GTT Inside

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PIONEERING PROGRESS

NAVIGATING THE MARKET

TECH IN FOCUS

NOTE FROM THE CEO

Philippe Berterottière

Chairman & CEO of GTT Group

This new edition of GTT Inside reflects GTT's unwavering commitment to innovation as we address the energy and environmental challenges facing maritime transport today. In a context of tightening regulations and accelerating energy transition, we are delivering practical, high-performance solutions to support our partners on the path to a sustainable future.

This month, we highlight our Recycool™ technology, a cutting-edge recondenser system that optimises boil-off gas (BOG) management on LNG-powered vessels, reducing emissions and enhancing energy efficiency. This innovation demonstrates our ability to combine technological performance with environmental responsibility.

We also explore the arrival of Ultra Large Ethane Carriers and how GTT's cutting-edge membrane technology is setting new benchmarks in operational flexibility, energy efficiency, and carbon reduction.

Finally, we address the challenges associated with LNG cargoes containing high nitrogen levels – a complex issue that GTT is tackling with proven, robust solutions to ensure the safety and performance of vessels under challenging conditions.

Innovation remains at the heart of our strategy. By investing in tomorrow's technologies, we continue to strengthen our ability to anticipate our clients' requirements and deliver increasingly efficient and sustainable solutions.

Thank you for your continued trust in GTT.

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TECH IN FOCUS

RECYCOOL™, A CUTTING-EDGE RECONDENSER SYSTEM

As environmental regulations continue to evolve, improving energy efficiency and reducing emissions from LNG-fuelled ships have become critical challenges. High-pressure ME-GI engines, chosen for their low methane slip and high-power efficiency, are often selected as the main vessel propulsion. However, managing the boil-off gas (BOG) in such high-pressure engines remains complex, requiring a reliable, simple and cost-effective solution.

In LNG-fuelled ships powered by ME-GI engines, the fuel gas supply system requires a forced vaporisation of LNG, generating a large amount of cold energy. Recycool™, the Recondenser system developed by GTT, optimises cold energy recovery, offering several advantages compared to other solutions available on the market. The first successful applications on container ships have confirmed its efficiency and reliability in operation.

Regulatory Landscape and Market Context

The adoption of the Initial IMO Strategy on GHG emissions reduction is pushing ship operators toward a cleaner fuel choice. LNG, thanks to its low carbon-to-hydrogen ratio, is seen as the most viable transition towards low-emissions solutions. Additionally, LNG has become the industry's preferred alternative fuel in terms of the number of orders placed in 2024. The latest regulations encourage ship operators using LNG as fuel to adopt efficient engine technologies with low GHG emissions.

One of the preferred choices is the two-stroke high-pressure ME-GI engine, which requires a high gas supply pressure (around 300 bar). Compared to two-stroke low-pressure engines, ME-GI engines provide higher efficiency and a significantly lower methane slip.

However, maintaining high pressures at the engine intake requires large, energy-intensive and expensive high-pressure compressors, regardless of tank technology (whether atmospheric or pressurised). These compressors also help maintain tank pressure and avoid any overpressure, which could force gas to be burned unnecessarily.

An alternative approach is to integrate a recondenser solution within a fuel supply system equipped with a low-pressure compressor.

