Technology for a Sustainable World

GTT Inside

The GTT newsletter - March 2022 - n° 24

Message from David Colson, Commercial VP of GTT

I am pleased to be able to introduce the second GTT Inside of 2022. After introducing in January our Digital solutions for vessel performance optimisation, we return in this edition to our traditional containment system business, but not just for LNG Carriers!

Of course, you will be interested to learn more about our latest low boil-off (0,085% of cargo volume per day) NO96 system evolution; the Super+, which is now in production for 10 vessels. In addition, we will be introducing innovative concepts for an Ultra Large Ethane Carrier (ULEC of 150.000 m^3) as well as a long-range Very Large Crude Carrier (VLCC) with a hull-integrated membrane fuel tank. We will also revisit our land storage tank design, concentrating on one of the key factors of its recent success; its low carbon footprint. All these innovations help reinforce our efforts to accompany the energy transition with technology for a sustainable world.

David COLSON

LNG AS FUEL

Long range LNG-fuelled Very Large Crude Carriers (VLCC)

Currently in the doldrums, the Very Large Crude Carriers (VLCC) shipbuilding market is expected to rebound by the end of 2022. In partnership with major shipyards from China and Korea, GTT has developed several designs for long-range LNG-fuelled VLCCs. Having tackled several key technical hurdles, including design, construction and operation, those vessels offer enhanced trading flexibility and reduced OPEX, while taking full advantage of the GTT Mark III system for the fuel tank.

As of today there are 760 VLCCs[1] crossing worldwide oceans. The vast majority are burning conventional fuel oil in vessel's main engine to propel 320,000 tons deadweight cargo at approximately 13.0 knots. Social pressure and newly implemented regulations have pushed ship owners to look for alternative bunkers in order to reduce emissions of greenhouse gases as well as particles. Among all the available options, LNG fuel has drawn most of ship-owners' and charterers' attention. Operational expenditure (OPEX) of VLCCs are significantly reduced when using LNG as fuel, driven by the price difference between long-term contracted LNG fuel and environmental compliant fuel oil.

GTT, in partnership with major shipyards, has carried out technical and financial assessment of LNG-DF VLCCs fitted with a long-range fuel tank capacity. Such long-range design feature allows the vessel to make a return trip with a single bunkering operation in order to optimize voyage duration and to bunker at the cheapest location, and also to minimize series of additional fixed costs such as bunkering fixed fees, etc.

GTT and shipyards have brought their expertise together to integrate this LNG fuel tank with limited impact on the ship design and shipbuilding duration.

[1] *Clarksons database*

Shipping routes and order forecast

Crude oil is the most traded product with a global traded value of around 1,000 billion US dollars in 2019 (The Observatory of Economic Complexity). The Middle East region is the main exporter (37%) while the main importer is Asia (54%).

Figure 1 - instant picture of VLCC trades - Source: IHS/MINT

The future of the VLCC market development mainly depends on fleet replacement, ship financing, environmental pressure, charterer's image and demand for new technology. Considering 20 years vessel lifetime, it is expected that 38 VLCCs per year on average would have to be replaced during the next 20 years.

Advantages of round-trip capacity

LNG fuel is quite different from conventional fuel oil bunkers. LNG bunkering infrastructures have known a fast development for the last 3 years, but it took almost a decade to launch 20 large LBVs (LNG bunkering vessels) in the world. The LNG bunker market is more mature in Europe with a wide availability of LBVs. Asia is catching up, especially in Singapore having ambitions to be a major LNG bunkering hub, while the LNG bunker offer in Americas is still limited in particular for large volume.

Routes	Distance for round trip (nm)	Required net LNG volume (m^3)	Required gross LNG volume (m^3)
Middle East – Europe *(via Suez)*	8,000	4,000	4,300
Asia – Middle East	13,000	6,100	6,500
Asia – US West/Panama West	17,000	7,800	8,300
Asia – West Africa	20,000	9,100	9,700
Asia – Europe	20,000	9,100	9,700
Asia – Latin America	26,000	11,600	12,400
Asia – Gulf of Mexico	30,000	13,300	14,200

Table 1 – Required LNG capacity for main VLCC trades

LNG bunker price in Asia is usually more expensive than in Europe or in the USA (less competitive market, less diversity of gas supply) – to the exception of the current recent situation. A VLCC fitted with a large fuel tank capacity can purchase LNG bunker at the cheapest location.

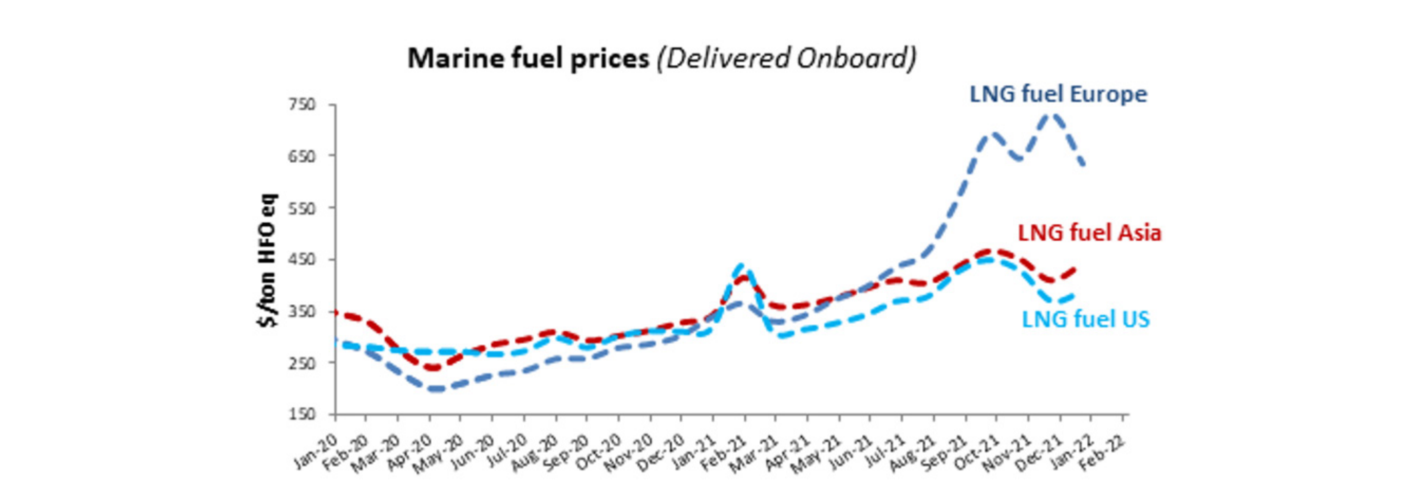

Figure 2 - LNG fuel contracted prices (including bunkering fees) - Source: GTT analysis from Henry Hub, ANEA and LNG Europe

LNG bunker price breakdown includes LNG price, chartering and terminalling fees of LBV. As shown in Figure 3, LNG bunkering cost becomes cheaper when bunkered volume increases, as economies of scale are done 1) on CAPEX & OPEX of LBV and 2) on terminalling fees (who have a share of fixed cost). Hence financial savings can be achieved if single bunkering operation is carried out for a round trip.

