Technology for a Sustainable World

GTT Inside

The GTT newsletter - June 2021 - n° 22

Message from Anouar Kiassi, Digital & Information VP of GTT

Developing technologies for a sustainable world requires solid convictions, a great deal of imagination and constant efforts in innovation. To tackle the new challenges that the maritime industry is facing, we need to combine various skills and complementary technologies. While answering the operational requirements, the new solutions must comply with the highest safety standards and remain simple. This has been the GTT goal over the last 55 years. Indeed, technological sophistication must go hand in hand with simplicity to increase the adoption of new technologies and reduce the risk of human errors. In this regard, digitalization is key. Smart algorithms can hide the physical complexity to allow unambiguous decision-making for efficient and safe operations.

In this issue of GTT Inside, we will see how these principles apply to GTT innovation. We will present digital solutions for efficient Boil-off gas management, ship-to-ship optimization and tank predictive maintenance. In addition, we will present the evolution of the GTT membrane capabilities for LNG fuel applications. Finally, we will share with you some exciting scientific findings we discovered during the LNG Brick test campaign.

Anouar KIASSI

DIGITAL

Sloshing Virtual Sensor

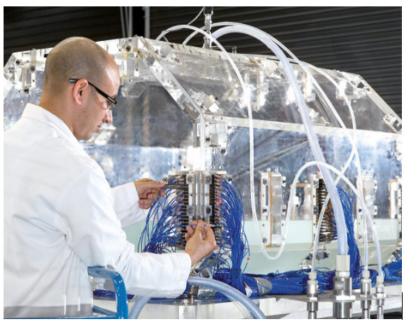
On worldwide shipping routes, LNG tanks sometimes face harsh weather conditions. Sloshing inside LNG tanks can create high loads on the containment system. GTT has developed tools to quantify it and even predict it at sea. This methodology can be applied not only for voyage management, but also for predictive maintenance of the tanks.

Methodology

GTT's researchers leverage machine learning techniques from our motion analysis platform (see picture). The resulting function behaves like a Virtual Sloshing Sensor.

The KPIs are made accessible to clients via dedicated solutions in order to support decision-making for:

- Sloshing management at sea
- Fuel gas pump tripping prevention at sea
- Tank maintenance



Combined with GTT's IoT platform, a robust onboard data acquisition, these features are supporting ship-owners in their daily operations, giving them, more than ever, an eye in the tank.

Sloshing prediction

Prediction of sloshing activity at sea is key parameter for efficient voyage management. While containment systems are well designed to sustain the impacts of liquid motion in tanks (sloshing), sloshing activity may nevertheless be significant. The cargo motion is not only a safety matter; it also has an impact on the ship performance.

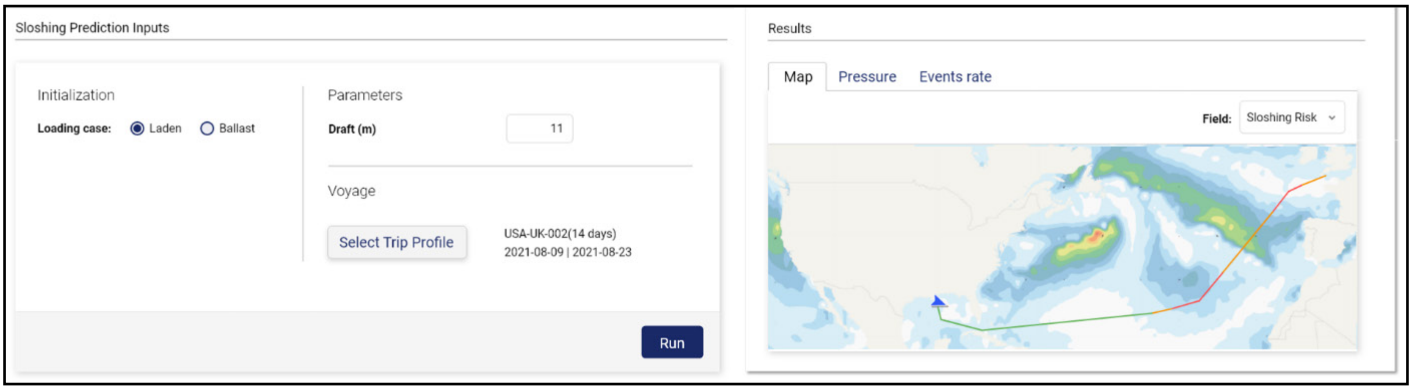
GTT has developed a tool to characterize the liquid motion activity from weather forecasts. Two main characteristics are estimated, the sloshing frequency and the sloshing pressure, which can be derived to define a sloshing intensity.

