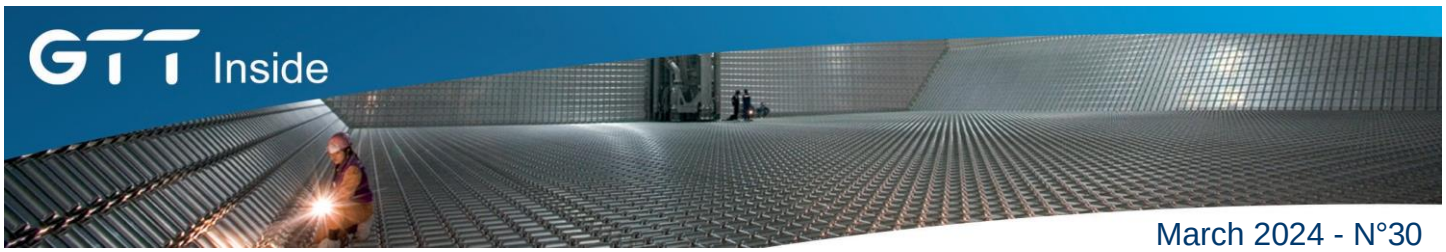


March 2024 - N°30

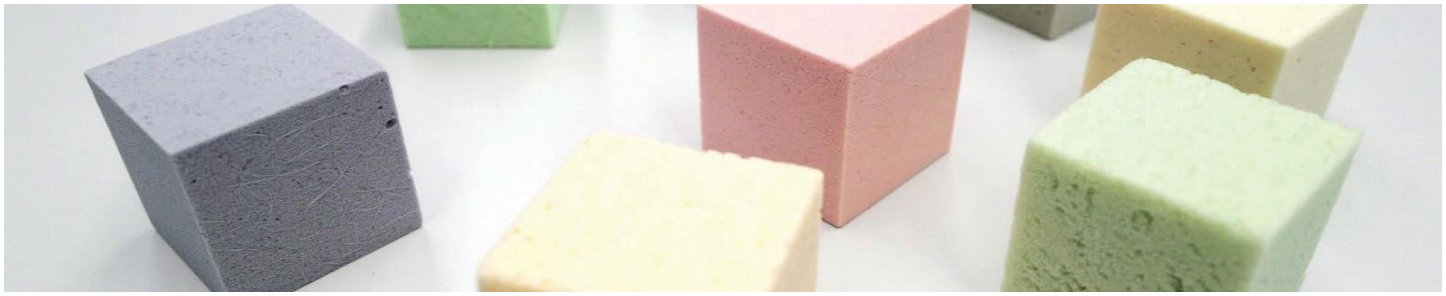
Message from Philippe Berterottière, Chairman & CEO of GTT

In this issue of GTT Inside, we are highlighting how GTT is more than ever concerned by environmental issues.

Beyond the very significant reduction of the CO_2 footprint of LNG carriers obtained over the past decade, GTT is also actively working on the environmental footprint of materials used in containment systems.

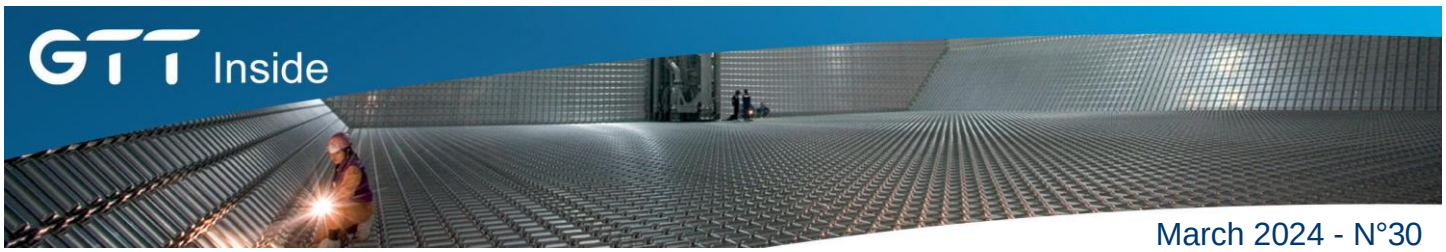
You will read how HFO foam offers a drastically reduced global warming potential compared to foams using current blowing agents. Another way of adressing the issue of materials is to render acceptable plywood with more inclusions on external plies with no noticeable impact on the overall performance of the product.

