

Message from Philippe Berterottière, GTT Chairman and CEO

«In this edition, GTT is presenting our latest evolution of the Mark III Flex technology. It was introduced in 2011 to give ship-owners the option of a further reinforced insulation system from specific applications (eg off-shore platforms) or a reduced guaranteed daily Boil-Off rate down to 0.085%Volume/day. 47 vessels have been delivered with this system.

The latest version, the Mark III Flex+, introduces an increased insulation thickness from 400mm to 480mm and an enhanced secondary barrier arrangement. The guaranteed daily Boil-Off Rate is reduced to 0.07%V/day. General Approval has been received in September and shipyards can now propose this containment system to the market.

This new evolution of Mark III allows GTT to revisit, in parallel, the Mark V system, which has undergone some delays due to our wish to re-validate the system. This will in turn postpone its general availability to the market. The delay is due to the discovery of a convection phenomenon on a laboratory prototype tank which was higher than expected during the initial phase of the project.

GTT has also recognised that the incremental cost in the Mark V system is such that it is not as competitive as we would wish in today's market conditions. We will therefore use this additional time to seek improvements in the cost structure in order to supply an affordable, competitive system to meet the current market requirements.

In addition, in this issue we will highlight the work that was carried out on the validation of the ice-breaking vessels for Yamal (the first vessel, the Christophe de Margerie has been delivered recently), the development of an LNG fueled bulk carrier with Arista, and GTT's ability to carry out specific studies looking at Boil-Off generation during ship to ship transfers.»

Philippe Berterottière, Chairman and CEO

TECHNOLOGIES / Mark III Flex+

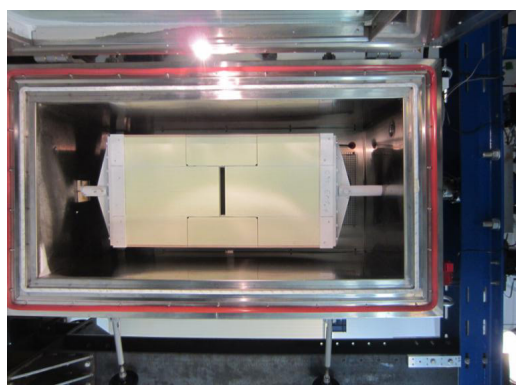
MARK III Flex+ is a variant of the Mark III Flex system with an increase in the insulation thickness in order to offer a Boil-Off Rate of 0.07%V/day while keeping the advantages of the well-known and mature Mark III technology.

The evolved system, part of GTT's on-going development program since the introduction of the Mark III Flex system in 2011, maintains the standard insulation configuration with a 100mm thick primary space, while increasing the thickness of the secondary space to 380mm. This new configuration incorporates an optimized primary arrangement with a reinforced design which further improves the safety coefficients of the cargo containment.

Several aspects were looked into during its development, particularly in relation to the effects of the increased insulation thickness on the bonded joint and therefore the flexible secondary membrane. Complete Finite Element Model (FEM) studies with strength and fatigue tests were performed. They demonstrated that the loads acting on the secondary membrane would increase by only 10%, mainly due to the change in the thermal stresses imparted by the change in insulation thickness. The effect of this increase in load has been overcome by the modification to the assembly, which, in fact further strengthens the resistance of the system to thermal loads.

A solution developed and already installed on six ethane carriers in 2016 was applied. This consists in doubling the triplex arrangement under the top bridge pads of the primary insulation layer. GTT were able to divide by nearly a factor of two the level

of stresses transmitted through the bonding planes of the secondary membrane. The tests performed demonstrate that the fatigue life of the bonded joint is increased by a factor of ten.



Fatigue test bench under cryogenic conditions

The required documentation has been reviewed by Class to confirm the design, including calculations to evaluate the thermal and mechanical behaviour of the special areas of the tank; the corners, the gas dome, the liquid dome, tank penetrations, pump tower base support, etc. All these studies revealed no significant change compared to the standard Mark III Flex design.

Class has granted a General Design Approval for this technology. ■

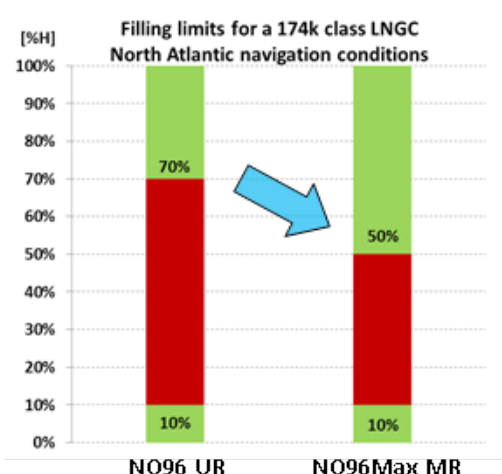
TECHNOLOGIES / NO96 Max

GTT has developed the NO96 Max system in order to improve the historical NO96 concept for better performance and increased flexibility.

