THE GOAL IS

Kjetil Sjølie Strand, CEO, LNT Marine, Norway, details how the company is developing a cost-efficient solution for the mid scale LNG carrier segment, with plans to scale up to larger sized vessels.

In April 2020, the first LNT A-BOX® type LNG carrier entered commercial service. This was the result of 10 years of development, and the first novel containment system to enter the fleet since IHI launched the first SPB ships in the early 1990s. Now, the vessel has been in operation for nearly two years, and valuable experience has been gained.

The idea behind the LNT A-BOX containment system was to develop a simple and efficient cargo containment system for LNG which could enable more shipyards to build LNG carriers. Based on experience with development of small scale LNG supply chains, where unit costs per energy unit are very critical, the inventors had seen a need for cost-efficient, mid-size LNG ships and terminals. Small scale LNG carriers based on Type C tanks were proven as an industry standard for the smallest sizes, but when scaling-up to sizes needed to achieve economies of scale for greenfield projects, the Type C

solution tended to become inefficient due to low volume utilisation and the high weight of the tanks. Downscaling traditional solutions for large scale LNG, such as Moss spherical and membrane systems, on the other hand, had also proven to be costly. As such, the initial focus for the LNT A-BOX system was to develop a cost-efficient solution for the mid scale segment, which when proven, could be scaled-up to larger sizes.

The first design and order for an LNT A-BOX type LNG carrier was the 45 000 m^3 LNG carrier *Saga Dawn*, ordered by Saga LNG Shipping at China Merchants Heavy Industry (Yangzhou, China). The vessel was handed over from the yard to the owner in early 2020, and entered its first charter party and commercial operations in April 2020.

Proof of concept

During the vessel's first one and a half years of commercial operations, *Saga Dawn* operated successfully in Southeast Asia on a time charter for a trader and importer of LNG. The vessel carried a total of 23 cargoes to China amounting to approximately 425 000 t of LNG. The vessel frequented six different terminals in the region and loaded cargoes from large scale LNG liquefaction plants, re-export hubs, as well as ship-to-ship transfer from a conventional-sized carrier and delivered to a second-tier Chinese terminal with draught and deadweight restrictions. During the course of its first term charter *Saga Dawn* was also carrying part cargoes at approximately 50% loading. As such, *Saga Dawn* has already demonstrated and proven the technology and underpinned flexibility

and market dynamics that analysts and traders expect will be needed more going forwards.

From a technical point of view the LNT A-BOX has performed over and beyond expectations. To date, zero issues related to the cargo containment system have been reported or noted, which is quite remarkable for a novel design and from a yard that had never built any gas carriers before.

The first new-building project and the first one and a half years of commercial operation have offered important confirmations and valuable experience for further development and new designs.

The cold interbarrier space between the tank and the secondary barrier which covers the insulation on the hull side is truly unique and sets the LNT A-BOX apart from any other designs on the market. This arrangement has proven to offer benefits for the operations of the vessel. This cryogenic temperature volume filled with nitrogen creates a thermal break around the LNG tank, which has proven to provide stable temperatures between laden and ballast conditions. This gives a number of benefits for the cargo operation cycles, such as short ramp-up to full loading and limited use of compressors. In warm conditions, this space can be ventilated and utilised for easy inspection and maintenance of the secondary barrier, the tank structure, and the tank supports – without gas freeing. This was proven and demonstrated during the acceptance testing and commissioning of the vessel.

Other than this there have been numerous lessons learned on several aspects during the design phase, construction, commissioning, and operation of the *Saga Dawn*. These have been mainly positive learnings, but of course also provided points for improvements.

Further development – up-scaling

From the inception of the concept, the intention was to make a scalable solution which could be rolled-out for larger applications after being proven in the mid-size segment. Therefore, the engineers at LNT Marine are now looking into up-scaling to see how the LNT A-BOX technology can be utilised for larger LNG carriers. The company has also teamed-up with industry majors to set up a joint industry project to develop a new design for larger vessels, including a 174 000 m³ LNG carrier.

This up-scaling implies both opportunities and challenges. As a representative of a major gas exporter stated, "With the LNT A-BOX, we see the advantageous combination of trading flexibility – as with Moss LNG spherical tanks – and at the same time better volume utilisation than membrane ships". The fact that the LNT A-BOX is based on a self-supporting independent tank Type A with internal structure means that there will be no imitations with regards to filling level for an LNT A-BOX type carrier, which is a flexibility only Moss type (and SPB) vessels are offering in the large scale segment today. Furthermore, and maybe contrary to what many would expect, the LNT A-BOX offers better volume utilisation and thus lower gross tonnage than membrane type vessels. The main reason for this is the flexibility with regards to the shape of the tanks, which means that the forward and the aft tank closest to the engine room typically will utilise the hull in a better way than membrane systems with their pre-defined angles and knuckles. This fact is also enabling greater freedom for the ship designer to design an optimum hull form when the LNT A-BOX containment system is selected.

The weight of the tank structure will, however, be heavier than a membrane primary barrier. As such, tank weight and optimisation to minimise this penalty is a challenge when scaling-up the containment system. One option is therefore to consider alternative tank materials.