This predicted sloshing activity, can nurture mitigation actions, such as change of speed or course, if required (or tank to tank transfer operations for offshore units).

Pump tripping

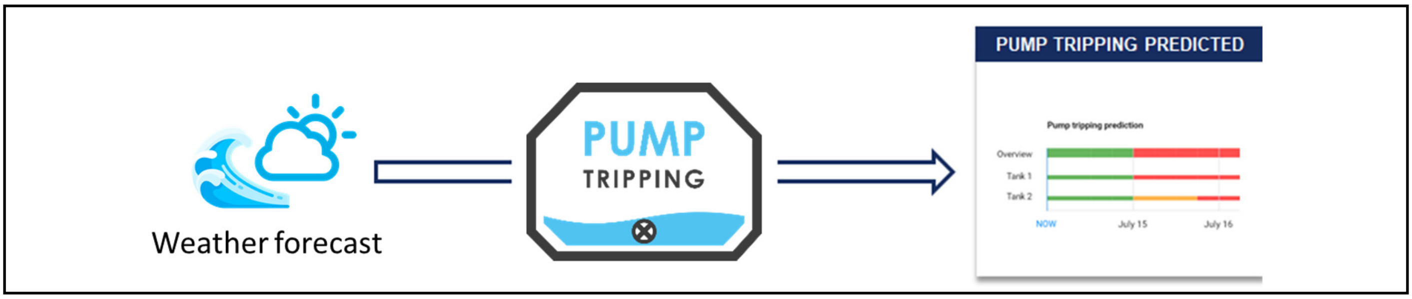
In the context of LNG fueled ships, fuel gas pumps in the tanks must be fed with liquid continuously.

The pump tripping, a situation in which the minimum liquid level above the suction head of the pump is not respected, may induce cavitation. Due to the acceleration of the liquid in the pump, the pressure can significantly decrease which may lead to the formation of the gas bubbles. This liquid phase change can generate shock waves in the pump power system and possibly create damage.



GTT has developed a digital solution to predict the risk of pump tripping for very low filling levels of liquid in the tank, when the ship is confronted with harsh sea conditions.

This tool, trained on refined numerical simulation results, can predict the risk of pump tripping for each tank on the planned route, based on the sea condition forecasts.



From this prediction, crew can then elaborate mitigation actions, such as enabling fins (if available on the vessel), change the vessel's speed or course, or adjusting the flow-rate of the pumps.