You could read also how bound4blue, windsails for ocean going vessels, promises to significantly reduce the fuel consumption at an affordable cost. Enjoy!



Eco-Friendly Advancements in Foam Insulation: Embracing HFO Gas for Sustainable Solutions

Foam insulation has played a crucial role in the transportation and storage of liquefied natural gas (LNG) for the past three decades. Among the leading innovators in this field is GTT, whose technologies have continuously evolved to ensure optimal conditions for LNG containment. In recent years, GTT has further embraced environmentally-friendly practices by transitioning to low Global Warming Potential (GWP) foam insulation.



March 2024 - N°30

Leading innovation in Reinforced Polyurethane Foam

For three decades, GTT has continuously evolved its technologies to optimize LNG containment conditions. Reinforced Polyurethane Foam (R-PUF) remains a key factor in this success due to its low thermal conductivity and cost-effectiveness. Specifically, it allows the Mark III, NO96 and future NEXT1 technologies to limit the passive boil-off rate of LNG at -163°C. R-PUF production is well mastered by GTT's approved suppliers, and has been historically located near shipyards in South Korea and China.

To give an idea of the order of magnitude, around 28,000 m^2 of insulation surface area are required for the four tanks of a 174,000 m^3 LNG carrier. In this scenario, GTT's Mark III Flex+ technology, with a 480 mm thick insulation, generally requires a net volume of R-PUF of around 13,500m^3. To produce R-PUF with a typical density of around 130 kg/m^3, approximately 5 kg of blowing agent is needed per cubic meter. This means that for a ship that requires around 13,500 m^3 of R-PUF, over 75 tonnes of blowing agent would be needed.

The blowing agent allows the liquid polyurethane to foam and expand during a cross-linking chemical reaction, resulting in a lightweight cellular material with small gas-filled cavities. Traditionally, hydrofluorocarbons (HFCs) have been used as the blowing agent, as they are highly effective at foaming. To enhance the thermal insulation properties and reinforcement, around 10% glass fibre is incorporated into the polyurethane foam in the form of continuous filament mat layers. The addition of this glass fibre is essential, as it allows the R-PUF to withstand the considerable thermal gradient of over 180°C that exists between the extremely cold LNG cargo at -163°C and the warmer vessel surfaces.

Acknowledging regulatory efforts to curb high-GWP refrigerants, GTT is proactively seeking lower-emission blowing agent alternatives to future-proof its industry-leading insulation technologies in the face of increasingly stringent climate policies while, at the same time, maintaining optimal LNG cargo performance.

GTT's Breakthrough with Low-GWP HFO Gas

Like all gases, blowing agents are refrigerant gases characterized by coefficients indicating their impact on the ozone layer and on global warming.

GTT has been diligently complying to regulations and proactively anticipating industry changes for several years. For over 30 years, GTT has been constantly improving mechanical, thermal and environmental performance. Until today, all GTT technologies delivered use foam with a blowing agent with an Ozone Depletion Potential (ODP) of 0. However, starting 1 July 2024, GTT will only approve R-PUF with blowing agents that have a very low global warming potential - at least 800 times lower than the majority of blowing agents used today.

