November 2022 - N°26

Message from Philippe Berterottière, Chairman and CEO of GTT

I am very pleased to introduce the latest GTT Inside with more news on our recent developments.

As you will see, we continue to work on improving our designs, either slightly or more significantly. We feel that this finally ends up in a very significant progress for the Industry. It is the case with an optimised utilisation of the LNGC tank volume thanks to a sump or devices for slightly increasing the filling limit. It means higher revenue for a given LNGC design. It is also the case for the design of a small LNGC without any ballast, which reduces its cost.

We also propose a membrane tank for PCTCs ; membrane tanks can give these ships a larger autonomy.

Another specific development has been conducted with DELTAMARIN and DNV on the possibility of having a 2 barg tank rating. This will give a larger flexibility for pressure rise in the tanks and help in handling the boil-off during ship operations.

Please enjoy this edition.

TECHNOLOGIES

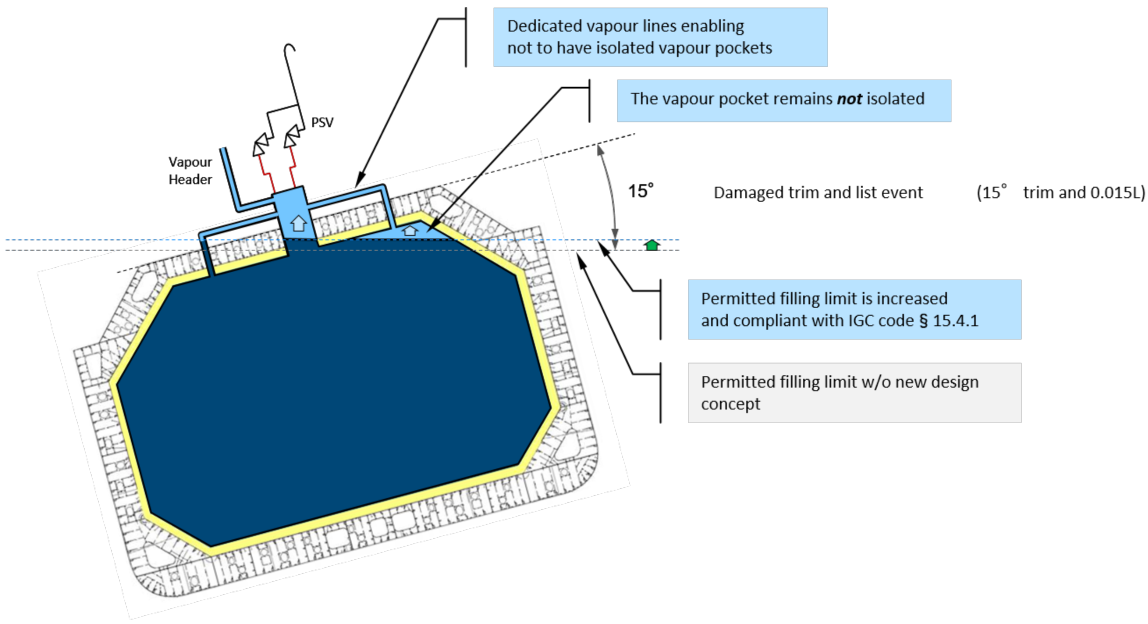
GTT Design for increased transport capacity for LNG carriers

The 2016 edition of the IGC code introduced more constraints on the conditions for the acceptance of increased cargo tanks filling limits. A major change was the introduction of the concept of Isolated Vapour Pockets (IVP) also widely known as gas pockets.

Following a grounding, a collision or an allusion, of severe damage conditions may result and lead to high levels of static trim and list. Under these conditions, no IVP may be created in the tank, which remain out of pressure control, or cannot be alleviated by pressure control.

In parallel with the elaboration of operational emergency procedures to cope with such an event, GTT has designed a solution the purpose of which is to maintain each part the vapour space connected, thereby avoiding the formation of any isolated vapor pocket (IVP). This new design fully meets above IGC code requirements.