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TECH IN FOCUS - RECYCOOL™, A CUTTING-EDGE RECONDENSER SYSTEM

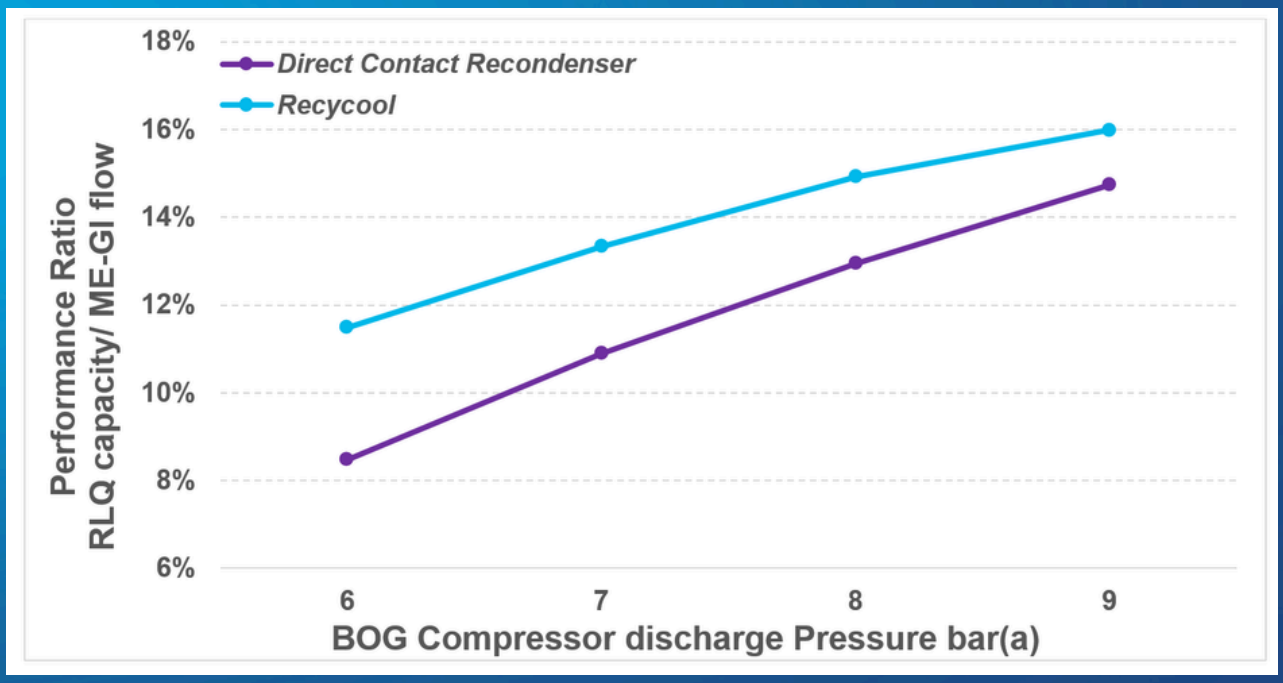
GTT's Recycool™ Solution

The primary recondenser solution available on the market today (Direct Contact Type Recondenser) originates from the Floating Storage and Regasification Unit (FSRU) segment. This system, which allows direct contact between LNG and BOG streams, effectively promotes BOG condensation, but comes with an operating limit. The maximum separator pressure is constrained by the maximum pressure of the BOG compressors, which, in turn, limits the maximum temperature to which the LNG can be heated, reducing cold energy recovery. The need for a separator limits the compactness of the unit.

To overcome these limitations, GTT has developed Recycool™, which utilises an indirect heat exchange process between excess BOG and LNG. Indirect heat exchange decouples the inlet pressure of the high-pressure pump, and is independent from the BOG compressor pressure ratio, therefore eliminating the need for a separator.

Recycool™ offers the best reliquefaction performance. A low BOG compressor outlet pressure favours the Recycool™ performance and therefore gives a higher performance than the Direct Contact Recondenser.

Assuming a high pressure pump inlet pressure for Recycool™ of 9 bar, when the low pressure compressor outlet pressure is at a typical operating value of 8 bar, the system performance is 13% better than the Direct Contact Recondenser performance. Moreover, this performance improvement could be considered even higher if the additional heat input due to the presence of a buffer/separator is taken into account.



The Recycool™ design allows for:

- A more compact system (eliminating the need for a buffer/separator)
- Optimised efficiency and stable operation
- Increased BOG reliquefaction capacity

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TECH IN FOCUS - RECYCOOL™, A CUTTING-EDGE RECONDENSER SYSTEM

Recycool™ minimises the volume of BOG that would otherwise be directed to the boilers. This is achieved by cooling the compressed BOG (from the BOG compressor) by recovering cold energy from the fuel gas sent to the high-pressure engines. The condensates are then returned to the tank in liquid form.

The system operates when the ship's main engine is running on gas (i.e. the ship is in motion), with cold energy recovery occurring in two different locations:

- Downstream of the high-pressure pumps in the Precooler.
- Upstream of the high-pressure pumps in the Recondenser.

When integrated with a power take-off (PTO), Recycool™ further enhances the advantages of using the ME-GI engine for electricity generation, offering operational expense reduction and lower greenhouse gas emissions.