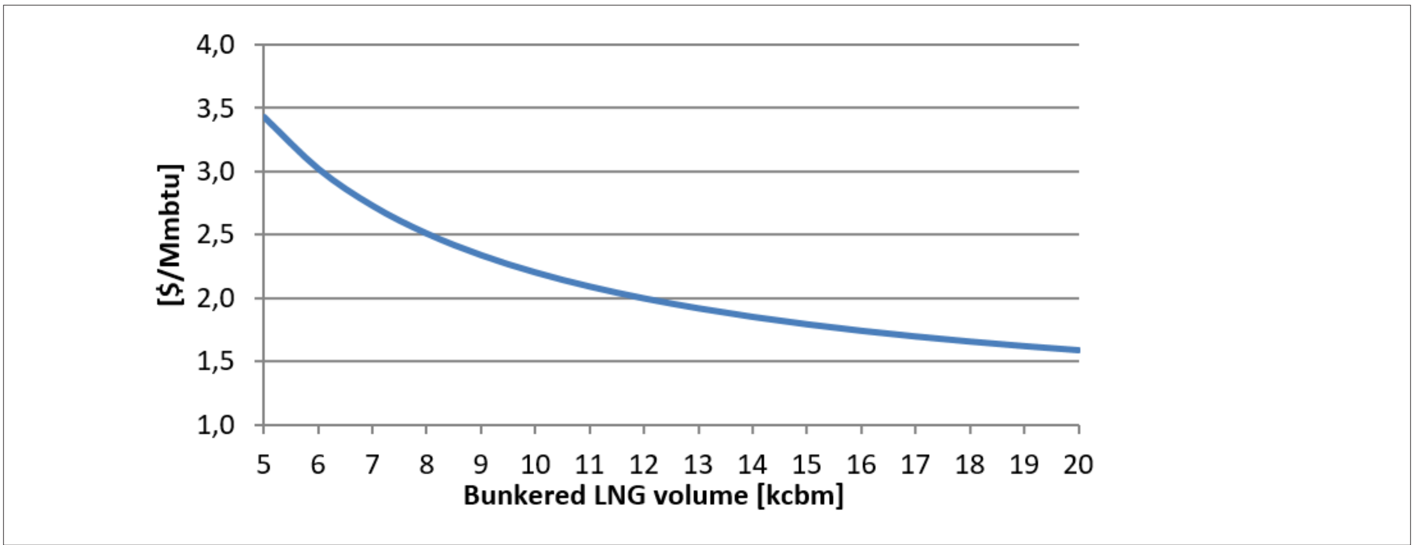

Figure 3 - Bunkering cost (without price of the molecule) - Source: GTT analysis

Thanks to potential LNG price arbitrage, cheaper bunkering cost and shorter idle time per round trip, an LNG-DF membrane VLCC could offer savings of up to 1M$ per year[2] . The advantage of having a large fuel tank onboard can maximize the cruising range and the flexibility.

[2] *Estimated at 300k$ for LNG price arbitrage at 1$/Mmbtu, 600k$ for cheaper bunkering cost and 150k$ for shorter off-hire. Source: GTT analysis.*

Integration of membrane LNG fuel tank

Overall, a VLCCs length is usually between 330 to 340 meters and the maximum deadweight is between 280,000 tons and 320,000 tons. LNG-fuelled VLCCs should keep the same main particulars as conventional VLCCs. The cargo area consists of three lines of five oil tanks separated by two longitudinal bulkheads and two slop tanks.

After looking at several positions, the most suitable location for the LNG fuel tank is in the cargo area in order not to affect the visibility and to avoid weather exposure on the main deck. The tank geometry has been customized to fit in between the two longitudinal bulkheads, close to the mid-ship of the vessel.

This location comes with several other advantages from an operational viewpoint but also from a performance standpoint. Firstly, the mid-ship of the vessel area comes with perpendicular to the sea water's side shell, suitable for safe mooring of the LBV. Secondly, the LNG bunkering station and the LNG fuel tank are close to each other, minimizing piping distance and related cost. Thirdly, the mid-ship location has a limited impact on the vessel stability behaviour, and enjoys reduced accelerations.

Many parameters of the tank dimensions are then fixed, such as breadth and height. The LNG volume can be adjusted by increasing the tank length according to the targeted cargo capacity and vessel cruising range.

Several VLCC designs have been studied with different tank configurations from 9,000m^3 to 14,000m^3 and a careful attention to remain above the cargo target of 2.1 million barrels.