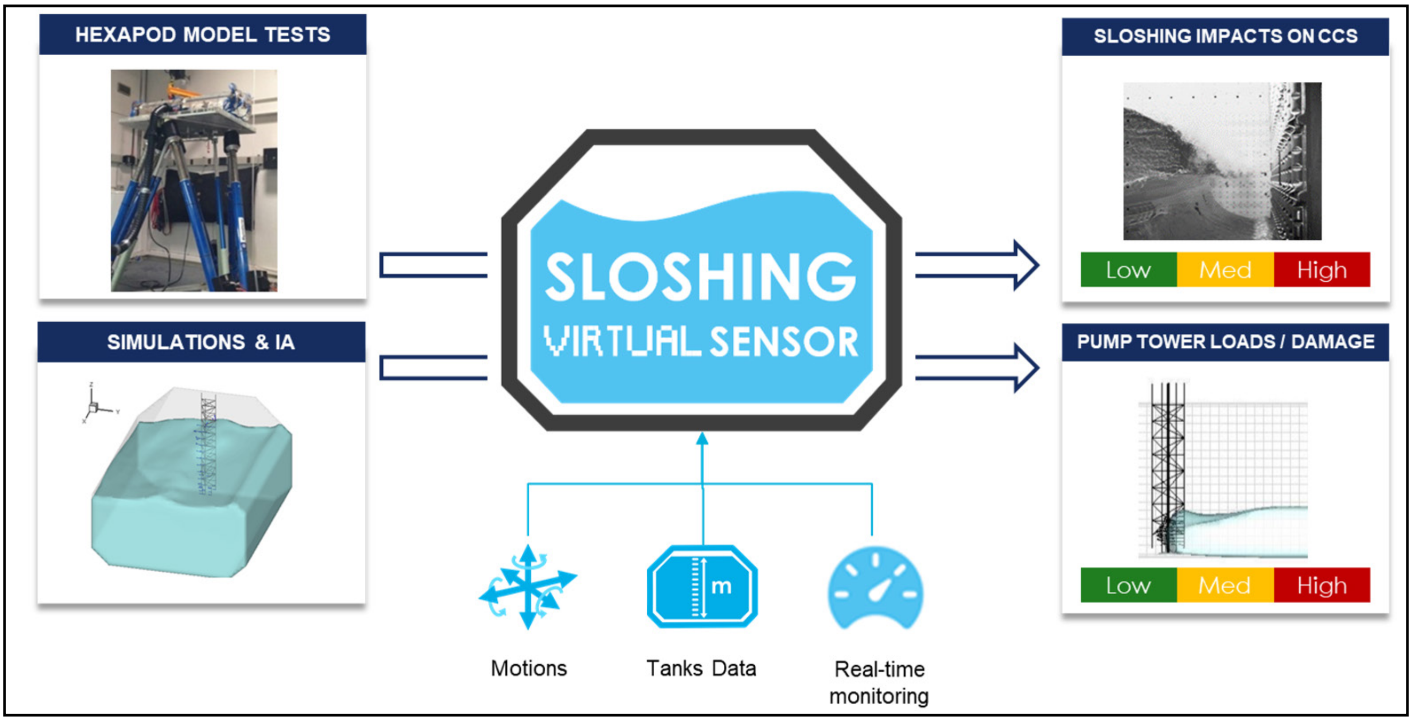
Virtual Sloshing Sensor to optimize the tank maintenance

Alternative inspection plans aim at increasing vessel utilisation and reduce downtime. In fact, a credible alternative to the regular inspection and maintenance cycle applied to LNG membrane tanks can lead to important savings and greater operational flexibility.

By combining risk analysis and the latest digital technologies, GTT offers effective tools to answer that objective without sacrificing the safety and the reliability of LNG tanks.

In the framework of an Alternative Survey Plan, the list of indicators to monitor is defined along with the associated thresholds and criticality of each trigger. More importantly, a digital system, combining an MRU and IoT platform provides the full range of data required to monitor the tanks continuously and optimize tank entries.

Our unique fatigue prediction algorithms and the collected data enable the Sloshing Virtual Sensor. Trained on a large scope of operational conditions of Sea States or Motions and loading cases (Draft, filling level…) seen by the ship, it derives the relevant indicators allowing informed decision-making regarding inspection optimisation. This is applicable to both the containment system and the pump tower (fatigue and strength).



In addition, all necessary critical parameters are monitored in real-time. Abnormal deviations are automatically detected by our supervisory rules and double-checked by the officer on duty in our 24/7 monitoring center. If any risk is confirmed, the Customer is promptly informed.