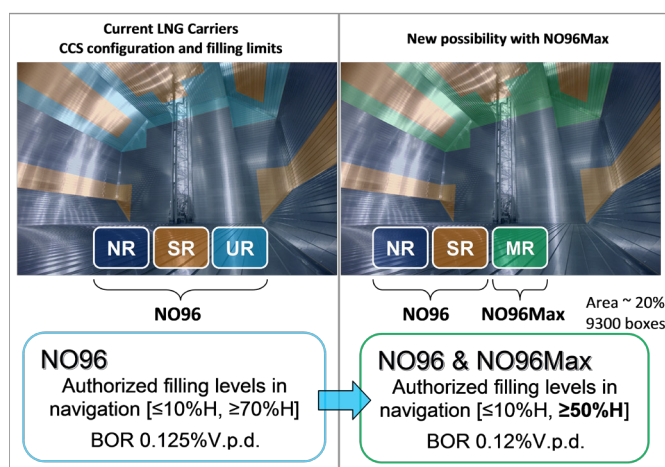
Additional operability can, for instance, be provided on LNG carriers thanks to the NO96 Max cargo containment system. Indeed, while the pillar structure in the box offers better thermal insulation, it can provide higher reinforcement strength from a sloshing point of view.

Therefore, an upgrade of the reinforcement with NO96 Max MR in the upper part of the tank can allow the **navigation of LNGCs with a liquid level above 50% of the tank height** instead of above 70% Height for current LNGCs.

In such a way, as illustrated in the figure below, a mixed configuration NO96/NO96 Max, where a limited area (20%) is equipped with NO96 Max, offers higher operability and Boil Off Rate at 0.12% Volume per day with a limited impact on cost.



UR: Ultra Reinforced; MR: Mega Reinforced



GTT has been granted with a **General Approval for Ship Application** of the system by the **DNV-GL**. ■

LNG AS FUEL SOLUTIONS / Project FORWARD for ARISTA SHIPPING



Innovative and cost-effective design of 82K LNG-fueled Bulk Carrier

Project FORWARD was launched by Greek ship-owner ARISTA SHIPPING and US classification society ABS in 2013. From 2013, this Joint Development Project (JDP) incorporated DELTAMARIN (DM, acting as Project Manager), GTT, WARTSILA and SHELL.

This JDP brings an innovative, environmentally friendly reference to the Bulk Carrier market.

B.Delta82, an efficient and optimized Bulk Carrier design from DM, was selected as a starting point. It is derived from B.Delta37, a well-known bulk carrier design from DM.

The targeted autonomy of 40 days - corresponding to 2,500 m³ of LNG - for use also outside ECA zones, was one of the biggest challenges for the project.

Due to the hatch covers located on top of every cargo hold, any designer would naturally look first at the Aft Deck in order to install the LNG tank. Because of the limited available space aft of the accommodation block, the required LNG capacity could not be met with a C-type tank.

The JDP initially investigated two options with an LNG tank located aft, which both have a negative impact on the accommodations arrangement and deadweight.

The team then investigated a third option with the LNG tank integrated between cargo holds. With the membrane system, the LNG capacity could be accommodated in a jumboization module of only 9 meters in length.

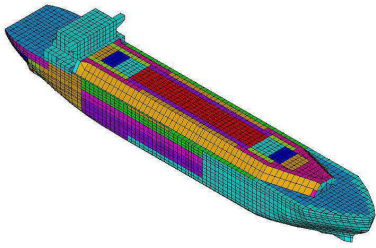
Thanks to a better weight distribution, this third option had a similar lightweight to the two other designs, yet without any impact on the accommodation.

Together with an innovative and compact Engine Room concept based on only two 4-stroke engines for propulsion and power generation, as well as hull optimization, the FORWARD design is now able to carry an increased deadweight of 83.5K, with a similar fuel consumption and a limited additional CAPEX compared to the standard Marine Diesel Oil (MDO) fuelled design.