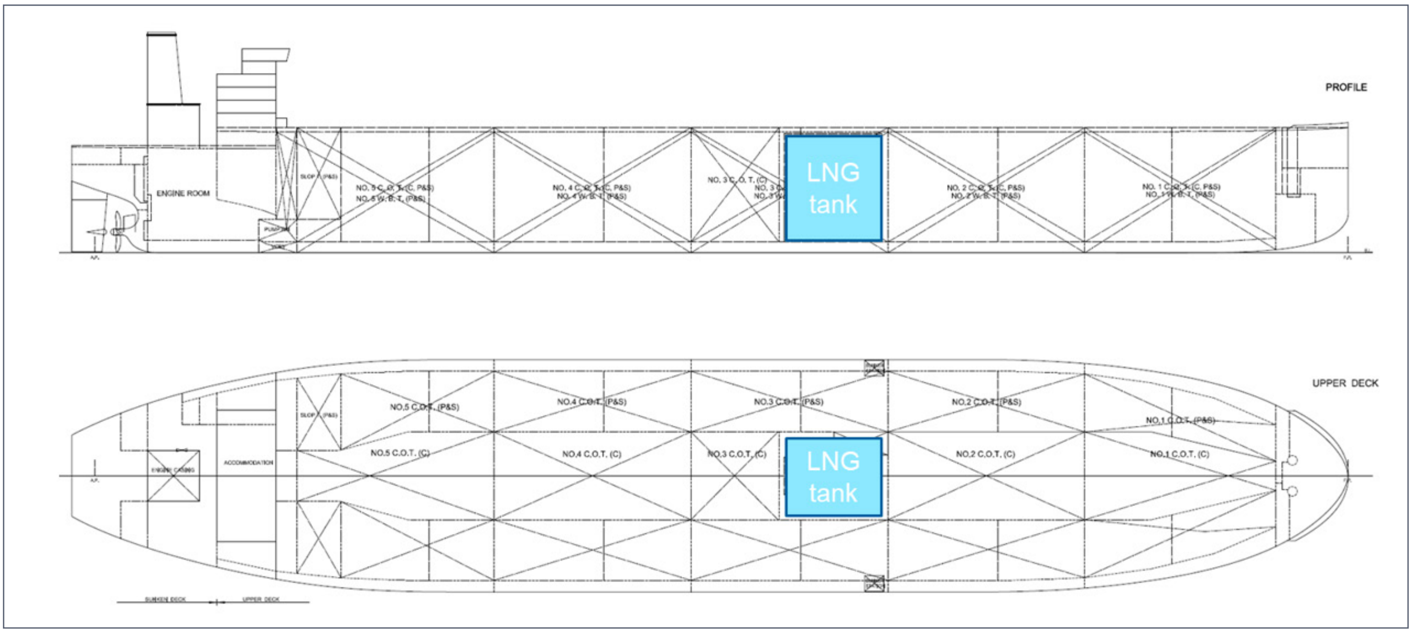

Figure 4 - VLCC fitted with 11,000m^3 membrane LNG tank - Source: HSHI

VLCCs are amongst the largest ships in the world, with design draft above 20m and moulded breadth (B) of 60m. These very stable ships usually have long rolling period, especially in laden condition. A narrow LNG tank will have a short resonance period. These two period values are distant so sea waves have less effect on liquid inside the tank, as shown in Figure 5. Thanks to this low value of ratio B(tank)/B(ship), sea waves will generate limited waves in LNG tank, resulting in low sloshing loads.

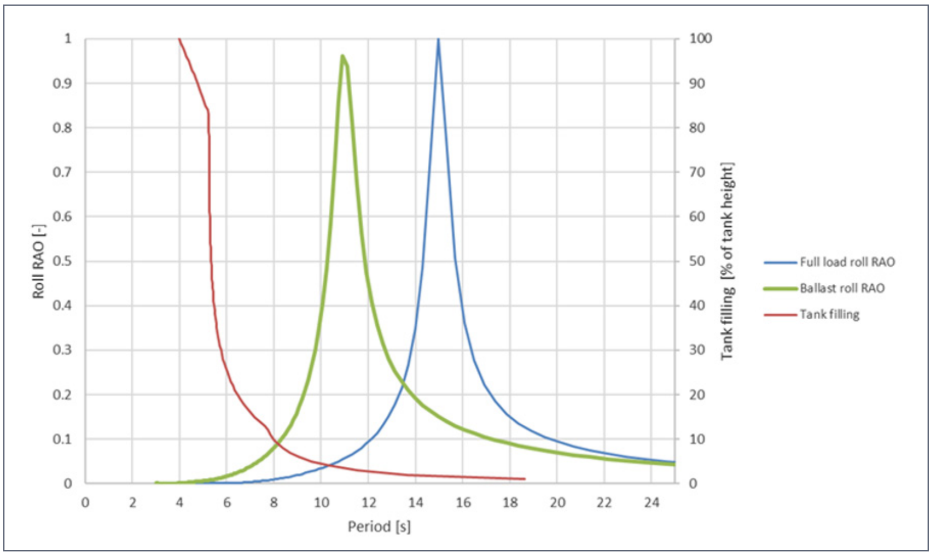

Figure 5 - VLCC roll RAO (Laden and ballast conditions) vs resonance period in LNG fuel tank

Extensive test campaigns on hexapod rigs as seen in figure 6 confirmed these low sloshing loads and enabled GTT to select a typical LNG carrier insulation panels of 130kg/m³ density, which are more cost effective and provide a better boil off rate (BOR) performance.

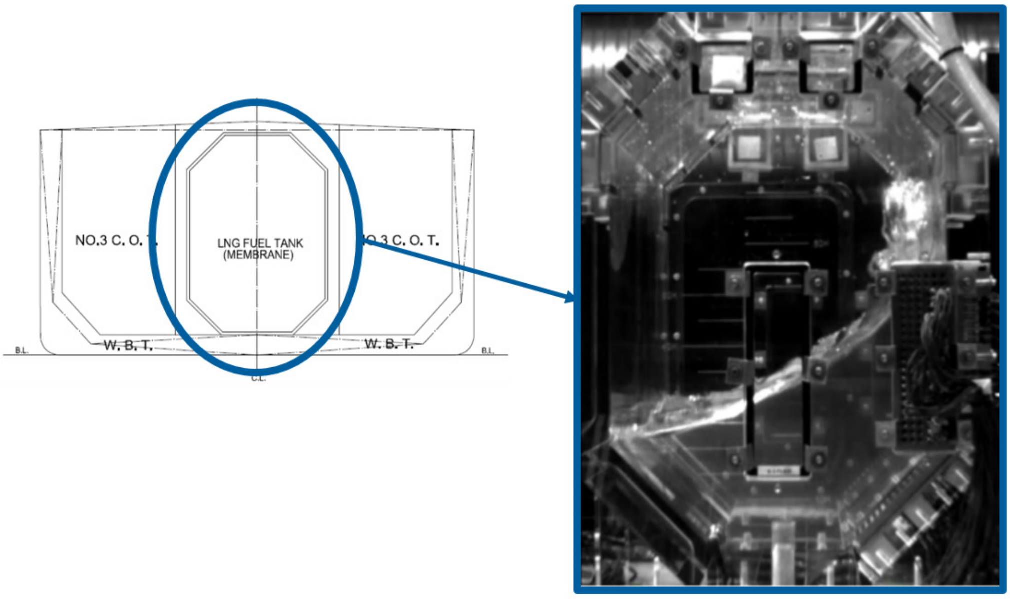

Figure 6 - VLCC sloshing campaign

Main voyage phases	Singapore to Middle East (ME)	Idle ME	Crude Loading ME	Middle East to China	Idle China	Unloading China	China to Singapore	Bunkering Singapore
Duration	13 days	5 days	2 days	18 days	1 days	2 days	5 days	1 day
Consumption	15MW	850kW	2,1MW	15MW	850kW	10,1MW	15MW	850kW

Table 2 - Typical VLCC operational profiles sailing back & forth on Middle East - China road - Source: GTT and charterers

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The standard foam density in LNG tank containment system results in a limited natural evaporation of fuel from the tank. Based on a typical operational profile covering a round trip voyage from Middle East to China via Singapore as described in Table 2, pressure evolution results (Figure 7) show that the highest tank pressure (around 350 mbarg) will occur at the end of the bunkering operation, when the onboard electrical load is the lowest and the LNG bunker is heated by the transfer. As soon as the bunkering is completed and the vessel starts sailing or running cargo pumps, the fuel tank pressure can be reduced down to 100 mbarg. The pressure in the tank always remains within a sufficient with a margin with regards to the maximum pressure of 700 mbarg (MARVS).