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DIGITAL

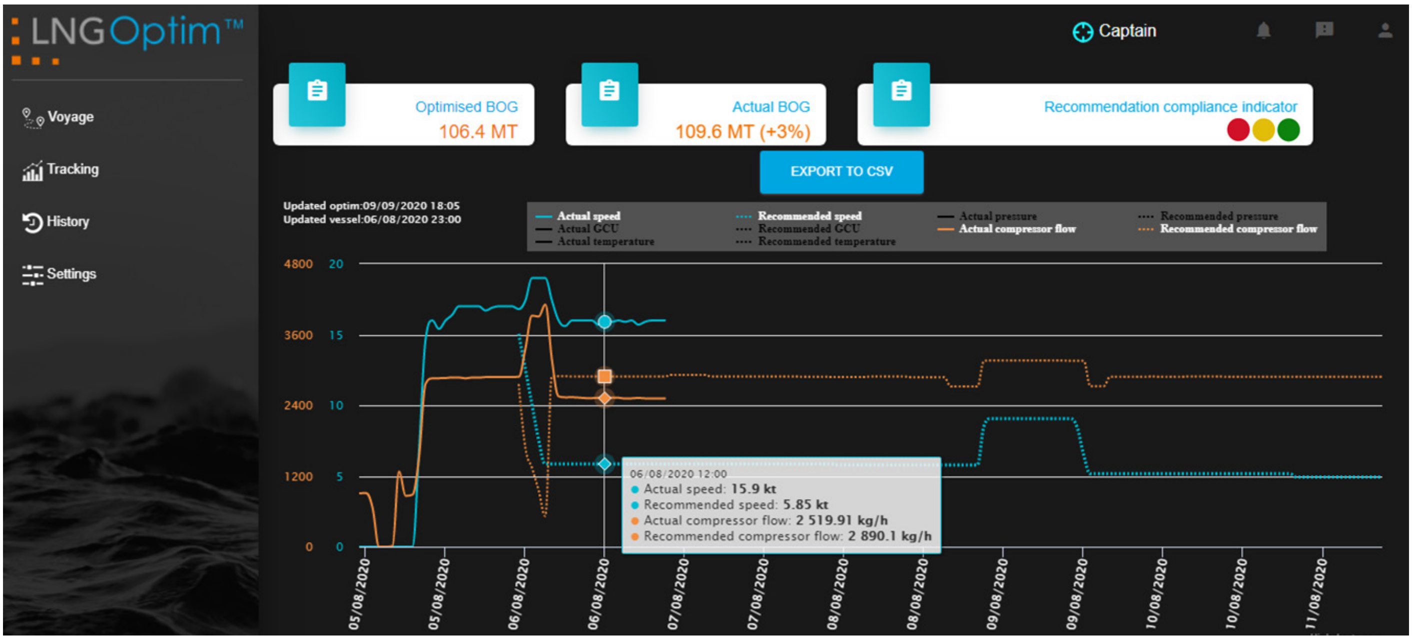
LNG Optim

Boil-off gas is a key parameter in LNG Carrier design and operations. It is directly related to the economics of the LNG transportation industry. Traditionally, we divide Boil-off gas into two components, static and dynamic. The first depends on the ship design and the performance of the insulation system. The second includes all the other factors that are variable during the operations such as the environmental parameters or the navigational decisions. Once the ship is designed, there is little margin to improve the static boil-off. However, the margin to improve the dynamic boil-off is significant.

Every LNGc operator has its own strategies and benchmarks to manage the boil-off. In addition, the way they monitor it is different depending on many factors like the maturity of the company, the awareness of the crew, the charter party conditions, etc.

GTT has studied the boil-off management of many ships in operation for a number of years. This confirmed that the operator metrics and strategies are indeed different. It also showed that some metrics and strategies lead to counterproductive "singularities" especially when the focus is exclusively on the Gas Combustion Unit and not on the overall consumption.

Based on its unique expertise, GTT has developed advanced algorithms to predict the LNG consumption during LNGc voyages. This includes the modelling of complex phenomena such as LNG ageing and the influence of sea states on Boil-off gas generation, in addition to the impact of active systems like reliquefaction plants and subcoolers.



LNG Optim helps plan the voyages in advance in order to reduce the overall consumption. If there is any changes in the voyage plan during the sea passage, the systems updates the recommendations accordingly.

LNG Optim is already deployed on many LNG carriers, old and recent. Old vessels use the system to improve the operational economics and reduce the emissions. In fact, with the environmental regulation becoming more and more stringing (e.g. EEXI), managing emissions is becoming a hot topic. For the new vessels with active Boil-off gas management equipment, GCU usage is rare in theory. This is no longer a relevant KPI for good energy management. Thus, LNG Optim makes sure the combined systems are used at the optimum level to avoid unsuspected over-consumption.

