TIME FOR A NOVEL DESIGN

Jorn M. Jonas, LNT Marine, Norway, outlines how a new variety of novelly designed LNG fuel tanks can meet the latest requirements of the shipping industry.

Space saving LNG fuel tanks are increasingly being requested by the shipping industry, as a wide range of ship types are being designed or converted to use LNG as fuel. The ideal match for most LNG fuel applications is a combination of tanks constructed according to available ship volume and with the ability to withstand some pressure.

IMO Type C LNG fuel tanks

International Maritime Organization (IMO) Type C tanks have until now been chosen due to a lack of alternative LNG fuel tanks designed to withstand increased pressure loads. Type C bi-lobe and even tri-lobe are offered for the combination of high fuel volume and pressure tolerance for ship types such as large containerships, cape size bulkers, very large crude carriers (VLCCs) and car carriers.

Type C tanks need, per regulations, to be designed for a pressure higher than 2 barg, depending on the tank size, with larger sizes giving higher minimum design pressure. In many cases, this does mean using more tank steel than needed with regards to restrictions in weight optimisation. Due to the rounded form of Type C tanks, there are further restrictions in volume efficiency.

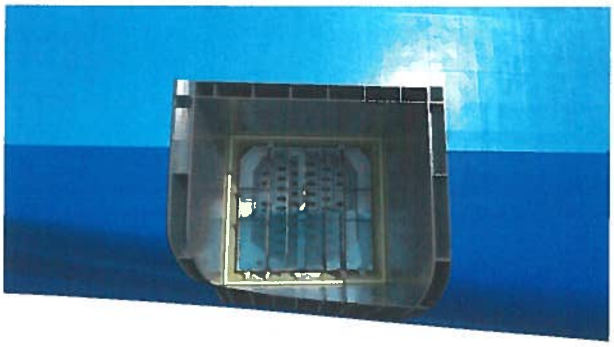

Figure 1. Prismatically formed LNG fuel tank.

Figure 2. Foam insulated IMO Type C fuel tanks.

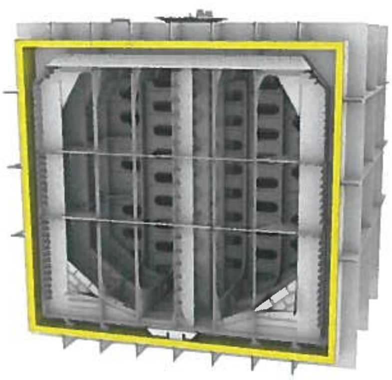

Figure 3. Arrangement of an LNT Fuel-Box.

Prismatic LNG fuel tanks

The market has responded to the restrictions relating to the IMO Type C tank by choosing very large, prismatically formed LNG fuel tanks – the CMA CGM container ships project in China being one high-profile example. Furthermore, there are now different types of prismatic fuel tanks hitting the drawing board for several other large scale LNG fuel tank projects.

Prismatically formed LNG fuel tanks (i.e. membrane types, IMO Type A and IMO Type B) have high volume utilisation, but IMO regulations have restricted their pressure capacity to an upper limit of 0.7 barg. For many projects, an operation pressure limit of 0.7 barg is too low. One concern is the holding time capability, which requires that the ship be able to remain in an idle condition for 15 days without venting gas. Other concerns relate to various operational factors, such as how cold does the LNG need to be to avoid a build-up of excessively high pressure in the tank after bunkering? How quickly is it possible to bunker within the limited pressure inside the tank? Movements inside the tank in rough weather may cause a rapid increase in pressure; how can this be handled within the 0.7 barg pressure margin?

A solution to this problem is to fit boil-off handling equipment, which can become expensive and power demanding.

Pro and contra considerations for Type A, B, C and membranes reveal that volume efficiency, steel weight and tank pressure are strongly influencing the investment and operation costs associated with using LNG as fuel.

Novelly designed LNG fuel tanks

LNG fuel tanks that are constructed according to available ship volumes, and at the same time can tolerate a pressure above 0.7 barg, were not accepted in the earlier revisions of the IMO International Gas Carrier (IGC) Code. In the latest revision, LNG tanks of novel design have finally been introduced.

Novelly designed LNG tanks create the opportunity to combine prismatically formed tanks and pressure build-up possibilities, with the freedom to choose tank design pressure. A thorough design and safety philosophy is a prerequisite for getting authority and class approval for novel designs. This design method is called 'limit state design'.

Briefly described, the reliability and safety of a novelly design tank, under increased pressure, shall be equivalent or better than the prescriptive tank types defined in the IGC Code.

2 barg pressure prismatic LNG fuel tank

LNT Marine specialises in prismatically shaped marine LNG tanks and LNG tank insulation. The company's novelly designed LNG tank, which is called the LNT Fuel-Box, has been developed in close cooperation with the classification society ABS. As a result of this cooperation, ABS issued an approval in principle (AiP) for the LNT Fuel-Box in 2019.