Figure 1. Naming ceremony for the 45 000 m³ LNG carrier, *Saga Dawn*.

Figure 2. *Saga Dawn* conducting ship-to-ship (STS) loading from a large scale LNG carrier.

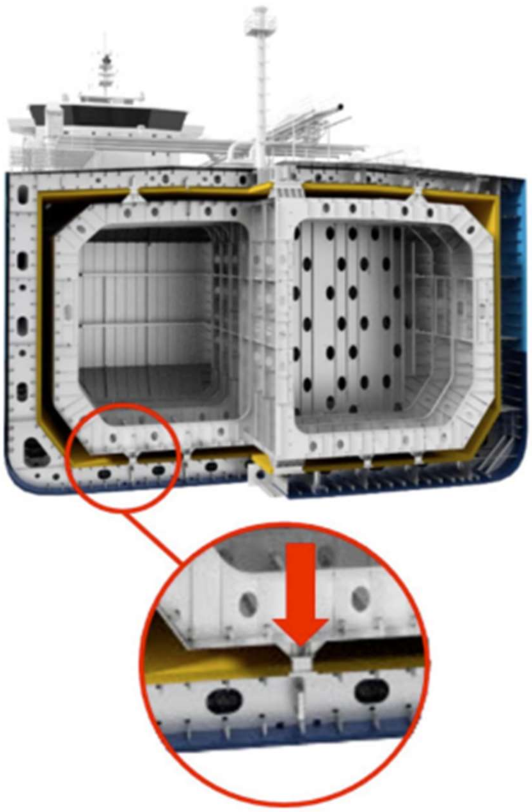

Figure 3. Tank supports transferring static and dynamic loads to the hull structure.

Figure 4. Large scale LNG carrier based on LNT A-BOX.

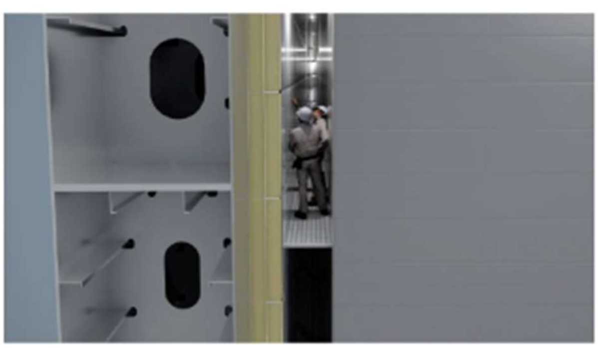

Figure 5. Interbarrier space between tank and secondary barrier, accessible in warm conditions.

The *Saga Dawn* featured tanks made from 304L stainless steel, and 9% nickel steel is also an obvious option. For larger vessel sizes and to optimise the weight and costs, aluminium and high manganese steel could be relevant alternatives. High manganese steel is, however, not yet adopted by the IMO for such applications and would in any case not give any significant weight savings. Thus aluminium is currently a more attractive option. The material density vs strength parameters for aluminium is expected to enable lower tank weight.

Fully automated production methods used in complex aluminium constructions have the potential of simplifying larger parts of the construction volume compared to normal tank building in steel. Profiles, especially plates with stiffener elements, can be extruded and then joined by the friction stir welding (FSW) technique in an extruder workshop instead of using traditional fusion weld. The production methods and thus reduction of manual welding may also have a positive cost impact. Consequently, studies for large scale carriers include tank design in aluminium, identification of material suppliers, assessment of material production methods such as extrusion and FSW processes for panels, block assembly, onsite welding, testing, and transportation. Altogether, aluminium has the potential to reduce the weight penalty and at the same time automate and shorten the production time.

Another aspect which also will counter some of the disadvantage on weight is the insulation system. Since the independent Type A tanks are supported by support keys transferring static and dynamic loads from the tanks with its cargo to the hull structure, the insulation system is not exposed to loads from the tanks and cargo, and as such compressive strength is not a concern for the design of the insulation system. Consequently, low density polyurethane foam offering the best possible thermal performance is used. This is completely different from the insulation system on a membrane type LNG carrier, where all static and dynamic loads from the cargo are transferred to the insulation system and compressive strength is critical for the integrity of the system. Therefore, higher density foam and glass fibre reinforcement are used in the insulation system on membrane type LNG carriers. The result of this fundamental difference in loads is that the insulation system on a membrane type LNG carrier is three to four times heavier than the insulation on an LNT A-BOX type. Besides the disparity of weight, the difference in density means difference in thermal performance, meaning that for any given thickness of insulation an LNT A-BOX type carrier will always offer lower boil-off than a corresponding membrane vessel.

These aspects represent some of the central challenges as well as opportunities from a technical point of view when the LNT A-BOX technology is to be scaled-up to the large scale segment. An equally big challenge may, however, be the mindset of the LNG industry. The industry has an exemplary safety record which to a certain degree may be due to the conservatism of the industry, but this mindset does also mean that it is extremely challenging to introduce and commercialise new technologies in the industry. The LNT A-BOX technology is now proven in the market and major industry players have teamed up with LNT Marine to take the technology to the next level and new size classes of ships. Finally there seems like there will be some long sought-after competition in this field. **LNG**