First Worldwide Application and Performance Validation

Recycool™ has been successfully installed on ten LNG-powered containerships built at Samsung Heavy Industries shipyard. All ten vessels are now in commercial operation. Another order to equip ten more LNG-powered containerships was announced on September 2024.

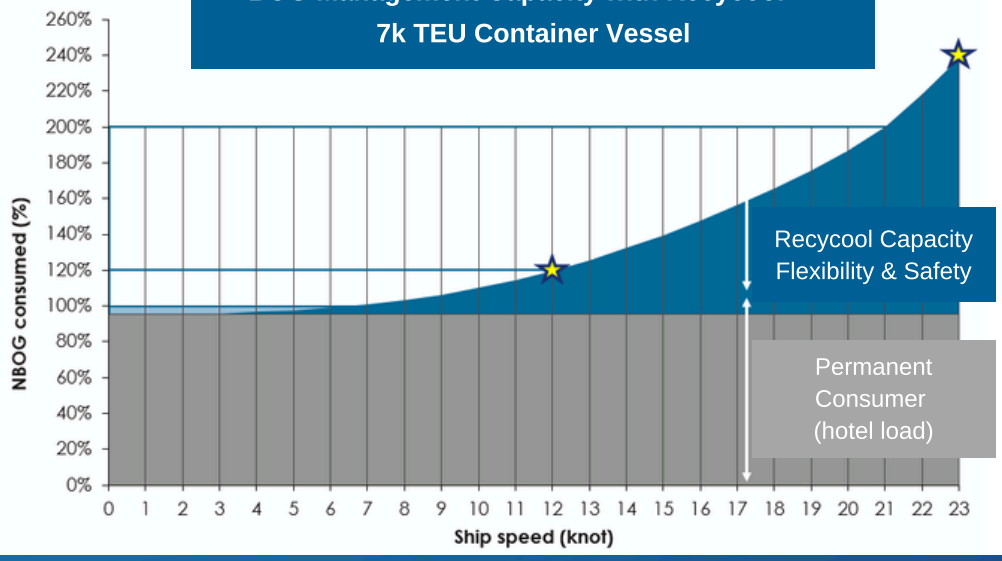
The Recycool™ skid is placed next to the high-pressure pump skid, allowing seamless integration.

In this first application, GTT combined the Precooler with the high-pressure vaporiser into a single heat exchanger, further enhancing system compactness.

Recycool™ performance, validated during gas trials and commercial operations, demonstrates stable operation enabling the crew optimal management of tank boil-off and pressure.

With its proven performance and reliability, compact design, and optimised efficiency, Recycool™ stands out as a key solution for LNG-fuelled vessels powered by high-pressure two-stroke engines, contributing to both operational cost savings and emissions reduction. ■

BOG Management Capacity with Recycool™
7k TEU Container Vessel



Measures performance as expected values.

Performance validated on two operating speeds :

- **12 knots**
- **Design ~ 23 knots**

TECH IN FOCUS

OPTIMISATION OF ETHANE TRANSPORT: A DEDICATED TECHNOLOGY BY GTT

The demand for ethane transport is increasing and is expected to grow steadily over the coming years. When vessel flexibility - such as the ability to carry different types of cargo like LNG (Liquefied Natural Gas), is not required - GTT has developed a membrane technology specifically designed for ethane transportation, leveraging the proven experience of its Mark III system.

A Technology Adapted to Ethane Specificities

The containment system developed by GTT is based on the well-established Mark III technology, which has demonstrated extensive reliability at sea. However, unlike versions designed for LNG transportation, this new solution is dedicated to ethane. One of the key differences between ethane and LNG lies in their boiling points. As ethane has a higher boiling point compared to LNG, it is possible to reduce the insulation thickness. This adaptation results in a significant cost reduction compared to the standard Mark III technology. Additionally, decreasing the insulation thickness increases cargo capacity by more than 1,000 m^3, thereby enhancing transportation efficiency. As a result, Mark III technology adapted to Very Large Ethane Carriers (VLECs) increases the capacity of these vessels from 100,000 m^3 to 101,000 m^3 on the current largest capacity VLEC.

An Optimal Investment Strategy

The current market for ethane carriers predominantly involves vessels with a capacity of approximately 100,000 m^3. In contrast, typical LNG cargo volumes traded are around 174,000 m^3. Consequently, using a 100,000 m^3 vessel exclusively designed for LNG transport may not be the most efficient or cost-effective solution. In this context, dedicating this capacity to ethane transportation is a strategic and relevant investment. It should also be noted that this « ethane » design is also capable of transporting LPG, Ethylene, Butane, etc.

