GTT Inside

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Message from Karim Chapot, Technical Director, GTT

« The thermal performance of LNG cargo containment systems is one of the chief concerns in the LNG sector, as it has a direct impact on transport costs and CO_2 emissions.

Technological advances have made it possible to continuously improve this performance over recent years, halving LNGC emissions in the space of a decade. Furthermore, there is a strong correlation between thermal performance, vessel power usage, emissions and the efficiency of the containment system.

The desire for ever-better performance has had a real impact on the guarantees given by all stakeholders. Considering the importance of this topic, we wanted to clarify the challenges that these guarantees pose, and offer the reader some food for thought. »

Karim Chapot

OPERATIONS

Boil-off clarifications

The purpose of this article is to clarify Boil-Off Gas (BOG) and GTT guaranteed Boil-Off Rate (BOR).

The Liquid Natural Gas (LNG) is a cryogenic liquid mixture composed of methane, ethane, some heavier hydrocarbons and nitrogen. The main parameters that dictate the behavior of LNG are the composition of the cargo, its temperature, its gas pressure, its liquid gas ratio and accelerations.

The temperature of the cargo and accelerations are themselves depending on the insulation performance and the vessel motions.

The term **"Boil-Off Gas"** corresponds to the evaporation of LNG.

The term **"Boil-Off Rate"** corresponds to the design performance of the cargo containment system.

What is charter party guaranteed Boil-Off Gas (BOG)?

A difference in volume between loading and unloading over a voyage duration is guaranteed in a charter party.

The variation includes transient operations (tank cooling down, loading, unloading…) and is also dependent on LNG composition and conditions (temperature & pressure) at loading terminal as well as at unloading terminal (requested temperature and pressure). Sea state and weather conditions will also impact the BOG.

This difference is translated into an average % of loss per day. This part is commonly considered as Boil-Off Gas.

What is Boil-Off Rate (BOR) guaranteed by GTT?

The design BOR corresponds to the amount of heat transferred to the tank under IGC code design temperature conditions (ambient air temperature = +45°C, sea water temperature = +32°C) with its insulation under a thermal steady state. Consequently, the guaranteed BOR depends only on the performance of the cargo containment system thermal characteristics.

GTT guaranteed BOR does not take into account cargo loaded, actual environmental conditions, tank and insulation cooling down, propulsion system and more generally the way the vessel is operated.

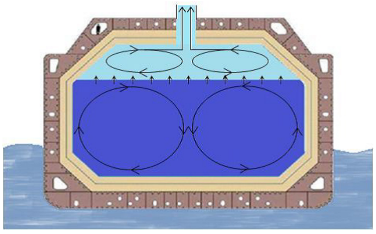
The insulation efficiency affects BOG but is not the only parameter impacting the BOG rate. There are cases where BOG and BOR will greatly differ as explained hereafter. BOG refers to the entire LNG chain, involving not only the performance of the cargo tank insulation system, but also the way both LNG carriers and terminals (export and receiving) are operated.

What are the main sources of Boil-Off?

There are several sources responsible for Boil-Off Gas generation: (1) heat ingress source, (2) sloshing of cargo, (3) cooling down of tanks, (4) LNG loading and unloading conditions and (5) the cargo tanks pressure.

(1) Heat ingress

The ingress of heat via the cargo tank insulation into cargo tanks is due to the difference between the temperature in the cargo tanks and the temperature of the environment surrounding it.



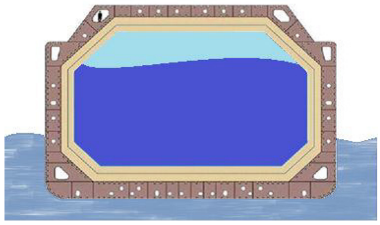
The liquid bulk receives the heat flux through the side and bottom walls of the tanks. A warm boundary layer is formed along the walls. The heat is evacuated by evaporation when the layer reaches the surface. Then, the cooled layer dives to the tank bottom.

Like the liquid area, the gaseous phase receives the heat flux by the side walls. A convection loop is formed which evacuates the evaporated flow from the liquid area and the warmed boundary layer by the gas dome.

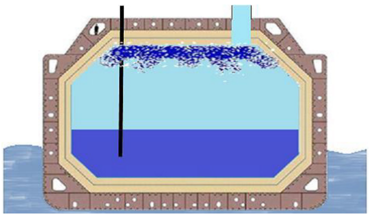
As the cargo stays at its boiling point according to cargo tank pressure, any heat ingress causes evaporation (BOG).

(2) The sloshing of cargo: Liquid Motion

The liquid movement inside the tanks (due to waves or navigation) brings mechanical energy to the system. It contributes to the evaporation (energy dissipation through turbulence), but it also acts as a spraying action and performs a partial cooling of the gas and the tank walls above the liquid level.



(3) The cooling-down of tanks

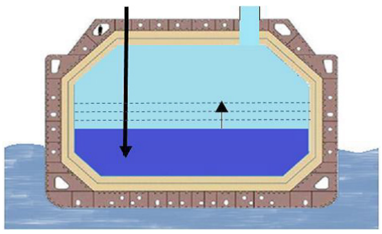


During the tank cooling-down, the sprayed liquid natural gas undergoes a sudden change of pressure which leads to its evaporation, a decrease of the tank temperature and generates BOG.