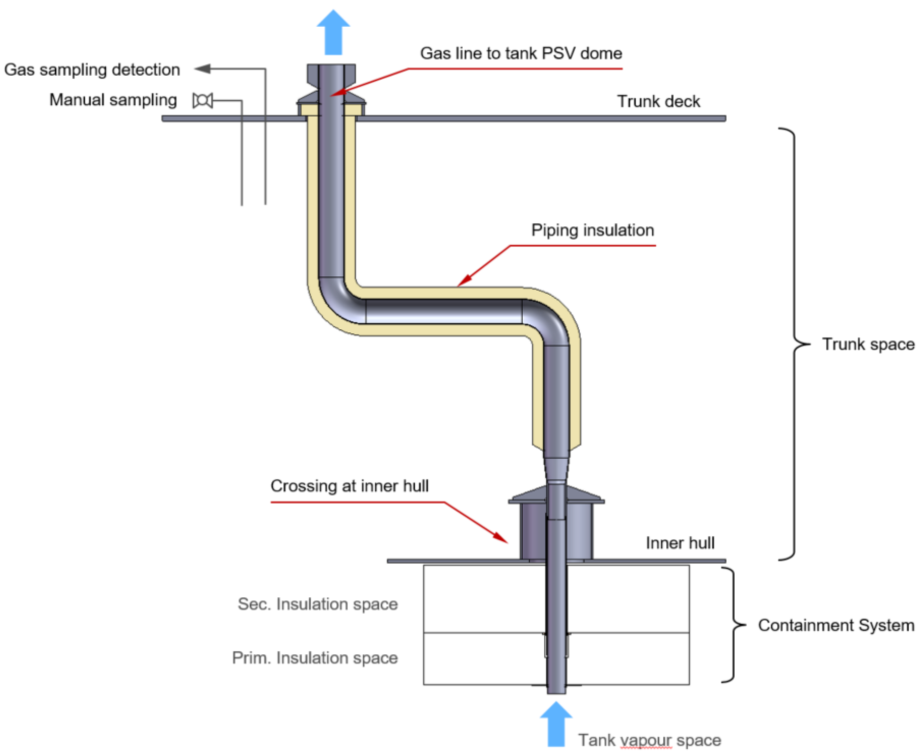
This design involves the introduction of gas crossing pipes in the ceiling of the membrane tanks connecting the areas where IVPs are potentially likely to arise to the tank dome and pressure safety valves. These connections pipes cross the tank insulation and trunk space. For a typical vessel configuration, only two gas crossings are necessary to deal with all trim and list conditions, each of them located close to the middle of top tank ceiling dihedrons. The access is sufficiently recessed to avoid influence from high areas of tank liquid motion or sloshing



This design is approved by all Classification Societies

As a result of this design, a higher filling limit up to approximately 99.4% of tank volume may be allowed for vessels so equipped. This means that between 1.2% and 1.4% more the cargo volume can be loaded, transported and discharged (i.e between 2 000m3 and 2 500 m3 per voyage for a standard 174k LNGC).

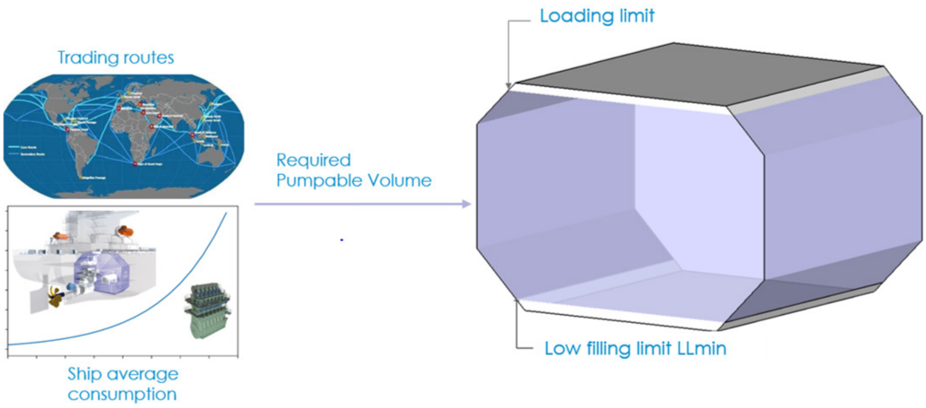
Both solutions for NO and Mark families are now offered by all active GTT licensed Shipyards and they are now being applied on more than 170 ordered vessels, 28 of which have already been delivered.



TECHNOLOGIES

Optimizing LNG volume available in a fuel tank for increased flexibility

LNG pumpable volume in a fuel tank is a key design basis for LNG fuelled vessels since it determines the navigational range that can be covered by the vessel for a specific main engine consumption. Therefore, this aspect should be assessed very precisely at design stage.



The maximum navigational range and the derived maximum LNG volume is not equal to the tank total capacity, but is the difference between the loading limit and the lower unpumpable filling limit (LLmin), as described in the schematic below.

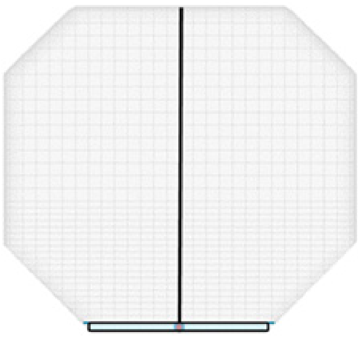
The Loading limit is driven from the tank filling limit (ca. 98% of tank Volume) and the characteristics of the bunkered LNG (LNG density at reference and loading temperature).