With its Mark III technology dedicated to VLECs and Ultra Large Ethane Carriers (ULECs) with capacities of up to 150,000 m^3, GTT reaffirms its commitment to providing innovative, cost-effective solutions tailored to the evolving needs of the liquefied gas transport sector. ■

SUSTAINABLE AND EFFICIENT ETHANE TRANSPORTATION

In the evolving landscape of ethane transportation, GTT has pushed the boundaries with the largest Very Large Ethane Carriers (VLECs) and has also developed and promoted Ultra Large Ethane Carriers (ULECs).

2024 marks the beginning of a new era in ship types with the ULEC, a 150,000 m^3 liquefied ethane carrier. The chemical giant "Zhejiang Satellite" has decided to charter eight ULECs (with an option for two additional vessels), with EPS as the ship-owner and Jiangnan shipyard (JN) and Hyundai Heavy Industries (HHI) as the shipbuilders. These eight carriers will be delivered in 2027.

In early 2025, Thailand's Siem Cement Group and PTT decided to move ahead for their half dozen VLEC shipping programmes, with SHI and HHI as the shipyards, utilising the world's largest VLEC size of 100,000 m^3 and equipped with GTT Mark III technology.

This growing preference for GTT technologies is driven by several key advantages that enhance operational efficiency, reduce costs, and improve overall vessel performance.

Key Advantages of GTT Technology

GTT technologies offer unparalleled cargo flexibility. Unlike self-supporting IMO tanks, which are restricted to ethane, ethylene, and LPG cargoes, membrane tanks can accommodate a broader spectrum of liquefied gases, including ethane, ethylene, propane, propylene, butane, LNG, and ammonia (with loading limitations due to its 25% higher density).

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@ Energy Transfer Terminal

PIONEERING PROGRESS - SUSTAINABLE AND EFFICIENT ETHANE TRANSPORTATION

This multi-cargo capability enables ship-owners to diversify operations, adapt to market fluctuations, and maximise fleet profitability. One of the most significant benefits of GTT's technologies is its lower Boil-Off Gas (BOG) rate. Advanced insulation reduces BOG generation, minimising the need for reliquefication plants. Unlike LNG carriers, where BOG is burned in the engines for propulsion, ethane carriers run on liquid fuel, requiring full reliquefication of the BOG. GTT's thermal insulation performance not only lowers operating costs (OPEX) but also enhances energy efficiency. Additionally, its increased design pressure (compared to the conventional 250 mbarg) further reduces reliance on reliquefication units, providing greater operational flexibility and enhanced energy savings.

The GTT technology systems also provide a significant lightship advantage. Weighing approximately 1,650 tons, the membrane technology is considerably lighter than self-supporting IMO tanks, which can reach up to 5,000 tons in their nickel alloy version. This weight reduction results in lower fuel consumption or faster service speeds, and easier compliance with CII regulations.

Regarding operational efficiency, GTT's VLEC and ULEC designs are capable of loading cargo more quickly. At major terminals, self-supporting IMO tank VLECs experience a 25% longer loading time for ethane cargo due to higher BOG generation as well as thermal inertia, which together conflicts with the reliquefication unit capacity. In contrast, GTT's superior insulation prevents excessive BOG, enabling quicker loading times and increased efficiency.

Given its construction philosophy and compliance with International Gas Codes requirements, GTT cargo containment systems come with easier inspection and maintenance plans compared to self-supporting IMO tanks, which often require welding repairs and scaffolding installation. Continuous monitoring of GTT cargo containment system tanks ensure higher reliability, enhanced safety for the crew, and lower maintenance costs throughout the vessel's lifetime.

Recent Design Breakthroughs

In recent months, GTT and its partners have introduced a series of ship design optimisations. Korean shipyard partners, SHI and HHI, have both refined their latest designs developed in 2025, increasing cargo tank capacity from 98,000 m^3 to 100,000 m^3. Additionally, GTT has collaborated with its Chinese partner CMHI-JS and ship designer Delta Marin to develop a three-tank GTT Mark III VLEC, enabling a cargo capacity of 103,000 m^3. This layout further reduces construction costs (CAPEX), enhances hull integration, and optimises cargo space utilisation. Lastly, GTT and ship designer MARIC have developed a 155,000 m^3 ULEC design, which was granted Approval in Principle by Bureau Veritas in late March 2025.