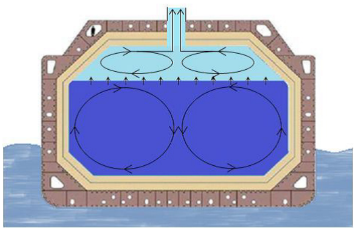
Additional heat ingress might also occur following completion of the tank insulation cooling-down during the first 48 hours of the laden voyage as the insulation and surrounding structure's temperature normalizes.

(4) LNG loading and unloading conditions

During loading of an LNG tanker, differences in operating pressures between the ship's and the terminal's storage tank and the quality of the LNG can greatly influence BOG generation during the voyage. For instance, if the cargo is loaded at low pressure, the temperature of the LNG will decrease thus reducing BOG generated. If the cargo has a strong content of nitrogen, the BOG will be increased at the beginning of the voyage as the lighter nitrogen boils-off. Transfer of LNG (use of Pumps and valve manipulation) can be a further source of heat energy ingress to the LNG as it is transferred.

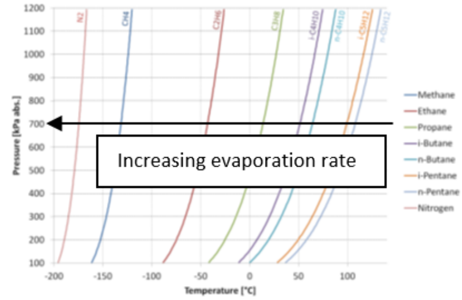


(5) Cargo tanks pressure decrease



Decreasing cargo tank pressure will modify the boiling point of the LNG. The LNG will then become superheated compared to this boiling point and will tend to evaporate at an increased rate until reaching the new boiling point.

The vessel loads its cargo at a given temperature imposed by the loading terminal and needs to deliver its cargo to a receiving terminal under specified conditions. The vessel has thus the “responsibility” to condition the cargo without having direct control on its characteristics.



To do so, the vessel is equipped to provide effective BOG management within the maximum pressure allowable inside the tanks. In the case that “warm” LNG is loaded the associated BOR will be high, reducing cargo tanks pressure management flexibility. As a consequence, it may be necessary to manage excess BOG via the Gas Combustion Unit (GCU) instead of retaining the LNG for sale, valued as fuel or reliquefied.

The LNG composition is a significant parameter / variable and could in specific conditions even dictate the BOG generated as detailed hereafter:

LNG is composed of several components of varying volatility, each having its own pure component boiling point at any given pressure. The presence of other volatile components in a mixture affects the boiling temperature of all the components in the mixtures.

During a voyage the most volatile (lightest) components like nitrogen will evaporate first. This phenomenon is called “ageing” and has some importance on the BOG generated as the voyage progresses.

Effect of ageing of a cargo can differ greatly based on the cargo composition and the duration. The boiling temperature of the cargo can increase significantly due to the presence of heavy components such as propane and ethane.

The evaporation rate of LNG depends not only on the composition of the product but also on the temperature of LNG when the cargo is loaded at the loading terminal. If the temperature of the cargo is too high according to the cargo tanks pressure it will evaporate more on voyage.

Another imposed constraint during the voyage concerns the temperature limitations of the LNG at the receiving terminal. While the cargo is mixed with a significant amount of heavy components, there are few options:

- Reliquefaction of BOG is one possibility but does consume energy.
- Ideally BOG is used for useful work.
- Last option consists in burning the gas by decreasing cargo tanks pressure to reach an acceptable temperature imposed by the receiving terminal.

What could be done to minimize BOG?

It is clear that composition, ageing and operating constraints imposed by the terminals are of a major importance to BOG generation during the laden voyage.

There is an efficient way to limit the BOG generated which requires further cooling of the LNG during loading, or in the cargo tanks during the loading operation but this supplementary energy consumption can be important for the value chain.

It would be possible to rank the quality of the loaded products. Based on this ranking, it would be fair to agree on an extra Boil-Off margin agreed in the charter party when typical conditions are not met.

Apart from loading LNG as cold as possible, there are also operational considerations which can be employed to improve and optimise the generation of Boil-Off Gas.

- Reducing the pressure inside the tanks at loading as far as possible (use of HD compressor to send gas to shore).
- The level of liquid motion inside the cargo tanks has an influence on the level of natural boil-off from the tanks.
- Define a route or heading to reduce ship motions.
- Anticipate slow or agitated passages by reducing cargo tank pressure when possible.
- Fuel Gas System set-up to avoid recirculation of warm fuel gas whilst maintaining a stable supply to consumers
- Monitor cofferdam temperatures and maintain the temperature at the desired value.
- Wherever operationally possible, arrive with tanks cold and ready to load at the loading terminal.

GTT, through its subsidiary Ascenz, proposes advisory services and onboard software to assist owners in monitoring and optimising these parameters (LNG Advisor™ and Sloshield™).