The first low-GWP foam to receive approval in 2016 used a Hydro Fluor-Olefins (HFO) blowing agent with an OPD of 0 and a global warming potential of 1. The transition to low GWP R-PUF gained significant momentum in 2019 with the production of the first HFO foam for a Floating Storage Regasification Unit. This pioneering

foam leveraged a blend of HFO and CO_2 in a 40/60% ratio, maintaining the same ODP and GWP standards. Thus, the use of HFO emerged at the time as a more sustainable solution for reinforcing polyurethane foam. In comparison, according to a reference from the Intergovernmental Panel on Climate Change, the global warming potential of HFCs in use is 858. In 2020, GTT achieved another milestone with the production of the first low-GWP R-PUF designed for land storage. Notably, this foam relies on pure HFO, demonstrating GTT's dedication in pushing the boundaries of environmentally friendly insulation solutions. Last but not least, the production facilities of GTT's approved R-PUF suppliers are well-equipped for the utilization of HFO. This strategic alignment ensures seamless integration into the manufacturing process.

Pursuing Excellence with Sustainable Material Choices

Understanding the key factor of thermal conductivity in insulation performance, GTT recognizes that the thermal conductivity of R-PUF is intrinsically tied to the gas present in the closed cells. In pursuit of optimal thermal performance, GTT emphasizes the utilization of HFO over CO_2, given HFO's superior thermal conductivity. This strategic approach aligns with the company's dedication to maximizing efficiency in LNG transportation and storage.

GTT will officially inform its suppliers and future suppliers, specifying the details of GTT's decision to qualify only low-GWP foams from July 1st, 2024. They have already been made aware of this and they are focusing their development towards this type of blowing agent.

Navigating Flexibility: Birch Plywood Optimization in GTT’s Technologies

Within GTT’s technologies, the unassuming yet crucial role of birch plywood takes centre stage, echoing a history that traces back to the earliest maritime construction. This indispensable material, sourced from renowned European suppliers like UPM, Metsä Wood and Latvijas Finieris, forms the backbone of vessels fitted with GTT’s technology.

In order to enlarge the sources of birch plywood supply, GTT is introducing a new, more flexible, method of acceptance of inclusions on the plywood faces, all the while ensuring that the overall performance of the material

remains uncompromised. During the intricate process of birch plywood production, a critical initial step involves meticulously peeling the trunk tree to obtain plies. These plies undergo a sorting process based on factors such as size, quantity, and the type of inherent inclusions arising from both the wood and the manufacturing process. These inclusions may include holes, knots, splits, patches and more.

The hierarchy of ply usage is dictated by inclusion severity. Plies bearing the most inclusions find their place in the inner layers, while those showcasing the best appearance are reserved for the outer faces. This meticulous selection process contributes not only to the vessel's aesthetic appeal but also to its functional qualities.

Noteworthy is the grading system employed: the plywood used for Mark III technology meets BB quality standards, while the plywood used for NO96 and Super+ technologies meets WG quality standards. Despite its higher incidence of inclusions compared to BB-grade, WG-grade plywood still meet the stringent requirements of these advanced GTT technologies.

Yet, to ensure the resilience of these plywood materials, extensive mechanical bending and tensile tests have been conducted on specimens with varying degrees of inclusions. These tests, spanning a multitude of samples, underscore the unwavering commitment to quality and safety inherent in GTT technologies.

The study clearly demonstrates that increasing inclusions on the external plies of plywood has no noticeable impact on the overall performance of the product. These promising results have paved the way for a practical optimization while maintaining a high level of quality.

Furthermore, the material specification dedicated to the plywood used in Mark III technologies has recently undergone a significant revision. Marked as “nb 04”, this revised Mark III version has received approval from the main classification societies, including the American Bureau of Shipping (ABS), Bureau Veritas (BV), Lloyd's Register (LR), and Det Norske Veritas (DNV). This collective endorsement from renowned classification bodies emphasizes the adherence to the highest industry standards and validates the use of plywood with an increased tolerance for inclusions.

This adjustment provides shipyards with added flexibility in sourcing birch plywood. It signifies a nuanced approach that strikes a balance between operational efficiency and technical standards, reflecting the industry's commitment to pragmatic solutions in the face of challenges. This shift in specifications positions the maritime industry at the forefront of adaptability, ensuring a steady course forward with GTT technologies.