GTT's Membrane Technology Featured in MARIC's ULEC Design

The recent AiP awarded by Bureau Veritas to MARIC for its 155,000 m^3 ULEC design, underscores the suitability of GTT's Mark III membrane technology for large ethane carriers. With optimised cargo capacity and reduced boil-off, this design enables ethane to be transported even more efficiently.

GTT is also developing a new portfolio of dedicated cargo containment systems, with both Mark III and NO96 technologies, for LPG and LEG cargoes that are warmer than LNG. Not only will the cost be lower, but the cargo volume will be increased thanks to a thinner insulation system.

GTT technologies offer superior operational efficiency, cargo flexibility, increased cargo volume, and reduced maintenance costs compared to self-supporting IMO tanks. These advantages make GTT an optimal choice for both ULECs and VLECs, supporting the industry's shift toward sustainability, adaptability, and cost-effectiveness. ■

BOG LINE

A SIMPLE LEVER TO IMPROVE ENERGY EFFICIENCY OF PRS, FRS AND A-PRS

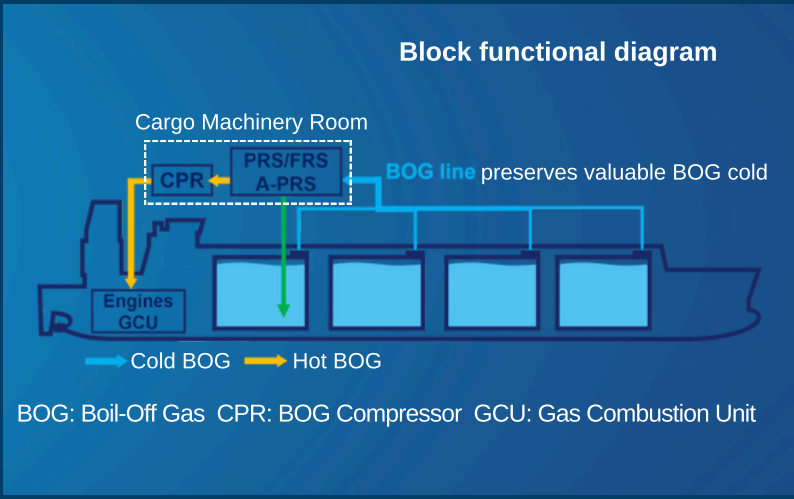
At the forefront of cryogenic system technological advancement for LNG carriers, GTT continuously improves the thermal performance and reliability of its containment systems. To enhance the overall energy efficiency of vessels, GTT also focuses on optimising boil-off gas (BOG) conditions when supplying subcoolers, reliquefaction units or full re-liquefaction systems (FRS), partial re-liquefaction systems (PRS) or advanced partial re-liquefaction systems (A-PRS).

To support this objective, GTT has developed a BOG supply line designed to maximise the operational efficiency of the BOG reliquefaction process. Beyond enhancing system performance, this innovation also simplifies the deck piping system, including the vapour headers.

Two Implementation Approaches

GTT has identified two ways to integrate the BOG supply line:

Option 1 - A fully dedicated BOG line. A single, optimised gas line, running from the LNG tank to reliquefaction units (such as PRS, FRS or A-PRS), ensures that BOG reaches the treatment system at the lowest temperature possible. The line is specifically designed with an optimal diameter, insulation thickness and piping features to minimise heat ingress and pressure losses.



Option 2 - Insulated Gas main line with reduced diameter. In this approach, the existing gas main, typically used for maintenance operations, is adapted to also route the BOG towards the reliquefaction system in an improved manner. Gas main insulation thickness and diameter have been revisited and the impact on maintenance operations has been properly assessed. This option offers further opportunities for vapour headers simplification and CAPEX reduction.

Measurable Gains in Efficiency

Both configurations result in significant efficiency improvements:

- Colder BOG at reliquefaction units, FRS/PRS/A-PRS entry: up to 12°C colder according to estimates.
- Higher liquefaction capacity: e.g. 4-7% for FRS and 6-12% for PRS.