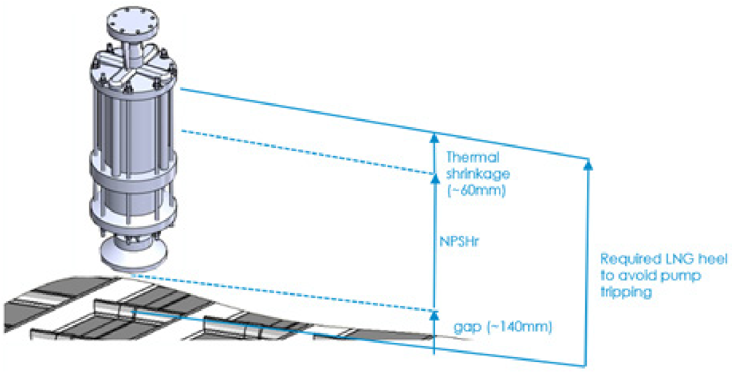
The volume loaded during bunkering is usually limited to approximately 96% of tank volume.

Regarding the lower filling limit, different conditions may be addressed. For instance, when the vessel is at the port or terminal (static condition), the low filling limit is mainly determined by:

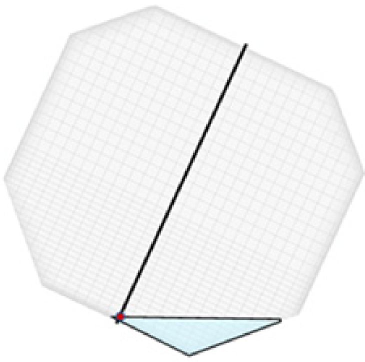
- The design gap, agreed with the fuel gas pump maker, between the primary membrane and the pump inlet to ensure adequate LNG suction.
- The Net Positive Suction Head required (NPSHr) of the fuel gas pump, which indicates the minimum LNG level to prevent tripping of the pump.
- The Pump Tower thermal shrinkage.

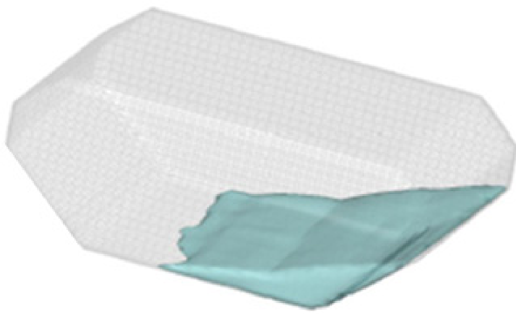
Although static assessment generally allows very small values of low filling limits, when the vessel is at sea, the liquid motions in the tank are likely to uncover the fuel pump for a few seconds and lead it to trip. Dynamic assessment is therefore considered more relevant to establish the tank pumpable volume (see examples below).



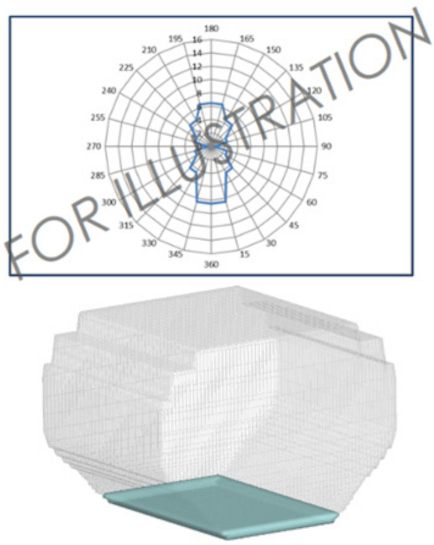


For each project, GTT assesses at the design stage the limiting sea conditions above which the fuel pump is likely to trip. The results are presented for different heel levels through polar plots (examples below).

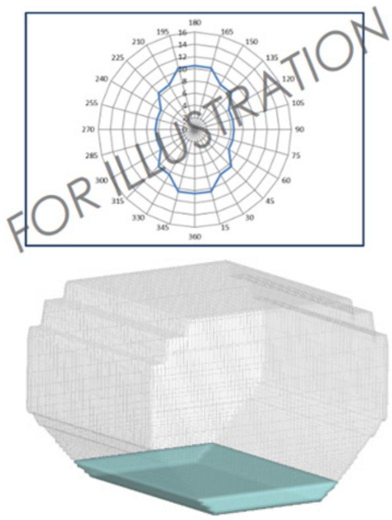




In order to help the crew, GTT has also developed a smart shipping solution to anticipate the risk of fuel pump tripping, according to the LNG level in the tank and the weather forecast on the ship's route.