Captain Guy Nicholls, Director Marine Operations of Cheniere Energy, said: *"Collaborating with the GTT LNG Optim program will assist with achieving our goals to continuously improve operational performance and decision making for*

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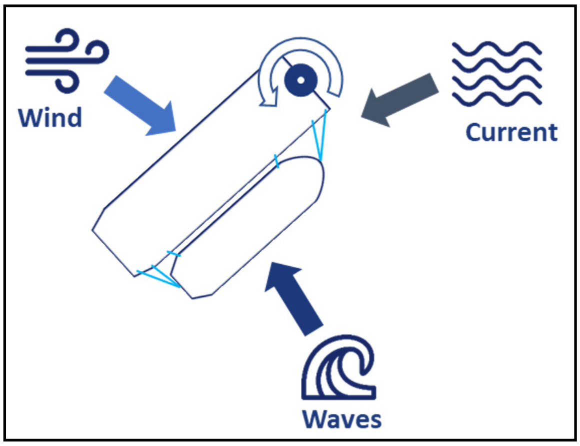
our globally-traded fleet and provide potential opportunities to further understand and reduce emissions."

LNG Optim is part of the GTT Digital Platform that offers other unrivalled smart shipping products for ship owners, charterers and operators.

DIGITAL

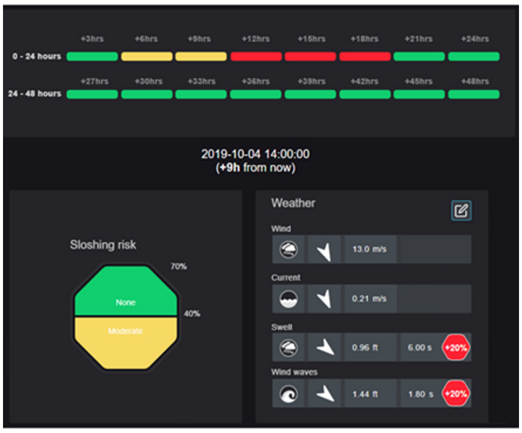
Ship-to-Ship optimisation: safety and operability enhancement

Offshore units (FLNG or FSRU) are loaded and un-loaded from/to LNG carriers during ship-to-ship operations. Some offshore units conduct up to 30 operations per year, and this number is expected to grow in the future, especially during winter where LNG demand is high.



During this process, the LNG carrier tanks can go through all possible filling levels. GTT membrane tanks are designed to withstand all sea states at high and low filling levels. However, some restrictions may apply for partial filling levels. When the weather conditions are harsh, the ship-to-ship operations can be forbidden.

In practice, the restrictions usually applied by LNG carriers are generic. They are based on statistical data or most-likely scenarios. This approach makes the restrictions too conservative most of the time, reducing the operability of the asset.



Thanks to our unique R&D facilities and modeling capabilities, GTT is able to assess in real-time the sloshing risk in any operating conditions (weather, filing levels ...) for any LNG carrier, FSRU or FLNG. GTT's sloshing assessment depends on the ship's specifics, and is therefore not over-conservative.

A recent study from a specific site revealed that the operability of the asset may be improved from around 80% up to more than 99% without any effect on the safety of operations.

GTT proposes a digital solution for sloshing risk assessment for LNG carriers during ship-to-ship operations for offshore units. It gives real-time prediction of sloshing risk based on weather forecasts, ship characteristics and operating conditions. This permits the anticipation of the potentially unsafe periods and maximise the operational window.

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INNOVATION

Approval in Principle (AiP) from DNV for membrane tanks with a design vapour pressure of up to 2 barg

Interest of increased design pressure

The maritime sector faces new challenges with the evolution of environmental regulations towards carbon neutrality and the corresponding nascent supply chains. LNG has proved to be the only immediate solution available for a greener shipping. Though a major opportunity for shipping, LNG comes with its challenges of usage of space and boil-off management.

GTT has developed LNG fuel solutions with the Mark III containment system, in particular for large applications like Container Vessels. The LNG tanks installed in those vessels usually have a design pressure or Maximal Allowable Relief Valve Setting (MARVS) of 0.7 barg in accordance with the IGF Code limitation for atmospheric tanks.

From our decades of experience of in-service vessels, this standard 0.7 barg design is compatible with the LNG supply chain and offers sufficient operational flexibility as long as the Boil-off gas (BOG) and relative tank pressure can be reasonably managed. The recent ULCVs equipped with GTT membrane tanks are a good example of this.