A Cost-Effective and Rapidly Amortised Investment

From a finanical perspective, both CAPEX and OPEX considerations indicate a return on investment within just a few years. GTT is committed to working closely with shipyards to identify the most suitable options tailored to the specific needs of LNG carriers. By collaborating with ship-owners and charterers on possible operating profiles, actual benefits have been consolidated, and the system is ready to be proposed. ■

NAVIGATING THE MARKET

LNG WITH HIGH NITROGEN CONTENT: ADAPTING TO A NEW REALITY

Over the last decade, numerous liquefaction trains have been commissioned to meet the increasing global demand for Liquefied Natural Gas (LNG). The LNG composition delivered from various terminals differs based on the characteristics of the gas field and the extraction processes used. While LNG typically contains a high proportion of methane, it may also include smaller quantities of heavier gases such as ethane, propane, butane, pentane, and, in some cases, nitrogen (N_2).

Although nitrogen content in LNG is generally below 0,5%, recent cases have shown levels exceeding 1%, with projections reaching up to 1,6% at certain terminals. This elevated nitrogen content in LNG presents several operational challenges:

- **Lower storage temperature requirements:** LNG with high nitrogen content can reach temperatures as low as -165°C compared to the standard -163°C, necessitating an update to the LNG Carrier's Certificate of Fitness.
- **Higher nitrogen vaporisation:** Since nitrogen has a lower boiling point than methane, it vaporises more easily during the laden voyage, representing up to 30% of the total boil-off gas (BOG). As nitrogen is non-combustible, this reduces the energy content of BOG potentially making it unsuitable for engine combustion and resulting in higher fuel consumption.
- **Tank pressure management:** the additional BOG generated by nitrogen vaporisation must be properly managed by Cargo Handling System (CHS) to avoid tank pressure increase.

Industry Support: Ensuring Safe and Efficient High-N_2 LNG Transport

GTT has prepared a comprehensive technical study demonstrating that both Mark III and NO96 technologies can safely operate at a temperature of -165°C. This study was reviewed by the four major classification societies in 2024, providing a solid technical foundation for LNG carriers operating under these conditions.

As the loading limit depends on the vessel design and the LNG composition, GTT has also worked with ship-owners to update the loading limit table calling at terminals supplying high N_2 LNG.

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NAVIGATING THE MARKET - LNG WITH HIGH NITROGEN CONTENT

To ensure safe and efficient management of tank pressure during laden voyages, GTT has conducted dedicated BOG Management studies with the following objectives:

- Analysis of the evolution of LNG composition and the amount & composition of BOG along the laden voyage.
- Assessment of the required quantity of forced BOG top-up to meet the engine's minimum Lower Heating Value (LHV).
- Estimation of the excess gas and verification that it can be handled by the Gas Combustion Unit (GCU).
- Proposition for alternative BOG Management scenarii in order to ensure the onboard systems (compressors, subcooler, reliquefaction units, etc.) can accommodate the operational requirements.