Limting sea conditions (Hs, Heading) according to tank level 1

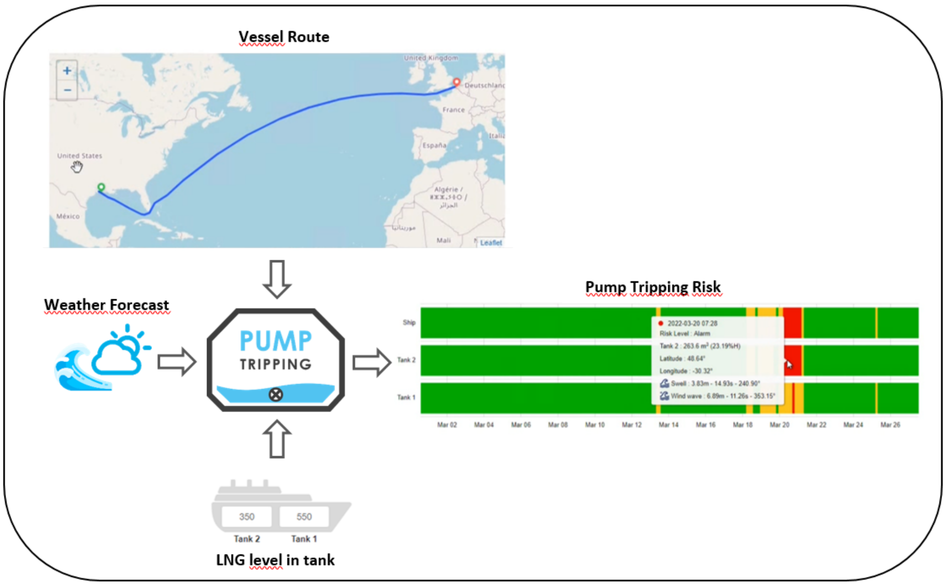


Limting sea conditions (Hs, Heading) according to tank level 2

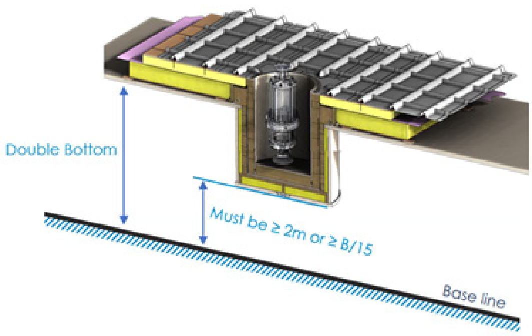
The embedded algorithm is trained on hydrodynamic simulations for a large set of sea conditions and ship loading cases.

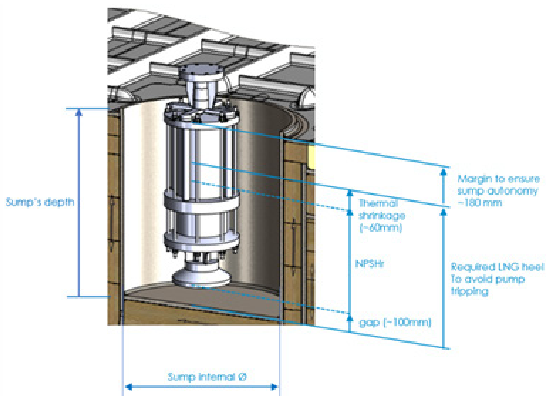
This enables the software to predict the leg of the trip at risk with regards to the fuel pump tripping.

Mitigation actions such as speed reduction, heading optimization or weather routing can be proposed to help the crew manage the situation.



In order to optimize the low filling limit, GTT has also developed a sump solution in order to maintain the fuel pump in LNG whatever the sea conditions met by the vessel.





The sump is designed so that in the event of liquid motion in the tank, it allows a sufficient autonomy between two refills so as to maintain the LNG height inside the minimum required level for the pump.

The distance between the sump bottom and the vessel base line is limited to two meters by the IGF code. This generally influences the sump depth according to the double bottom size proposed by the ship's designer.

Based on the sump depth that can be proposed for each ship's hull, a pump with an adequate NPSHr (generally between 0.1 and 0.35m) should be selected to ensure that the pump does not trip with a large volume of unpumpable LNG in the tank.

With the application of a sump and the selection of a pump with proper NPSHr, the LNG pumpable volume can be increased by 7% to 12% of tank Volume compared to a fuel tank without sump.

LNG AS A FUEL

Future-proof solutions for LNG fuelled PCTCs (Pure Car and Truck Carriers)

GTT has developed a new design of an LNG fuelled energy-efficient Pure Car and Truck Carrier in cooperation with its long-time partner, Deltamarin. The vessel will meet the current and future environmental targets by introducing a well-studied and genuinely clean-fuel technology, incorporating advanced GTT Mark III LNG tanks and Deltamarin's expertise in developing state of the art, fit for purpose vessels.

The shipping industry is facing environmental challenges that are urgent, yet difficult to solve. Global emissions have to be significantly reduced and actions must be taken now. Emission regulations exist for all sea areas and are becoming more and more strict. Efficiency can be improved, but other measures are certainly necessary. The next logical step and the most efficient way to comply with the new emission rules is to go forward by using low carbon fuels such as LNG.

Optimised ship arrangement with a Mark III tank

When using LNG, the operational challenge has been the autonomy of the vessel, bunkering intervals and loss of cargo space due to the larger space required for fuel storage.
To find the optimal solution as well as the most effective resolution, various arrangements were studied to find the optimised size and location for the LNG fuel tank on a PCTC.