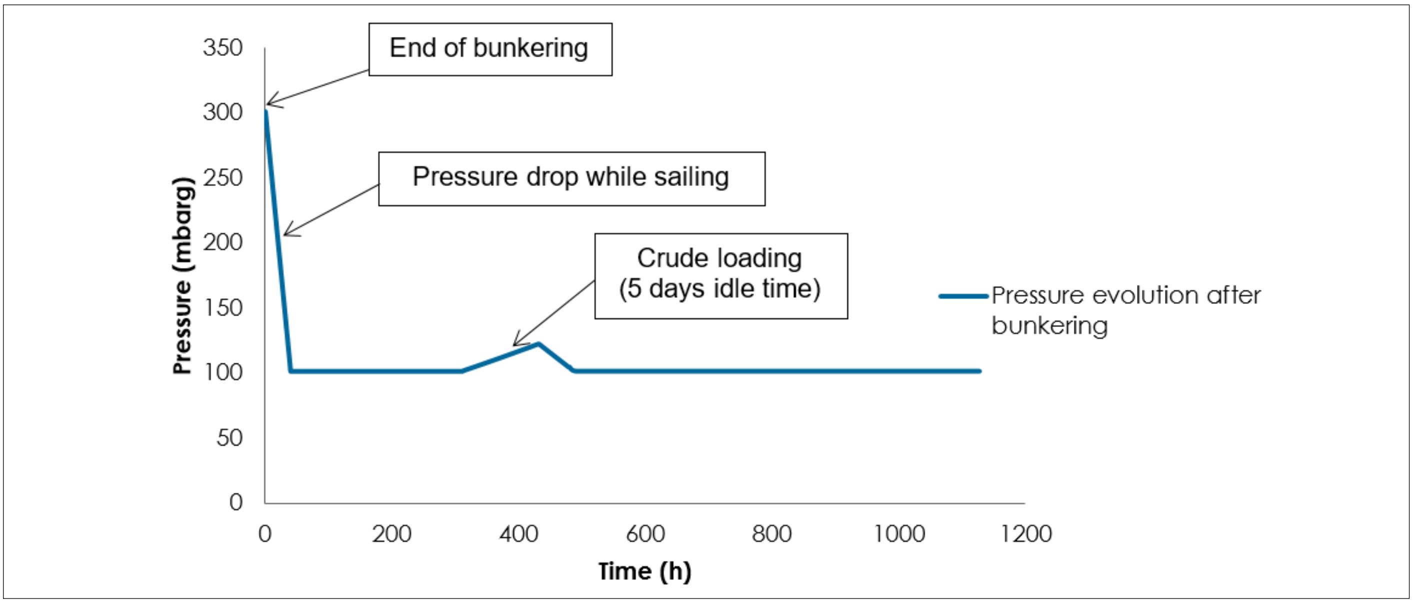


Figure 3 - Bunkering cost (without price of the molecule) - Source: GTT analysis

IGF standards require a boil-off gas management system for a LNG fuel tank to allow for pressure holding in tank during at least 15 days (21 days for USCG). By selecting a dual fuel boiler designed to take maximum design boil-off gas from tank, it is guaranteed that an infinite holding time can be safely reached. Operators also have the choice to keep pressure in tank without running boiler. GTT has carried out holding time simulations for different membrane fuel tanks, from 6,000 m^3 to 14,000 m^3. Hypotheses taken include an 850 kW electrical load and 90% loading level. Calculations demonstrated that for all sizes of LNG fuel tank, a minimum 30 days of pressure holding can be achieved when auxiliary engines run at minimum load.

Conclusion

Compared to a conventional VLCC, there are many advantages in adopting long range LNG fuelled VLCC. Such assets come with a high trading flexibility for the ship-owner and the charterer, able to efficiently operate on chart basis but also spot market. Her large fuel tank capacity is also seen as an advantage for re-sale market. Membrane VLCCs take full advantage of the Mark III system, with high thermal performance and maximum useful volume by locating the tank in the centre part of the vessel.

We have seen that significant operational expenditure savings can be achieved as the owner can bunker at the cheapest location, avoid unnecessary idle time and benefit from scale savings on bunker parcels.

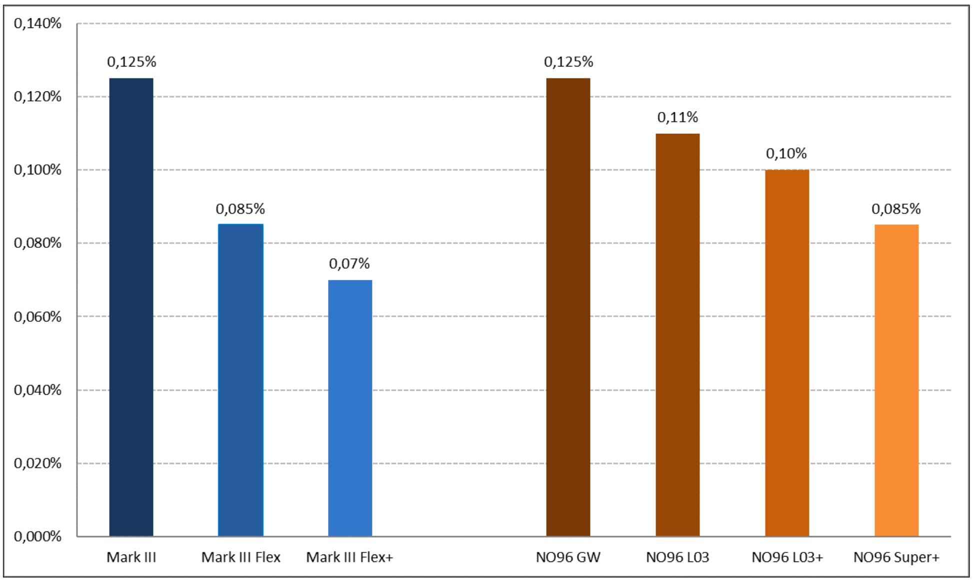
Most importantly, such a design is an immediately available solution to new environmental regulations and social pressure.

TECHNOLOGIES

NO96 Super+: the latest GTT's technology with increased thermal performances

GTT membrane technologies continue to evolve over the last years, based on significant feedback from operational experience, in order to meet the requirements of ship-owners and shipyards, while also complying with regulatory changes affecting the sector.

GTT has introduced several new technologies in order to minimise the evaporation of the cargo during operations. As highlighted on the below graph, since 2010, the guaranteed Boil-Off-Rate (BOR) achievable with GTT technologies has been significantly reduced from 0.15%V/day down to 0.07%V/day.



