bridge pads has been further developed with the Flex+ solution, through the addition of a supplementary layer of rigid triplex. This increases the strength of the barrier against thermal and mechanical loads.

GTT’s long-serving NO96 membrane design, with its distinctive invar

TABLE 1: EVOLUTION OF THE GTT MARK III MEMBRANE CONTAINMENT SYSTEM

	MARK III	MARK III FLEX	MARK III FLEX+
BOR*	0.135%	0.085%	0.07%
Main insulating material	Reinforced Polyurethane foam		
Primary membrane	Stainless steel corrugated membrane		
Secondary membrane	Single triplex	Strengthened by doubling triplex	
Thickness	270 mm	400 mm	480 mm

*Typical value for a 175,000 m³ LNG carrier in % of cargo volume/day. BOR is project-dependent due to vessel size, tank arrangement and reinforcements

TABLE 2: EVOLUTION OF THE GTTNO96 MEMBRANE CONTAINMENT SYSTEM

	NO96	NO96 GW	NO96 L03	NO96 L03+
BOR*	0.15%	0.125%	0.11%	0.10%
Main insulating material	Perlite	Glass wool	-	Glass wool and foam 130 kg/m ³
Membranes	Invar 0.7 mm			
Support	Boxes with bulkheads plywood	Boxes primary and top secondary with bulkheads: plywood	Boxes with bulkheads in plywood	Boxes with bulkheads in plywood Panels lower secondary: foam & plywood Panels: foam & plywood
Thickness	530 mm (primary box: 230 mm + secondary box: 300 mm)			

*Typical value for a 175,000 m³ LNG carrier in % of cargo volume/day. BOR is project-dependent due to vessel size, tank arrangement and reinforcements

36% nickel steel primary and secondary barriers, has also been further developed in recent years, in the quest for improved thermal performance. The basic NO96 system has now been augmented by the NO96 GW, the NO96 LO3 and the NO96 LO3+ versions of the design.

Table 2 shows the differences in thermal performance between the various NO96 options. Mark NO96 L03+ offers the best performance among the four NO96 versions; the guaranteed daily natural cargo BOR falls to 0.1% of the tank volume per day.

There are two main differences between NO96GW and the NO96 L03 or L03+ versions. With NO96GW the insulation material in the boxes backing the system’s two metallic barriers is glass wool (GW).

With LO3 and LO3+ the insulation in the primary insulation boxes is still GW, but the secondary insulation is split into two different layers. For L03, there is a box insulated with GW attached to a panel assembled from plywood and reinforced polyurethane foam (much like Mark III); for L03+, both secondary layers are made up of plywood and polyurethane foam.

Key FSRU considerations

GTT membranes have been chosen as the cargo containment system for all the floating storage and regasification unit (FSRU) newbuildings completed to date. As a general rule, FSRU owners have tended to opt for the older, established Mark III and NO96 versions of the two membranes for their vessels.

The choice has been mainly determined by owners of FSRUs and conventional LNG carriers having different expectations in terms of BOR. FSRU owners and operators generally have no great incentive to reduce their BOR and therefore favour the standard technologies, such as NO96 and Mark III, for economical and space availability reasons.

LNG carrier owners, in contrast, are now opting for the more refined GTT technologies, such the NO96GW & Mark III Flex membranes, as part of their efforts to reduce cargo BOR below those offered by the designer’s standard technologies.

“Notwithstanding this general observation, we are now >>>

>>> beginning to see owner inquiries for FSRUs requiring lower BOR, possibly because the vessels are intended for projects with a comparatively low or intermittent send-out and where cargo retention will be required,” said Mr Colson.

Building relationships

The ability to match fuel requirements and containment system BOR demands an understanding of the vessel’s operational profile, as well as the performance of the ship’s propulsion and cargo-handling system packages.

Achieving the right balance between a ship’s operational profile and the performance of its systems necessitates a close liaison between GTT and other key stakeholders, including shipowners, shipyards, engine manufacturers and designers of fuel gas supply systems (FGSSs) and reliquefaction systems.

A lack of integration between the various systems, particularly in the LNG-fuelled vessel market, can pose a challenge. While reliability is a given priority, shipowners and shipyards also need systems that are integrated. A wide range of solutions exist and often yards will have to turn to multiple suppliers - engine makers, FGSS integrators, tank manufacturers and designers - to meet their needs. These multiple interfaces between the various systems add complexity and risk.

GTT has addressed this concern by arranging strategic partnerships with Wärtsilä Gas Solutions and DSEC, both of which were finalised in December 2017.

The alliance with Wärtsilä provides customers with a complete service that combines their respective fields of expertise. GTT’s capabilities in developing cryogenic membrane containment solutions are complemented by Wärtsilä’s know-how in dual-fuel engines and LNG FGSS applications.