Vessel endurance and energy consumption have been simulated using known speed profiles and sea conditions on routes between Asia, Europe, Australia and New Zealand. With a 3,000 m3 LNG fuel tank, the vessel can achieve up to 19,000 nautical miles of autonomy running on LNG.

This targeted volume is reached thanks to a fuel tank of cubic shape, with limited breadth to fit between the pillar rows that are essential for the ship structure. The LNG tank arrangement is shown in Figure 1, with the membrane LNG tank in blue and the pillars highlighted in red.

The tank length is scalable to adapt to required LNG capacity, which could reach up to 5,000 m3 and can be adapted to specific ships profile. Mark III technology, thanks to its compactness and modularity, enables to minimize the impact of LNG propulsion on cargo loss, saving up to 2% of total CEU capacity compared with other LNG storage technologies.

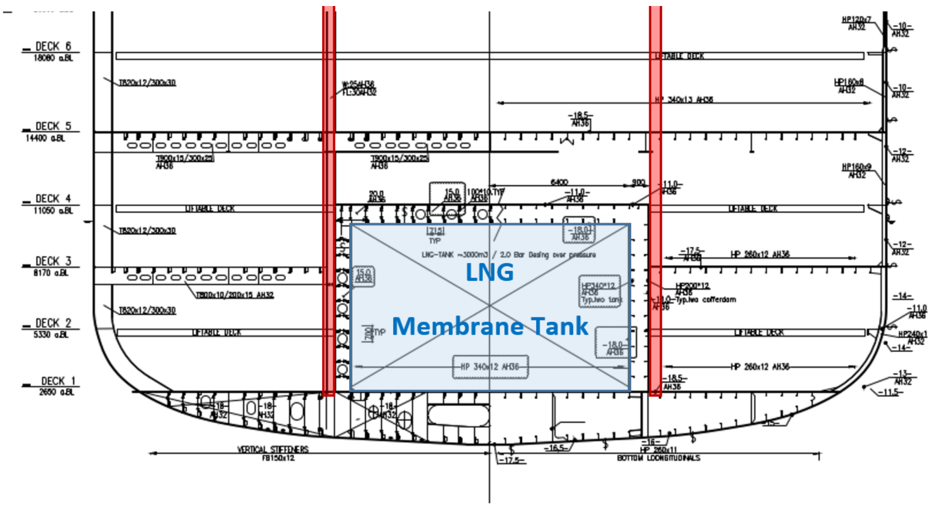


Figure 1 - Extract of PCTC Midship section in the vicinity of the LNG tank

Specific sloshing campaign leading to low Boil-off rate

This specific and particular tank shape, led to unknown sloshing behaviour inside the tank, especially in the corner areas. The containment system (CS) reinforcement has been validated by an extensive test campaign on hexapod rigs, covering the main PCTC loading conditions and many filling levels inside the LNG tank. This campaign enabled the CS reinforcement to be precisely adjusted. This limited reinforcement minimizes the natural boil-off rate (BOR), which can also be further improved by using Mark III Flex technology (CS thickness increased from 270 mm to 400 mm). This could be particularly helpful to adjust the amount of boil-off gas (BOG) at design stage depending on the expected operational profile of the ship and her fuel gas handling system (FGHS) architecture, including type of main engine, auxiliary engine and use of shaft generator.

During the research, the designer Deltamarin has optimised the main engine output to correspond to the actual power demand of the operational profile. This includes a recommendation on how to utilize the BOG in the most efficient way by various combinations between the main engines, auxiliary engines and shaft generator on different operational conditions. Then the complete FGHS architecture has been developed and studied on a generic PCTC design with our partner Høglund Gas Solutions, from equipment sizing to 3D integration in the Tank Connection Space and Fuel Preparation Room.

2 barg maximum pressure and extended holding time duration

In order to further enhance the vessel flexibility, the GTT fuel tank solution for PCTCs features an increased MARVS of 2 bar gauge (pressure unit in excess of the atmospheric value. This increased pressure has already been successfully applied on Le Commandant Charcot, PONANT's luxury exploration cruise ship fitted with two Mark III fuel tanks and classed by Bureau Veritas. This 2 barg application for Mark III technology also received an Approval in Principle from DNV and ClassNK. More details on this topic and the Alternative Design it requires can be found in previous edition of GTT Inside dated June 2021 and in a technical paper published for Gastech 2022.