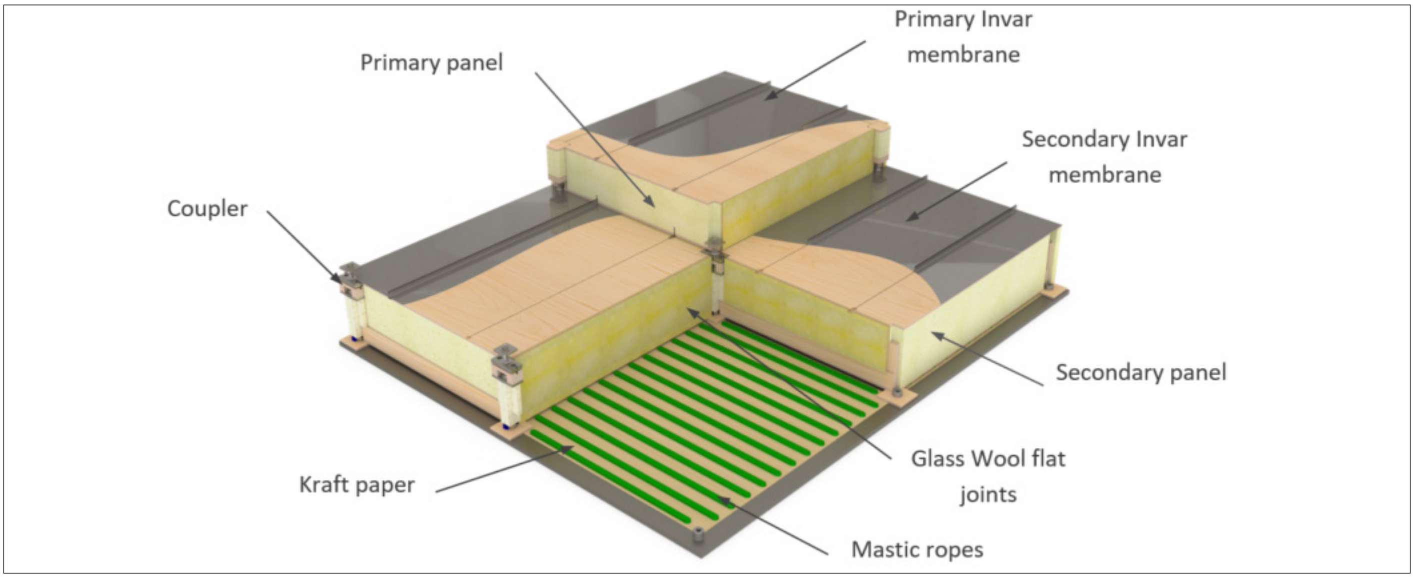
Boil Off Rate of Cargo Containment Systems on 174K LNGC

Until now, the lowest passive BOR available with NO96 system is equal to 0.10%V/d using NO96 L03+ system. In order to complete the NO96 family offer with a guaranteed Boil Off Rate equal to 0,085%V/d GTT has recently developed a new Cargo Containment System named NO96 Super+.

The new NO96 Super+ technology is an evolution of the NO96 containment system maintaining its principal features, in particular the double Invar® metallic membranes and the mechanical anchors fixing the insulation panels to the hull.

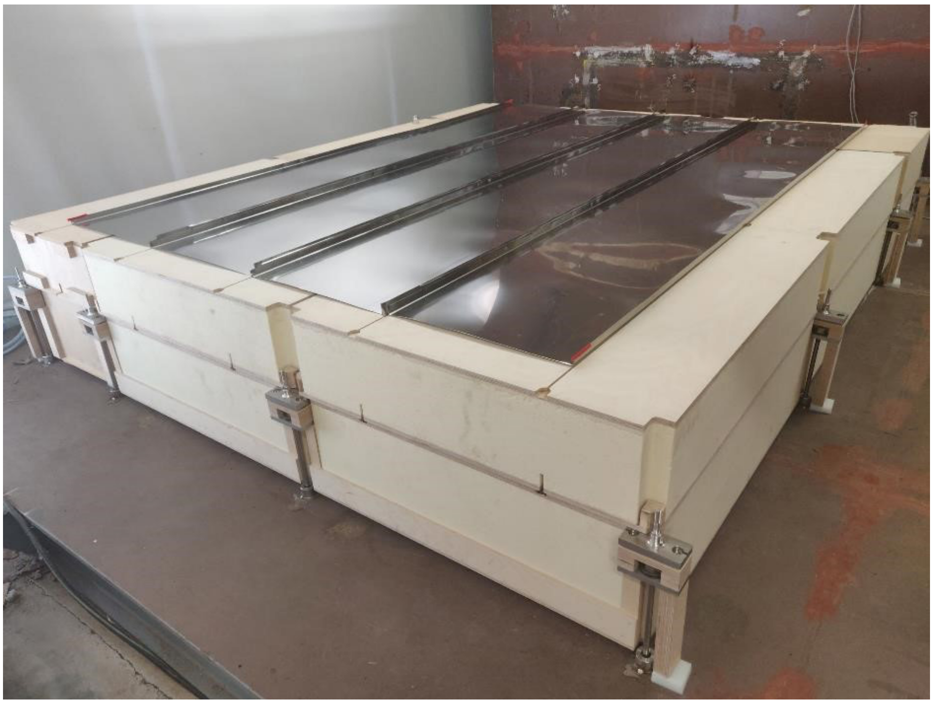
NO96 Super+ offers the advantage of a reduction in the heat ingress inside the tank by using insulating Reinforced Polyurethane Foam (R-PUF) panels instead of plywood boxes. Thermal performance is additionally improved by the addition of Glass Wool joints, inserted between adjacent foam panels.

With this innovation, GTT provides a solution to reduce the evaporation of the cargo, with NO96 Super+ guaranteeing ship-owners a daily Boil Off Rate (BOR) of 0.085% of volume for the current standard size design of LNG Carrier of 174.000 m^3.



NO96 SUPER+ design description

The erection philosophy is identical to other NO96 systems: the anchoring of the insulation panels is made with couplers benefiting from the excellent feedback for years on NO96 ships. The assembly of the NO96 Super+ have been validated through a mock-up at GTT premises.



NO96 SUPER+ mock-up

The design and validation of NO96 Super+ has been thoroughly reviewed by the classification societies in 2021. This review has led to a Final Approval of the containment system by American Bureau of Shipping (ABS), Bureau Veritas (BV), DNV GL and Lloyd’s Register (LR) as well as the first orders from ship-owners.

TECHNOLOGIES

Onshore storage - GST® Membrane Full integrity system environmental footprint assessment

What is the environmental footprint of an LNG onshore storage built with GST® membrane technology? How does it compare to the Full Containment 9%Ni technology, widely used in the industry?

With the current emphasis on decreasing CO_2 emissions, governments and financial institutions incite developers of LNG import and export projects to find solutions to minimise the carbon footprint. As a result, more and more players in the industry inquire us about the environmental performance of our technologies, as the carbon footprint has become a key indicator in the investment decision-making process.