However, most LNG fuel tanks being significantly smaller than LNG cargo tanks, there is a margin – an opportunity – to offer more flexibility to operators with a few modifications to the system. GTT has worked on an improved design which increases the flexibility of membrane tanks for specific applications

Offering an increase pressure rating brings two main advantages:

- Bunker LNG with warmer temperatures (from “lower quality” supply chain)
- Increase pressure holding time (with and without gas consumption)

Alternative Design

Setting a membrane tank design pressure above 0.7 barg is beyond the stipulations of the IGF Code. However, the IGF Code allows modifications to the prescriptive requirements as long as the alternative design meets the goals and the functional requirements of the IGF Code and provides a level of safety at least equivalent to that of a prescriptive design.

For any future newbuilding project, the alternative design process requires the involvement of the relevant Flag Administration at early stage and their approval at Design stage.

AiP with DNV

This innovation recently passed another major milestone by receiving an Approval in Principle (AiP) from DNV.

The AiP with DNV is based on assessment of safety equivalence with tanks/vessels built within the limitations given by the applicable regulations.

The safety equivalence was evaluated by DNV in a systematic way considering the implications of the increased vapour pressure on the main components constituting the LNG tank and associated systems. The system breakdown was as follows:

- The containment system including safety systems
- Fuel tank domes (area where all pipes penetrate in the tank)
- The fuel gas handling system
- The load carrying hull structure

DNV reviewed not only the technical documentation justifying the capacity of the Containment System to sustain a vapour pressure of up to 2 barg but also the implications in terms of operation as well as in case of potential downgraded situations such as system leaks.

Before construction and installation onboard any particular ship or object subject to classification, a complete set of documentation relevant for the particular ship is to be approved by the Society according to normal classification procedures and the alternative design process.

Previous achievements

Prior to being granted an AiP from DNV, the same concept was already Approved in Principle by Bureau Veritas. As well as a general approval when GTT designed the containment system with a design pressure of 2 barg for the exploration cruise vessel of Ponant with two LNG tanks for a total 4,500 m3 capacity.

The alternative design process was indeed successfully applied for Le Commandant Charcot of Ponant, which is currently close to completion. It mainly consisted in submitting a technical validation to the French Flag, with justification of the equivalent level of Safety between the new design and a conventional design at 0.7 barg. This dossier had been reviewed by Bureau Veritas, and the design was approved by the Flag.

A solution for smaller LNG fuel tanks

Today, GTT is very happy to propose this solution with enhanced flexibility for many types of LNG fuelled vessel, from Cruise vessels to Car Carriers (PCTC) or Container Feeders, already evaluated by two major Classes.

A small step in design, a major gain in operation!

INNOVATION

LNG Brick® campaign tests

LNG is a clean and competitive fuel chosen by major industry players, who have launched significant newbuild projects for LNG fuelled vessels (LFS). Unlike LNG carriers, who do not berth for extended periods for other operations than loading or unloading, merchant ships have longer port stays, during which they sustain electrical loads through on-board fossil fuel powered electrical generators (auxiliary engines). For LNG fuelled ships, electrical load at berth is mainly generated with gas coming from natural Boil-off gas (nBOG). As the nBOG rate varies with the liquid level in the tank and the electrical demand varies with the commercial operations at port, these two values very rarely match. If nBOG rate exceeds electrical generator consumption, pressure accumulation will occur inside the tank. As it is a key parameter for LNG tanks, GTT decided to carry out experiments to ascertain the LNG behaviour and anticipate such a pressure increase.

A test campaign was performed by GTT last autumn on a 110m^3 LNG test facility (GTT LNG Brick® with 2 barg maximum allowable pressure).

The tests have been specifically designed to simulate the specificities of the real LNG fuelling operation. The impact of the filling level, as well as the ratio between ship fuel consumption and actual boil-off rate, has been measured. Pressure rise with the tank fully and partially closed have been investigated.

The LNG used during the experiments contained almost no nitrogen (less than 0.04% by volume) and was representative of the expected LNG loaded as a fuel.

The behaviour of the LNG inside any type of tank is greatly depending on the behaviour of a small layer of LNG at the vapour/liquid interface.

Figure 1 : LNG facility located in UNEMSA factory, Spain

This region has been carefully monitored thanks to a floating device developed by GTT. This floating device is able to measure several temperatures below and above the interface for any liquid level in the tank.