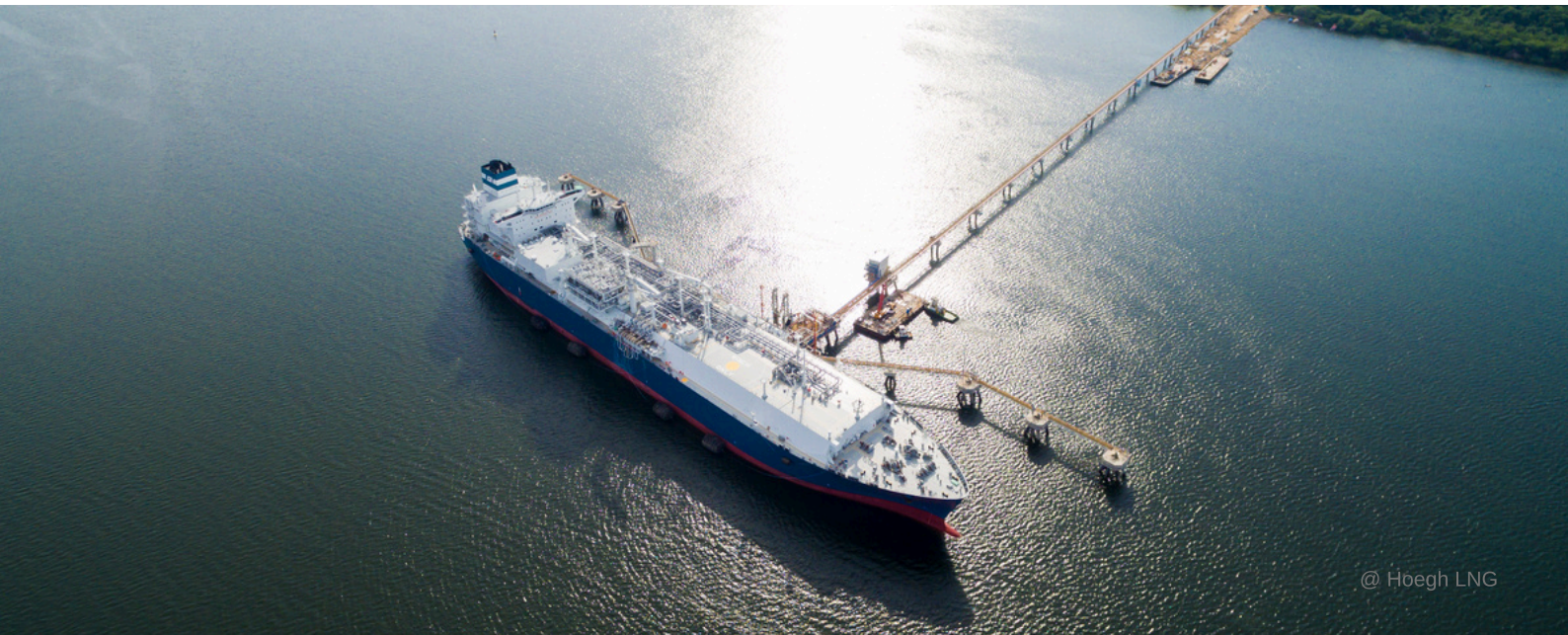
These studies support the updating of the vessel's Certificate of Fitness.

Tailored Solutions for Ship-owners and Operators

In addition, GTT provides tailored analyses to assist clients in adapting their fleet and operations to high nitrogen LNG cargoes:

- **Fleet analysis:** Grouping vessels based on design caracteristics (containment system, capacity, CHS, and engine type) to evaluate suitability for high-N_2 LNG.
- **Tank pressure rise analysis:** Evaluating pressure increases in LNG tanks when BOG cannot be fully managed by onboard gas supply system (BOG compressors) or consumers (engines, GCU, reliquefaction unit, auxiliary systems).
- **Voyage Data Analysis:** Leveraging real operational data to optimise future voyages involving increased nitrogen content.
- **Operational guidance:** Developping recommen dations for cool down and loading procedures to better manage pressure rise at the start of the laden voyages.
- **Support for terminal and newbuild projects:** GTT also assists the design of optimised CHS architectures for terminals handling high-N_2 LNG and advises on retrofit solutions to improve BOG management for existing vessels carrying High-N_2 cargoes.

Through these initiatives and a solid return of experience, GTT offers both standardised and customised solutions to help the LNG industry navigate the challenges associated with high nitrogen content LNG cargoes. By leveraging its expertise in LNG containment and BOG management, GTT ensures safe, efficient, and regulatory-compliant operations for ship-owners, operators, and terminal stakeholders. ■



MEET GTT

The GTT group will be taking part in these forthcoming events

6-8 May, 2025
Global Maritime Decarbonisation Summit
Amsterdam, the Netherlands

7-8 May, 2025
Global LNG Forum
Barcelona, Spain

20-22 May, 2025
World Hydrogen Summit
Rotterdam, the Netherlands

20-22 May, 2025
NavExpo
Lorient, France

19-23 May, 2025
World Gas Conference
Beijing, China

20-21 May., 2025
Offshore Support Vessels
Abu Dhabi, UAB

2-6 Jun., 2025
Nor-Shipping Exhibition
Oslo, Norway

LEARNING & DEVELOPMENT

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Use of Ammonia, LNG, Methanol and Hydrogen as a Marine Fuel
13-15 July (Online)

GTT Membrane Technologies Course
17-20 June (GTT HQ) / 15-17 July (Online)

LNG Cargo Operations (Online)
SIGTTO course: 14-18 July
Refresher course: 17-19 June & 12-14 August

FSRU Systems and STS Operations course
12-14 August (Online)

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