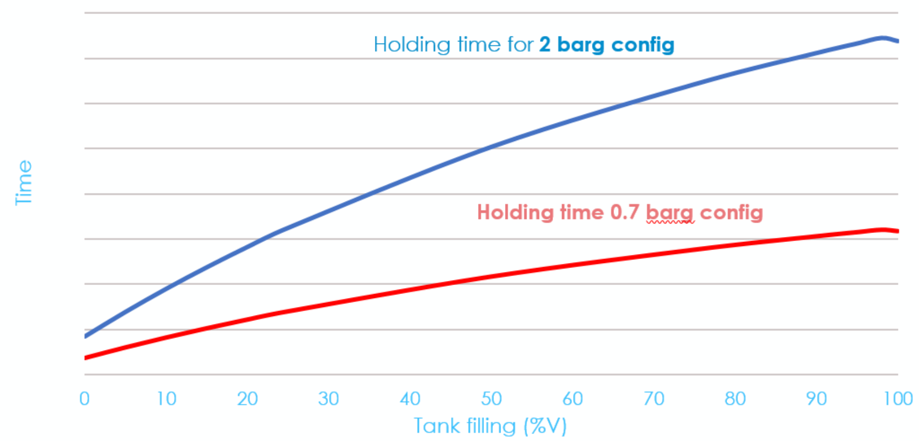


Figure 2 - Holding time comparison between 0.7 barg and 2 barg in a closed tank configuration

The hull scantling in way of the LNG fuel tank has been assessed considering this increased service pressure.

As the hotel load of PCTC is usually low, the 2 barg feature is then very useful in order to handle idle phases by pressure accumulation. We can see on Figure 2 that an increased MARVS improves the duration prior to safety valve opening, hence improving the safety on-board and providing a greater flexibility to operators.

The simulation has been made with the following parameters:

- Two tanks of 2,200 m3 (cruise ship application)
- Starting pressure = 50 mbarg
- No gas consumption
- BOR = 0.20%V/day (equivalent to 150 kg/h in pure CH_4)

Offering an increased pressure range brings several advantages:

- Increased holding time (with and without gas consumption) as it can be seen from above,
- Bunker LNG with warmer temperatures (from “lower quality” supply chain) when necessary,
- More flexibility with regards to high transfer rates and vapour return management,
- Minimize risk of wasting BOG during low consumption phase or venting BOG in case of emergency situations.

This new LNG fuelled PCTC design and all related deliverables have been reviewed by DNV and received an Approval in Principle in April 2022.

Thanks to this detailed study and the associated developments made with reliable partners, GTT is now able to offer a complete outline design package of LNG fuelled PCTC with a flexible concept able to adapt to shipowner’s specific requirements. Such a design allows shipowners and operators to capitalise on the potential of LNG as a marine fuel in order to comply with the emissions targets without having to compromise on cargo capacity.

INNOVATION

Ballast-water-free into the future

Every day, many ships carry on board a considerable quantity of seawater as ballast over the oceans. Technically, this is needed in empty or partially loaded conditions, in order to maintain seaworthiness, to reach sufficient draft for propeller immersion and to avoid excessive bow slamming.

Taking in big quantities of ballast-water requires investment for the on-board systems and leads to substantial operating costs. In addition, sediments may cumulate at the bottom of the ballast tanks, creating further costs and corrosion problems.

On the environmental side, in addition to the generated emissions, transporting ballast water may transfer harmful aquatic organisms and pathogens when the ballast-water is discharged in the arrival port.

The IMO Ballast Water Management Convention is dealing with this major global problem. In most cases today, the compliant solution is by installation of a ballast-water-treatment-system.
However, the best solution is not to use any ballast-water at all: then, the operator is 100% compliant without any treatment or investment.

Solutions with a so-called V-shape hull are generally proposed. The basic idea is to obtain a somewhat higher draft in the design load case, and by that, maintain also a sufficient draft for safe navigation, even when empty.

This principle can be used as far as a draft limit is not attained. For big deadweight carriers (such as Suezmax carriers) it will be impractical.

To overcome these issues, GTT has investigated several concepts and, in their latest approach, has extensively tested their proposed design to reach a fully operable and reliable solution.

The new concept takes full advantage of the specific membrane geometry: the hull lines and the incorporated membrane tanks are designed to match perfectly, and free surface effects of the LNG are reduced when the ship is partially loaded.

GTT Developments

GTT as technology provider is continuously innovating and proposing new solutions to the maritime world. Over the recent years, GTT has been working on this topic with different Designers and Shipbuilders.

7,500 m3 LNGc design

The view shows a 7 500 m3 single-screw design developed in cooperation with FKAB in Sweden. Such a design is well adapted for small-scale LNG distribution in highly sensitive areas such as the Baltic Sea.

« B-Free » 28,000 m3 LNGc design

Within a Joint Industry Project, a 28k single-screw vessel with two-tanks was designed. GTT Partners were Dalian Shipbuilding Industry Corporation, Lloyd's Register and Exmar from Belgium.

The studies comprised a full sloshing test campaign at GTT, seakeeping calculations made by LR, the vessel design work done by DSIC and interface and operation aspects reviewed by Exmar.

Also, a first batch of seakeeping tests were performed in SSSRI ship model basin in Shanghai.

The outcome and good results are very promising. An AiP was issued by Lloyd's Register, confirming the design feasibility.