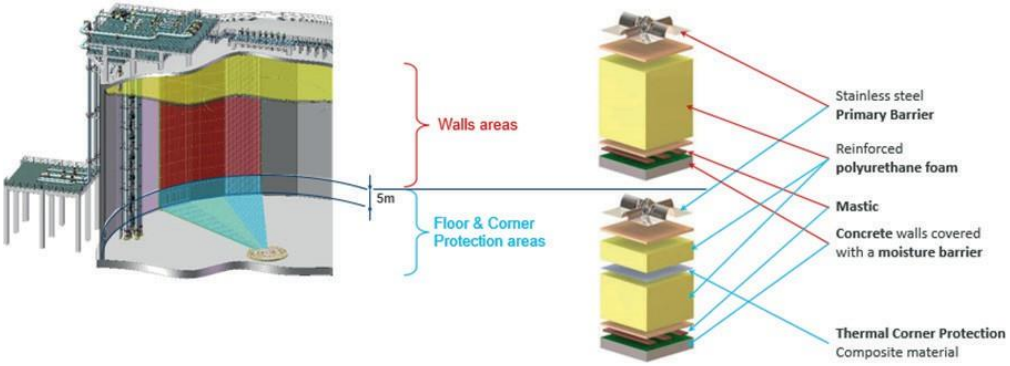
GTT Inside

March 2024 - N°30

The World's Largest LNG Membrane Onshore Tanks Now Successfully in Operation

On November 15th, 2023, the first four LNG tanks of the Tianjin Nangang LNG terminal operated by Beijing Gas were filled to 95% capacity. The first two 220,000 m³ LNG membrane tanks, the largest built to date, have officially entered into commercial operation, completing an adventure of nearly four years, including engineering, construction, and commissioning.

Almost four years after the signing of the agreement with Beijing Gas Group Co., Ltd. (BGG) in the presence of French and Chinese Presidents Emmanuel Macron and Xi Jinping, the first two land-based tanks equipped with GTT's GST® technology at Tianjin gas terminal Phase I were successfully commissioned. GTT supported the Chinese construction company China Huanqiu Contracting & Engineering Co. Ltd. (HQC) during the phases of engineering, material supply, construction, inspection, commissioning, and operations. The success of this first phase has demonstrated the relevance and competitiveness of the membrane solution compared to 9%Ni technology. With the continuous improvement of its supply chain in China, GTT's onshore membrane tank technology will become even more competitive in terms of investment cost, construction schedule, and other economic aspects. As a reminder, GST® technology is based on the Mark III containment system used in naval applications, and can store 10% more LNG than competing technologies for the same concrete structure. It consists of a corrugated (1.2mm thick) stainless steel primary membrane, installed on insulating panels made of reinforced polyurethane foam and plywood. The principle of the technology is illustrated in the diagram below.



GST Containment system description

Unlike in naval applications, the secondary barrier in GST® technology only extends to a height of five meters, as specified by the code. It is not necessary to have a secondary membrane covering 100% of the tank. The pre-stressed concrete enclosure, with an average thickness of 800 mm, is capable of containing LNG in the event of a significant leakage beyond this limit.

The assembly of the containment system was carried out by an EPC company experienced in the construction of land-based tanks and LNG terminals, but without experience in assembling the Mark III membrane technology. This was an opportunity for GTT to demonstrate its expertise and the know-how of its technical assistance by mobilizing representatives on site to support the EPC contractor and subcontractors, enhance their skills, and ensure quality monitoring during construction.

With an average duration of eight months between the start of the containment system installation and the completion of the membrane tightness tests, the construction schedule of a membrane tank proves to be as competitive as the 9%Ni. GTT's assistance on these tanks was not limited to the installation of the membrane. Indeed, the pre-commissioning, commissioning, and start-up operations were also carried out with the assistance of GTT's commissioning team. This was an opportunity to highlight this aspect of the expertise offered by GTT.