GTT has therefore worked with ‘RDC Environment’, an expert of environmental impact assessment, to calculate the environmental footprint of our GST® tank solution used for LNG onshore storage.

This is the first study on LNG land storage assessing the full potential environmental impact, including not only greenhouse gas emissions, but also other environmental impacts such as acidification, particle emission, resource depletion, etc.

This article unveils the results of this extensive analysis. This study has used EU standard as reference and enables the comparison with other storage technologies.

The main outcome of the study is that GST® technology improves the global environmental impact by 23%, and more specifically the CO_2 emissions by 16% compared to the Full Containment 9%Ni technology.

Scope of the study

The strength of this study is that it covers the entire life cycle: from the “cradle to the grave”. This avoids potential bias that could arise if only focusing on the final assembly of the tank, without including the raw materials, their extraction, transformation, transport but also the end of life such as the dismantling and recycling of the tank.

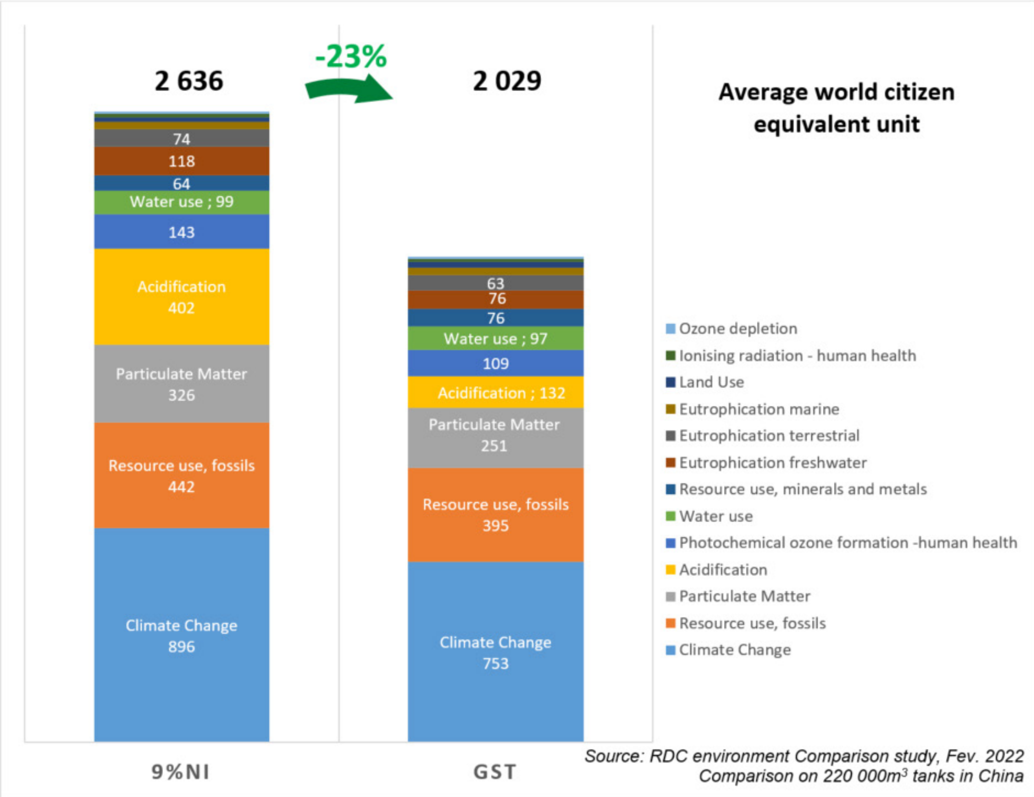
The study is based on figures referring to an LNG onshore tank of 220,000 m^3 considering a building location in China. Similar characteristics such as storage volume, performance (Boil of Rate), etc. are used for the different tank technologies for a fair comparison. The scope of the study includes the external structure (the concrete) and the tank containment system (insulation, etc.).

GST® Improves the global environmental impact value by 23%

The environmental footprint can be analysed through various angles. To begin with, we can consider what is called the “Global Environmental Impact Value”. It is the combination of 16 environmental aspects such as Climate Change (kg CO2 equivalent), Fossil Resources Used (MJ), Particulate Matter emissions, acidification (mole H+ equivalent), water used (m^3 world equivalent), mineral and metal resource depletion and many others.

The 16 sub factors are aggregated to establish a global value expressed in “Average World Citizen Equivalent Unit”. This is a representative unit defined by the JRC (Joint Research Center), an organisation providing scientific support to the European Commission on the environmental impact evaluation. To obtain such a unit, normalisation and weighting factors are used. The one considered comes from the standard JRC recommendation (EF v2.0).

The Global Environmental Impact Value of a 220,000 m^3 LNG onshore tank built with the GST® technology is 2029 Average World Citizen Equivalent Units. The same tank, built with the Full Containment 9%Ni technology, has a global environmental impact of 2636 Average World Citizen Equivalent Units. This means a 23% improvement when switching from Full Containment 9%Ni to GST® technology.

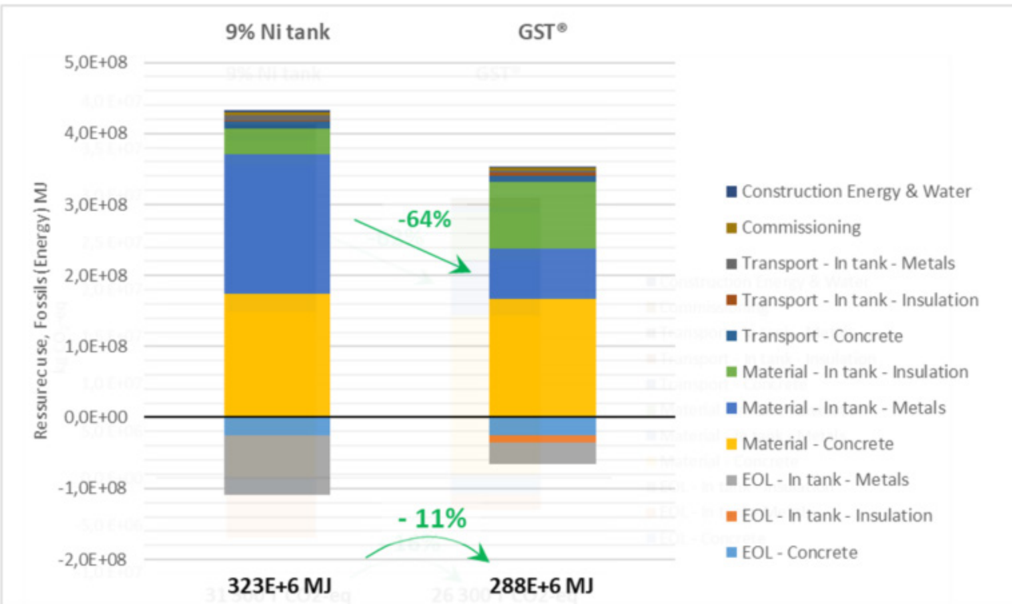


Source: RDC environment Comparison study, Fev. 2022
Comparison on 220 000m³ tanks in China