The « Shear-Water » project: extensive testing proves the concept

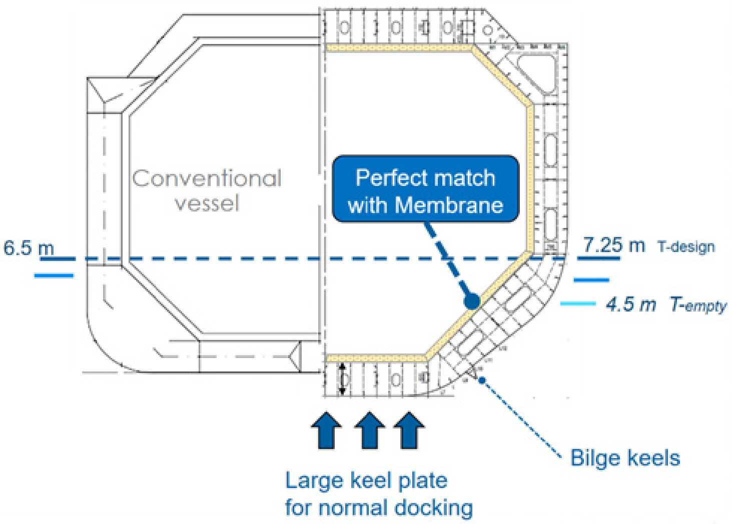
18,700 m3 LNG Feeder & Bunker vessel « Shear-Water »

Building on the experience gained on the previous ballast-water-free projects, as well as the recently constructed membrane type LNG Bunker vessels, GTT has developed a new concept for a vessel, which may serve either as LNG bunker vessel or as regional feeder.

The design proposes numerous advantages, such as reduced investment & operating costs, simplified operations, reduced corrosion and a prolonged lifetime.

General Dimensions are : Length x Beam x draft = 141 x 25 x 7.25 m
For a Cargo Volume of 18,700 m3 at a Design Speed of 14.0 knots.

Two identical cargo tanks are provided for simplified operations and a very effective Anti-Roll-Tank system is provided in the vessel's fore part.



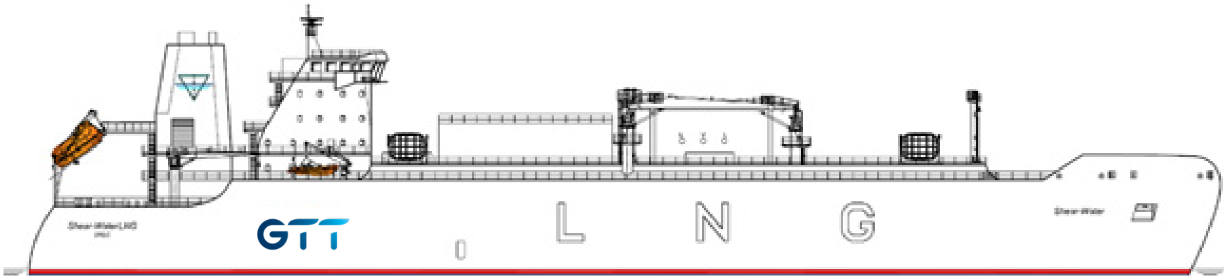
"Shear-wayer" Midship section versus conventional vessel

Compared with the two previous designs, Shear-Water has a twin-screw azimuth propulsion system, increasing the manoeuvring performance and providing a high power reserve in harsh conditions when empty.

Emissions are reduced through lower consumption, on average by a power reduction of over 10% versus a conventional vessel.

Specific issues such as pilot boarding, trim regulation and dry docking were identified, investigated and solutions validated by design.

Especially in coastal trades with frequent calls to major rivers, the benefits are substantial.



Ship design general aspects

Trim-management is one of the important design issues for such a vessel: careful longitudinal distribution of weight and buoyancy is made by design, and a genuine trim-water system is provided, using some dedicated fresh-water which is permanently on-board. The trim can always be managed in a satisfying, rules-compliant way. The vessel is designed in fully loaded condition at zero-trim and in empty condition with some aft-trim which improves the propeller immersion. In this respect, the use of a bulbous bow shape was not beneficial, also with regard to often changing drafts when operating as LNG-Bunker-Vessel.

The **cargo tank filling** can be at any level without restriction as demonstrated by the liquid motion campaign conducted. The operator has just to make sure the vessel's trim is in the required range - from zero trim to about 1.5 m aft or possibly 1 m forward - and compliant with visibility rules.

Roll-motions are effectively reduced by substantial bilge-keels and further by the Anti-Roll-Tank ("ART" from Hoppe Marine). The installation in the forward part is to say "ideal", as the space is available without any cargo loss. The ART design is made for the vessel in empty condition but it may also be used in loaded conditions with somewhat reduced effect. The operation of the ART is optional, not "mandatory", and it uses the onboard trim-water, without losing cargo-deadweight.

The question of **Parametric Rolling** was assessed by HSVA, the Hamburg ship model basin, and can be totally excluded due to the specific hull shape.

Effective construction is kept in mind for easy assembly and inspection of the hull structure. The full double structure (bottom, sides and also the upper deck) is mainly composed of void spaces giving substantial advantages compared to a ballasted structure.