The integrated packages available from the partners can be provided in modular configurations and include, if required, an in-service element to facilitate smooth ship operations. The GTT/Wärtsilä initiative is aimed particularly at the LNG-powered vessel sector, where ship bunkering arrangements can vary widely according to the type of vessel and the trade route it serves.

Formerly part of Daewoo Shipbuilding & Marine Engineering (DSME), DSEC is a Korean marine engineering company which has decades of experience in working with GTT’s membrane tank technologies, as well as expertise in LNG fuel gas supply and cargo-handling systems.

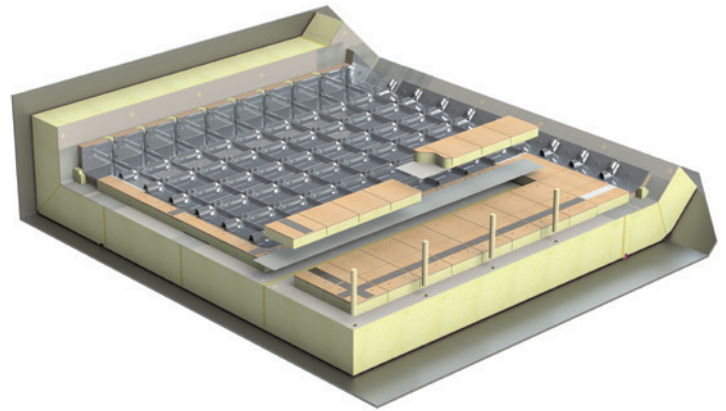
Under a new technical assistance agreement, DSEC has become a licensed outfitter of GTT membrane tanks, including for use in storing bunkers on LNG-fuelled vessels. DSEC is thus able to install GTT containment systems on behalf of shipyards that wish to subcontract the membrane tank erection work.

With these two partnerships in place, GTT aims to facilitate a shipowner’s decision to switch to LNG fuel, thanks to the fully integrated and low-risk nature of the overall package.

Seeking optimum solutions

“As important as the various industry relationships, including the two strategic partnerships, are, they in themselves are not enough,” stated Mr Colson. “GTT needs to be the lead expert in matters dealing with cargo containment and BOR and proactive in finding optimum solutions.”

He continued: “We have been working on an R&D programme with Airbus for more than two years to increase our knowledge of boil-off gas generation and pressure rise during a vessel’s lifecycle. We believe we are among the few actors in the industry that have reached this level of understanding concerning LNG behaviour in marine applications. This knowledge enables us to perform studies for a wide variety of owners to advise them on the optimum choices, covering



Cutaway showing the elements of a GTT Mark III Flex+ membrane containment system

both membrane systems and other technologies, for their operations.”

Mr Colson added: “While safety is the overriding consideration in all our technology offerings, we also need to propose cost-effective solutions. One such example of this is the LNG Brick prefabricated tank concept, launched in March 2018.”

The LNG Brick approach enables a membrane tank in the 300 to 3,000 m³ size range to be constructed at the specialised premises of GTT licensees, for subsequent delivery in a “ready-to-install” condition at the shipyard. Particularly suitable as an LNG bunker tank option for an LNG-powered ship, LNG Brick allows small- and medium-size shipyards with limited access to personnel skilled in LNG systems and no specific knowledge of membrane tank technology, to tender for the construction of such ships.

Designs for the future

GTT’s work to improve the thermal performance and strength characteristics of its classic Mark III and NO96 membrane designs targets operational benefits coupled with competitive pricing. The advances anticipate further improvements in dual-fuel engine efficiencies, however incremental they may be.

In addition, the increased strength of the membrane tank containment systems will permit the use of GTT technologies in projects characterised by harsher in-service conditions. These include applications involving tandem ship-to-ship transfers and on FSRUs and floating LNG production vessels operating at open sea locations.

Because membrane tanks are integrated with the ship’s structure, achieving higher tank pressure ratings requires reinforced hull scantlings, strengthened tank openings in way of the liquid and gas domes and adapted pressure relief valve settings.

Membrane tanks with higher pressure ratings are particularly desirable on vessels that experience extended periods of idle time during normal operations, such as LNG bunker vessels and dual-fuel bulk carriers, or on ships requiring greater handling flexibility. Ships with GTT membrane tanks rated for higher pressures can accommodate the boil-off gas generated by a mix of pressure increases and gas consumption in the engines.

GTT’s goal of anticipating the LNG shipping industry’s needs requires constant innovation. One-quarter its employees work in research and development, on programmes aimed at ensuring GTT retains and extends its competitive edge in the rapidly evolving LNG shipping sector. [LNG](#)