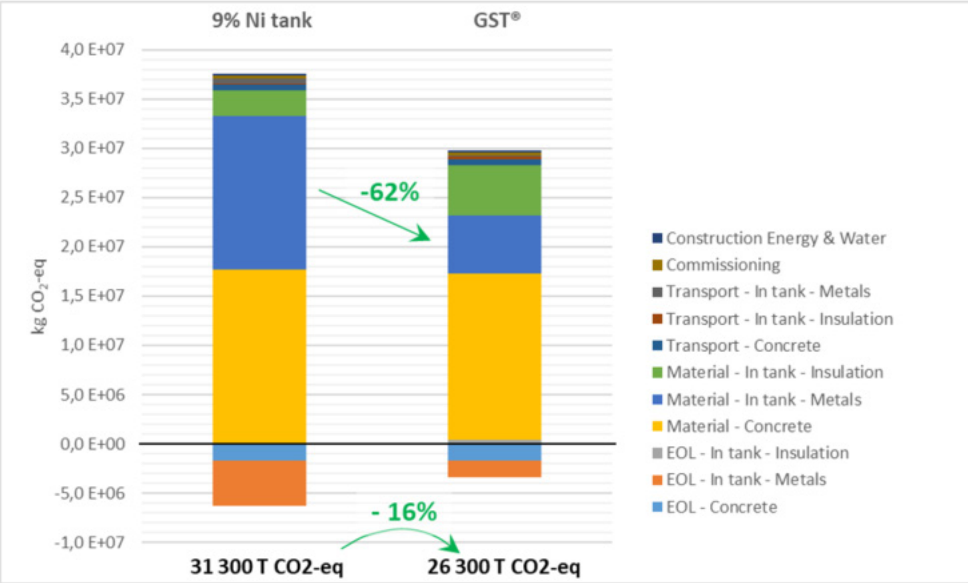
GST® improves the CO_2 emissions by 16%

Global reading values are interesting but not so tangible, so to go further into details, we propose to focus on the two main influencing parameters which are the Climate Change (CO_2 equivalent emission) and the Fossil Resources used (Mega Joule).

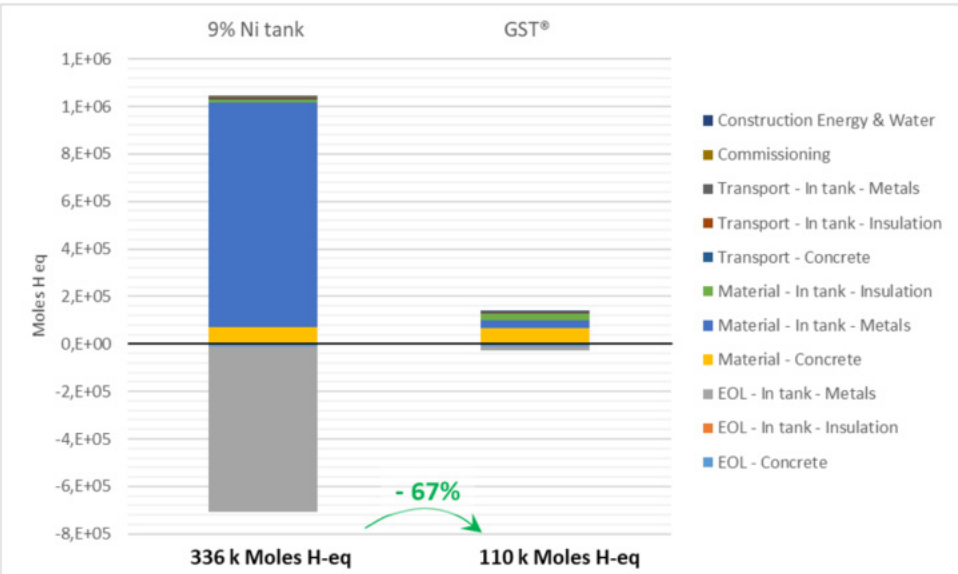
This shows that the GST® tank improves the Climate Change impact by 16% compared to the Full Containment 9%Ni tank (including the CO_2 emission and CO_2 saving from recycling process).



When looking at the Fossil Resources used, the study shows that the GST® tank reduces the energy consumption by 11% compared to the Full Containment 9%Ni tank (including the energy used and energy saving by reuse of the dis-mounted material)



The main differences between the GST® technology and the Full Containment 9%Ni technology are due to the “in tank metal material”, which significantly impacts the CO_2 emissions, the energy consumption and the acidification. The expla-nation is that the GST® technology relies on a metallic membrane, so a small amount of cryogenic metal is used in the tank, whereas the Full Containment 9%Ni tanks use a much thicker amount of steel.



Indeed, the Full Containment 9%Ni tanks use 4 times more steel, which means about 3 000 tons of steel for a 220,000 m³ tank. So, even if a high level of recycling of the steel has been considered (95%), the production and treatment of this steel material is affecting significantly the environmental footprint of the Full Containment 9%Ni technology.

Conclusion

Whatever the angle of analysis, be it global, such as the Global Environmental Impact Value, or more specific, such as Climate Change, Resource use, Acidification or Particulate Matter, the outcome remains the same: there is a significant improvement of the environmental footprint when switching from Full Containment 9%Ni to GST® technology.

GTT will continue to concentrate on the environmental factor in its future developments and improve them in order to meet its objective of developing technologies for a sustainable world.

INNOVATION

Ethane Shipping going larger with Ethane & LNG - The Ultra Large Ethane Carrier (ULEC)

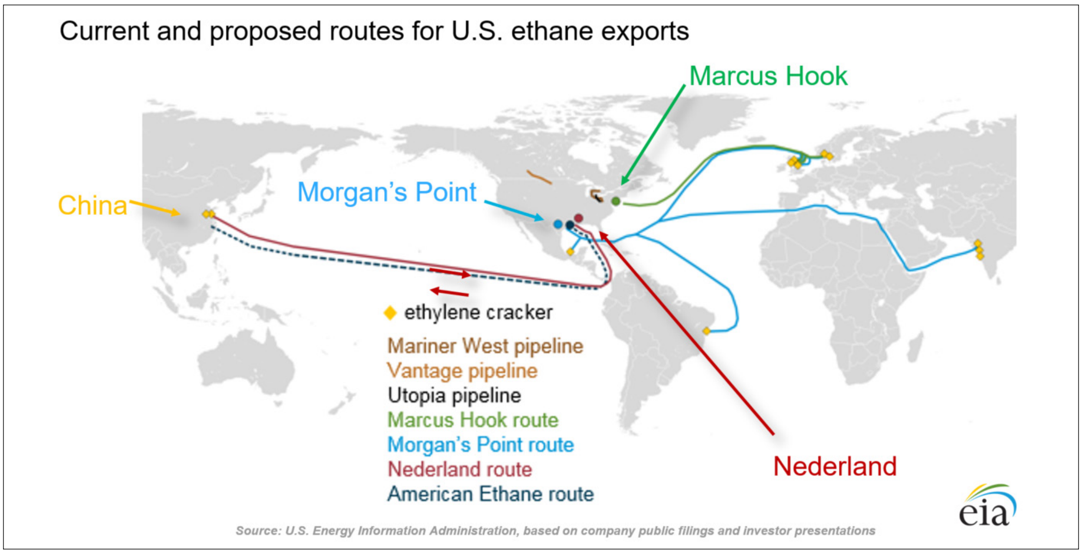
The US shale gas revolution has created a surplus of ethane production which cannot be monetized in the short and medium term in the US alone. This new supply provides opportunities for increased ethane trading between US and Europe, South America, India and most recently China.