Thanks to this unique device, GTT is able to identify the very specific behaviour occurring at the vapour/liquid interface during the test. The very thin fluid layer (film) forming the interface is constantly vaporizing or condensing the fluid depending on the heat and mass transfer. Heat is mainly coming from the liquid due to the heat transfer through the insulation. Part of the heat is also coming by radiation from the top of the tank. This heat ingress will participate in the evaporation and may limit the condensation. The amount of liquid evaporation is linked to the pressure of the vapour phase. When evaporation occurs, the interface composition is changed. Part of the liquid evaporates (energy balance between heat ingress and latent heat of vaporisation) and the other part is cooled down. In continuous operation at constant pressure, evaporation is stable and the amount is proportional to the heat received by the film and corresponds to the nBOG rate. The nBOG varies with filling level (heat coming from wet and dry surface of the tank), liquid composition and tank shape.

If the vapour flowrate extracted from the tank exceeds the nBOG flowrate, evaporation at film level will increase, bringing the “cold” liquid to return to the bulk. This will lead to the cooling down of the entire liquid bulk, resulting in the reduction of vapour pressure.

On the other hand, if the flowrate extracted is lower than nBOG, evaporation will be limited and the quantity of “cold” liquid returning to the bulk will reduce and may vanish. Heat will accumulate in the liquid just below the film and will form a thermal stratification. This stratification has been measured as being up to 12°C warmer than bulk liquid (closed conditions near 1600 mbarg).

Under low gas consumption, heat accumulation occurs below the vapour interface. Some “warm” LNG is trapped, due to lower density near the interface while, due to low gas consumption, evaporation is limited. This leads to a rapid pressure increase which may jeopardize the ability of the ship to manage pressure accumulation. The consequence of this phenomenon is a pressure increase much faster than expected by homogeneous heat repartition in the liquid (measured up to 12 times faster). At intermediate gas consumption, but still lower than nBOG, the phenomenon disappears due to higher evaporation. The pressure increase is slow and related to the liquid quantity.

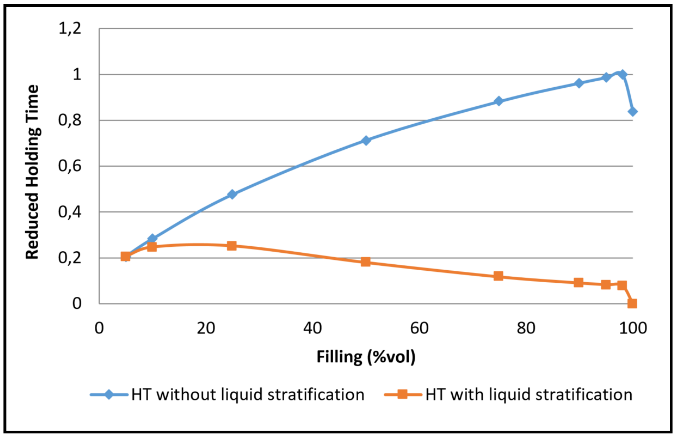

Figure 2 : Holding time for different filling levels

Obviously, the behaviour of this layer is linked to the operating conditions of the tank. Filling level and BOG consumption (including hotel load) has a strong impact on the formation of the stratification layer.

GTT has also successfully tested several methods and devices to limit the pressure rise and extend the holding time of the tank by promoting the mixture of the hot LNG layer beneath the interface. There is no direct action on the vapour phase, but the consequence of the mixing is a pressure decrease down to the bulk vapour pressure.

However, mixing methods are increasing heat ingress into the tank so that high intensity mixing may also be detrimental and induce unwanted pressure increase. Obviously, if there is no stratification in the tank, mixing is 100% detrimental. Stratification is therefore one of the key parameters to be detected in a tank before acting on the liquid.

An optimum between a low heat ingress with limited mixing effect and high heat ingress with high mixing effect, depends on many inputs such as LNG tank scale, filling level inside tank, LNG latent heat of vaporisation, gas consumption and parameters such as LNG vapour pressure, gas pressure, LNG density.

Some methods are very promising and GTT can now make recommendations on how to operate LNG fuel tanks at anchor or at berth.