In order to prepare for these crucial steps of cooling down the tanks, GTT's assistance began more than a year before commissioning, through training sessions and the drafting of procedures with the teams of the EPC and the terminal. One month before the start of operations, the final commissioning procedure was validated by the teams in Chinese language to avoid any operational errors. When the first LNG carrier arrived at the terminal, the terminal teams first commissioned the 9% Ni technology tanks. The cooling rate is particularly slow, around 1-2°C/h for this type of structure.

A few days later, the teams began cooling down the GST® tanks, which are not subject to the same constraints thanks to the high flexibility of the GTT membrane. Although regulations allow cooling rates between 10 and 15°C/h for membrane tanks, the teams started slowly and cautiously, before being convinced by the GTT commissioning teams that the technology can indeed support a faster cooling down. In the end, the cooling, achieved by transferring LNG from the 9%Ni tanks, was completed in 32 hours, half the time taken for the 9%Ni tanks.

Ten days after the completion of the cooling down of the first GST® tank, the commissioning of the second began. The cooling of the tank was completed in 27 hours. However, the cooling rate can still be improved, and the terminal teams are willing to further revise the startup procedure for the tanks in phases II and III.

Since then, new ships have arrived to fill the four tanks, which are now almost all at maximum capacity. Both membrane tanks are 95% full and operated smoothly by the operator BGG.

Convinced of the advantages of GST® membrane tanks, the decision was taken to construct the Beijing Gas Tianjin Nangang LNG Terminal Phases II and III, with a total of 6 units of 220,000 m^3 membrane tanks (using GTT onshore membrane technology) planned to be fully operational by mid-2024.

eSAIL®: Pioneering Green Shipping with bound4blue's Wind-Assisted Propulsion System

On September 7th, 2023, GTT announced that it had led a fundraising round to support the development of bound4blue, a technology developer of automated Wind-Assisted Propulsion System (WAPS) for maritime transport.

A product of bound4blue's ingenuity, eSAIL® enables vessels to harness wind as a free, abundant, and infinite energy source. This Wind-Assisted Propulsion System assists ship owners and operators in achieving regulatory compliance with the International Maritime Organization (IMO) and European Union regulations aimed at reducing greenhouse gas emissions and enhancing energy efficiency.

eSAIL® distinguishes itself from conventional wing structures by leveraging a thicker aerodynamic profile and suction to generate lift forces six to seven times greater than a regular wing sail. In other words, it can deliver the same propelling force with less surface area than a regular wing sail, all with minimal power consumption and without mechanical complexity (such as inertial loads, vibrations, constant movement, etc.), ensuring simple, safe, and reliable operations. When installed on a vessel, eSAIL® technology is designed so that its high-lift ability maximizes fuel savings in a cost-efficient manner.

bound4blue is able to tailor sailing plans for individual vessels, reducing payback periods to less than 5 years, and positions its eSAIL® WAPS as an attractive and sustainable option suitable for any type of vessel - including tankers, bulkers, Ro-Ros, cruises, ferries, and gas carriers, regardless of size or age.

bound4blue has already installed its eSAIL® system on vessels and secured agreements with esteemed shipowners, such as Louis Dreyfus Company, Odfjell, Marubeni, SNA Tuhaa Pae and Eastern Pacific Shipping. These partnerships demonstrate a growing recognition of the potential of eSAIL® technology.

In a notable development, the MV Atlantic Orchard vessel, Chartered by Louis Dreyfus Company and owned by Wisby Tankers, is scheduled for retrofitting with four 26-meter-high eSAIL® in 2024. This initiative aims to reduce annual fuel consumption and CO_2 emissions by a minimum of 10%, depending on vessel routing, highlighting the immediate impact of eSAIL® technology.

Similarly, fitting eSAIL® on the Ville de Bordeaux vessel will support Louis Dreyfus Armateurs' ambitious goal to halve CO_2 emissions from maritime operations by 2030, compared to a 2015 baseline. Based on bound4blue's estimations and depending on the vessel's routing, these eSAIL® could potentially achieve significant annual savings in fuel and CO2 emissions, amounting to up to 560 tonnes and 1,800 tonnes respectively.