Docking is made in the same way as any ship: even in empty condition, the vessel can be put in even keel condition to avoid hazardous conditions and the provided large keel plate with supporting side girders assures the required transverse stability even when dry, without further side supports.

The vessel's **Outfitting** is proposed on a state-of-the-art basis. Latest knowledge from other LNG Bunker vessels is taken into account for the user's benefit.

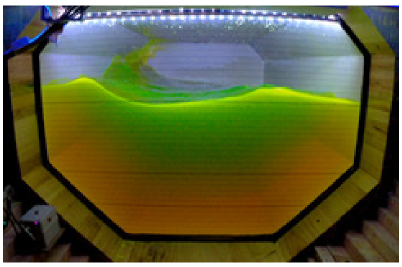
The **propulsion system** is chosen with Dual-Fuel electric power generation based on three identical gensets and two azimuthing propellers (design provided by Schottel) driven by electric motors. Such configuration gives the best flexibility, high redundancy and best economics for all operations.

The Shear-Water design is evaluated, based on the present propulsion system, to be **EEDI compliant** for ordering the vessel before 2030. Further improvements may be incorporated over the detailed design process, in close cooperation with the chosen Classification Society.

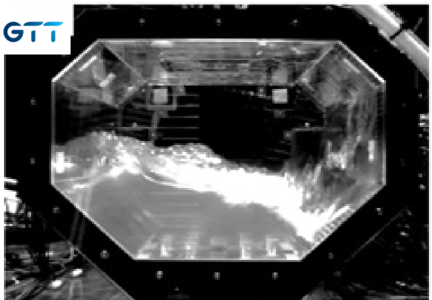
Hydrodynamics and liquid motions

Key design aspects are the hydrodynamics and in-tank liquid motions (sloshing).
On behalf of GTT, an extensive test-campaign was made by **HSVA**. It validated the ship's behaviour in calm-water and the vessel's seakeeping in severe sea-states.

In GTT's **headquarter laboratory,** the membrane system was validated for worldwide conditions without any filling restriction.



Incorporated model tank on board (HSVA)



Hexapod testing in GTT Laboratory

Both campaigns showed results ranging from good to excellent.

Hydrodynamics

The tests were made with a **self-propelled model** in a scale of 1:18, a length of 7.75 m and a laden weight of 2.8 tons.

Classical calm water tests covered speed-power and manoeuvring. Outcome showed a power reduction of 10-15% for the range 10-14 knots, when considering average values between fully loaded and empty conditions. All compared with a same size & same function, conventional vessel. *

Manoeuvring tests showed results exceeding IMO requirements and expectations. The design shows perfect course keeping, combined with excellent manoeuvring capabilities.

Seakeeping performance was tested in selected sea-sates up to NATO Sea-State 7 (Hs 7.5m). No unusual, excessive or dangerous behaviour in the selected sea-sates has been observed. Observations were similar to other ships in such conditions.

Tests and investigations covered motions and accelerations, rolling including parametric excitation, slamming, Propeller immersion, green water and speed loss in waves.
Course keeping in waves is considered good and the ship was never found to be out of control.

Further tests were made for pilot transfer operations. Comparative tests with & without Anti-Roll-Tank (ART) showed a roll reduction of about 60%.

Additional separate tests were made with the incorporated (single) LNG tank, investigating coupling effects between tank liquid motions and external wave excitation.

Sloshing campaign and optimised Membrane containment system

A dedicated **full sloshing campaign** was made for worldwide conditions. The obtained good results show no filling restrictions for the chosen containment system **Mark III Flex.** The insulation foam density is standard 130 and partially 150 kg/m3.

The design Boil-Off-Rate with the above values is 0.165%vol./day.

Cost reductions go with better environment

First estimates show a cost reduction of about 5% in terms of **Capex** as there is no ballast water system (pumps, valves & pipes, smaller sea-chests) nor treatment system (BWTS) and a reduction of air vents & sounding pipes control.

On the **operational** side, an annual reduction of around 100-200k$ can be expected thanks to fuel savings due to power reduction when empty (smaller displacement), and a reduction of energy consumption with the lack of ballast water system, no pump power consumption, consumables and spares. Maintenance costs are also reduced by eliminating ballast tank coatings, ballast tank anodes, ballast tank paint and no more maintenance due to sediments. It saves a lot of time due to less cleaning work during dry-drock and therefore savings in docking time.

Last but not least, **emissions** are reduced by 10-15% compared with a conventional vessel. A good step for a better planet.

Conclusion and Outlook

GTT's new Ballast-Water-Free design concept has been proven for safe navigation. Beyond this, « Shear-Water » marks a real environmental progress, combined with economic advantages.

The concept may also be used in other ship types, typical candidates could be tankers, container ships and general cargo vessels.
Key operational questions are addressed and Approvals in Principle were obtained from China Classification Society, Det Norske Veritas and Bureau Veritas. Full contractual maturity can now be reached in short time.