Another challenge for these ships consists in frequent and long idle periods with a very low hotel load. Thanks to the combination of low Boil-off Rate and increased LNG tank pressure, the ship is able to safely handle much more than the 15 days period which satisfies all regulations. ■

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INNOVATION / YAMAL LNG Arctic Vessel

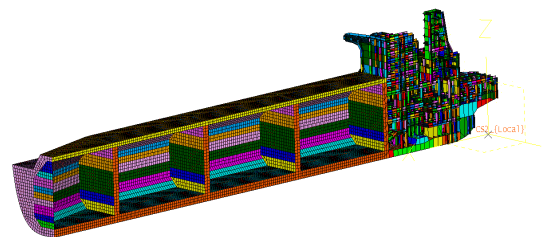


"Christophe de Margerie", the first icebreaking LNG carrier designed for the Yamal project, has been delivered to SCF at the beginning of June 2017. This ship is the first of a series of 15 hulls to be delivered by DSME to three shipowners by 2020.

The success of this specific project is the result of close cooperation between DSME Shipyard and GTT, in order to take into account the specificities of Icebreaking Arctic conditions. GTT's expertise combined with that of the Krylov research center in St Petersburg and the Russian Register, has led to the tank conception of this specific LNG Carrier. NO96 GW Cargo Containment System (CCS) behaviour under arctic conditions has been deeply studied by GTT to ensure the sustainability under extreme thermal conditions: -50°C air temperature and -2°C sea temperature. Furthermore, GTT has shared its expertise with DSME for steel grade selection of the hull structure. These vessels are also designed to

sustain icebreaking mode astern till 1.2m ice thickness at a speed of 6.6 knots. GTT has performed extensive studies to understand hull-ice interaction and studied NO96 cargo containment system to analyze the induced vibration, avoiding resonance of this CCS and to confirm NO96 CCS GW satisfactory behaviour from a strength and fatigue point of view for 40-year operation. Vibration studies have also been performed on pump towers installed in each tank in order to satisfy GTT and Classification Societies criteria.

Finally, the liquid motion inside the tanks, induced by the specific operations of the vessel on arctic seas and under ice conditions, was studied and validated. ■



OPERATIONS / Boil-Off Gas Studies: an operational-oriented answer for in-service vessels

Over the last four years, several Shipowners have sought GTT advice for Boil-Off Gas (BOG), pressure or cargo management (during single operation and over complete operational sequences) and for process optimization. GTT has performed simulations to ensure feasibility of planned operations: timeline, BOG handling capacity for Ship-to-Ship transfers and Ship-to-Ship Commissioning (Gassing-up and Cooling-down operations at sea). The same kind of simulation is performed on demand for emergency situations (unloading of cargo, transfer to remain in authorized filling levels). Specific support has been provided at design stage for LNG as fuel applications where LNG transfers will become a conventional daily practice with plurality of vessels, containment technologies, commercial constraints, operational profiles and shore installations (trucks, bunkering station, peak shaving & conventional terminal).

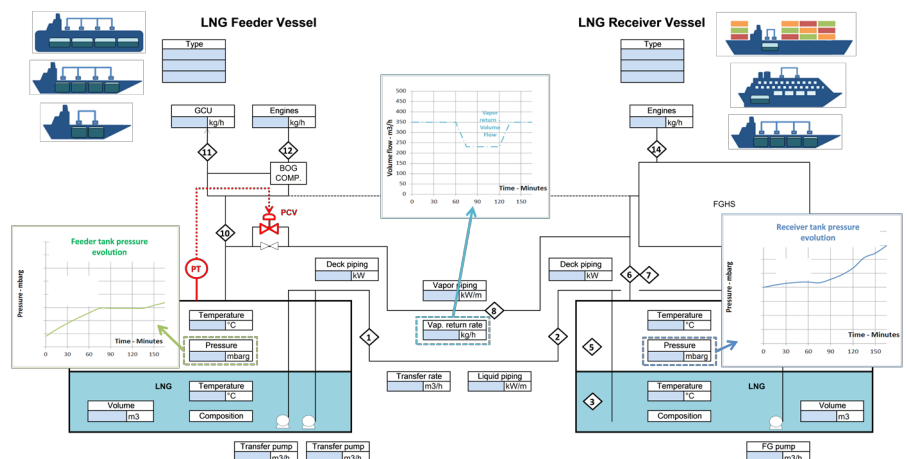
To meet the LNG market evolution, GTT is offering BOG Studies to answer various specific needs:

- Provide operational and technical solutions to manage BOG generation, pressure evolution and cargo handling, during non-standard or emergency operations, with onboard installed capacities (working on timeline, transfer rate, pressure management, window for equipment start).
- Provide decision-making assistance for equipment sizing and advice for process

optimization, which is very relevant for LNGC reconversion (FSU, FSRU) where operators are facing challenges on BOG management.

Results are provided with transparency about feasibility and limits. They are based on discussions with crews onboard and actual conditions (composition, temperature, pressure...) to ensure adapted, relevant, in-time and ready-to-use advice, with regards to operational constraints and environmental/local requirements.

In view of continuous improvement processes, REX of real operations is integrated when available. ■



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