In this context, during the past decade, the ethane shipping market has significantly increased and innovative ship designs allowing transportation of larger capacities have been developed. 2014 saw the FID of the first Ethane supply deal adopting the first membrane “large” Ethane carriers with a capacity of 87k, before further increasing in 2018 to almost 100k based on the Mark III containment system. Those vessels also include LPG and Ethylene on the cargo list.

As the VLECs reach the limit of the “VLGC” size, e.g 230m LOA, 36.6m beam to fit most of the world LPG terminals, going larger is possible with Ethane, but the fall-back cargo will need to be changed to another relevant cargo. LNG seems to be the most appropriated one.

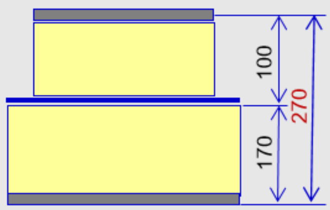
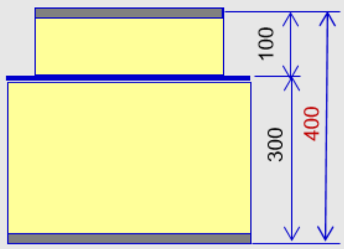
With the objective to support this growth, GTT developed through a Join Development Project (JDP) with Samsung Heavy Industries (SHI) a 150k multi-gases carrier able to carry either Ethane or LNG. This new design is a breakthrough solution, not based on a scale up of the previous Ethane Carriers, but based on the already optimized LNG Carriers design. It has been modified to carry ethane as a prime cargo and LNG as a fall-back, in order to give confidence to asset buyer through flexibility of trade.

The hull, with a LOA x B x Td of 274m x 42 x 11.9m has been developed with the objective to access all existing Ethane US terminals, Morgan’s Point, the Netherlands, and Marcus Hook, in addition to major existing LNG terminals.



With the idea to be active players in decarbonisation, SHI and GTT equipped this ship with a MAN ME-GIE (ethane) fuelled high pressure (380 bars) engine which, associated with a shaft generator, is able to reach 16.0 knots while satisfying the EEDI Phase 3 regulation. As an alternative, this engine is fuelable with methane thanks to general similarity with MAN ME-GI type engine. It is however not the case for auxiliary engines, where only methane fuelled engines are available so far on the market. The shaft generator will be in good use at sea to deal with this situation.

To anticipate future gas requirements, pure ethane, C1 Rich commercial ethane, pure methane and LNG have been considered as potential cargoes. Then, state-of-the-art low boil-off Mark III Flex (400mm insulation thickness) technology is applied with an optimized repartition of the foam density, which results in a breakthrough performance of absolute boil-off of ethane carriers. As an example, the absolute Boil off Rate for this 150k Ethane/LNG carrier is lower than the existing 98k Ethane carriers. The bellow figures presents this gain.

Items	98K VLEC	150K ULEC
B.O.G (t/h) for **Ethane**	**2.1**	**1.9**
B.O.G (t/h) for **Methane**	**2.6**	**2.5**
Insulation		

To manage this limited Boil off, the sub-cooling concept, safe and simple, limiting the Boil off Rate by reducing the temperature of the cargo, has been identified as the best solution and selected to equip this innovative ship. The subcooler is optimized for the LNG configuration. For ethane, the subcooler selected is capable to handle 100% of boil off.

GTT developed a smart solution to integrate the sub-cooler into the whole Boil off Gas (BOG) management system. Allowing both CAPEX and OPEX reduction. The GTT solution consists in integration of the subcooler with a low-pressure compressor and a fuel preparation system.

When the ULEC carries ethane, the process becomes the following:

- Fuel preparation system extracts methane rich gas from Natural BOG (NBOG) and supply of that gas to auxiliary engines.
- A Low-pressure compressor extracts NBOG from tanks and compresses it to the pressure required by auxiliary engines.
- Compressed gas is precooled by heat exchange with cold BOG into a pre-cooler heat exchanger
- Then, compressed gas is partially condensed by heat exchange with sub-cooled liquid ethane into a recondensor heat exchanger.
- Partially condensed gas enters C1-sep (liquid-vapour separator), vapour phase, rich in methane (>85%) is supplied to auxiliary engine.
- Methane number is controlled by variation of subcooled liquid ethane flow to recondensor heat exchanger.
- Liquid phase returns back to tanks.

No NBOG is fed to the main engines which allow the removal of the high-pressure compressor from the CHS scope. High-pressure compressor is an equipment requiring high maintenance. Removing it reduces both CAPEX and OPEX.

The main engine is fed with liquid ethane compressed by high-pressure pump and evaporated and heated through a high-pressure vaporizer. This has the advantage of supplying the main engine with a fuel with a stable composition and avoiding the risk of a too high methane content.

When the ULEC carries LNG, the fuel preparation system is in stand-by. The low-pressure compressor supplies NBOG to the auxiliary engines. The subcooler cools a stream of LNG and sprays it into tanks through spraying ramps. The main engine is supplied with liquid LNG through a high-pressure pump and a high-pressure vaporizer.

All main CHS equipment and FGHS equipment were checked for dual compatibility with suppliers and only a few days are necessary to change the cargo from Ethane to LNG making the solution very flexible.

By its versatility, this new generation of ship offers to customers being familiar with the LNG, a real opportunity to enter the Ethane market while keeping the LNG as a fall-back cargo.

As a first reaction, the fall-back cargo of LNG may be seen as too small. Surprisingly, the requirement for trade of such parcel, is needed especially for FSRUs. Therefore a 150k ULEC in LNG trading mode will find competitive advantage compared to this existing 130~150k fleet

A first analysis demonstrates a reduction of at least 20% of the Chartering cost per ton of ethane, compared to a 100k VLEC. This is mainly due to the scale effect.