There are very high level safety regulations applied to LNG containment systems based on limit state design. LNT Marine has opted to utilise a full secondary barrier outside the LNG tank in order to comply with the regulations. The principle is taken from the IMO Type A tank design, and LNT Marine has recently completed a ship project in China, based on its LNT A-Box containment system, which features a Type A tank.

Increased safety by two independent LNG barriers

Full secondary barrier is designed as an integrated part of the thermal insulation and is completely independent of the tank itself. In other words, a failure in the tank will not affect the secondary barrier or vice versa. In the unlikely event of a tank leak, the LNG inside the tank will be collected in the secondary barrier.

LNT Marine's strategy was to develop a self-supporting, novelly designed tank able to cope with a pressure of 2 barg. During this process, an important aim of the company has been that a standard quality workshop should be able to construct the tank, rather than having to depend on specialised workshops.

The company chose a design philosophy that is based on complete independence between the two LNG barriers, or in the terms in the IGC Code, LNT Marine has chosen the Type A tank method rather than the Type B tank method.

Prismatic shapes, with distinct stress concentrations and increased safety factors due to higher pressure, would be demanding to deliver without considering the added safety offered by a full secondary barrier. This is mainly related to weld finish. LNT Marine considered that the extremely high requirements of the welds would make a tank without full secondary barrier tanks too expensive. The estimated number of workhours to finish off the weld were also estimated to be outside of what is possible within normal commercial frames, and there is a risk to consider when it comes to construction time. LNT Marine claims, however, that the cost of secondary barrier per square metre is no more than the cost of insulation for Type B tanks. The full secondary barrier construction eases the safety considerations associated with the tank construction because it forms an essential part of the containment integrity.

Separate activities during construction

The full secondary barrier is installed separately inside the ship tank space and is integrated into the tank supports as one common secondary barrier surface. There are polyurethane panels embraced by plywood and crack arresting cloth, with a reinforced aluminium seal between the panels. The tank supports are integrated with the panels in the same manner as the panels are integrated with each other, all in a way that prevents global forces acting on the secondary barrier surface. As a result of the independence between the barriers, the secondary barrier is not exposed to any impact loads during operation, only minor movement in the flexible seal between each panel due to hull deflections. The density of the polyurethane foam is selected for its best possible insulating properties, i.e. a density of around 40 kg/m^3. The tank is constructed outside the ship and is lifted into the insulated tank space with integrated hardwood tank supports.

Low boil-off rate

The arrangement with insulated tank space and non-insulated tank space provides an access space in between the tank and the secondary barrier insulation. The access space is an important feature for lifelong quality control of the LNG barriers, with easy access to any part during drydocking.

Probably less evident is the insulating function of the access space. The access space is filled with dry nitrogen. The LNG tank is thus encapsulated by a volume of cold nitrogen gas with the secondary barrier insulation on the outside of the nitrogen volume. The access space is cooled close to cargo temperature before operation and maintained at this temperature.

Nitrogen gas' insulating properties improve by a factor of 2.5 times when cooled from 20°C to -160°C. The access space volume will therefore act as an effective heat transfer break between the tank shell and the insulation, i.e. increasing the total insulation performance. Together with the low-density polyurethane foam panels, this produces less boil-off gas (BOG) compared to the traditional arrangement, which utilises an insulated tank in an ambient temperature hold space.

Figure 4. LNT Fuel-Box – the tank is constructed in parallel with secondary barrier installation.

LNT Marine is considering several options to utilise the access space for further reducing BOG. With gas engines becoming increasingly efficient and pumps supplying fuel to the engines, the lowest possible boil-off rate (BOR) is always an aim.

LNG fuel gas operation

The present demand for marine LNG fuel technology contrasts with the available ships that are equipped with Type C vacuum insulated LNG fuel tanks. When these ships were designed, BOG was of no concern and gas supply pressure was achieved with a simple heat exchanger pressure build-up unit.

In the present transition from fuel oil to LNG fuel, factors such as fuel volume, pressure build-up time, ramp-up speed, bunkering speed, temperature restrictions for bunkering and tank pressure variation during operation, are all of concern to a ship operator. Fuel gas supply systems and boil-off handling systems are increasingly being optimised for individual ships' operating requirements.

LNG fuel operation is something new and different from oil fuel systems. A lot is being done to offer simple operation LNG fuel systems to enable the smoothest possible transition from fuel oil to LNG fuel.

Conclusion

By increasing the maximum vapour pressure for prismatic tanks from 0.7 to 2.0 barg, an important design basis has been achieved, particularly for large and volume sensitive LNG fuel tank installation.

Fuel supply and boil-off handling systems can be simplified. A holding time requirement of 15 days is far easier to fulfil. Boil-off compressors plants in regulation with LNG fuel pumps as fuel gas supply system may be replaced by fuel pumps only. The need for boil-off compressors for boil-off removal from the tank may be replaced by tank pressure build-up and possibly combined with compact LNG subcooler units.

All in all, there is potential for a much simpler operation than what is currently required of standard prismatic tanks. It could be concluded that, with the introduction of novelly designed LNG tanks, a milestone has been achieved in the transition from oil fuel to LNG fuel. **LNG**

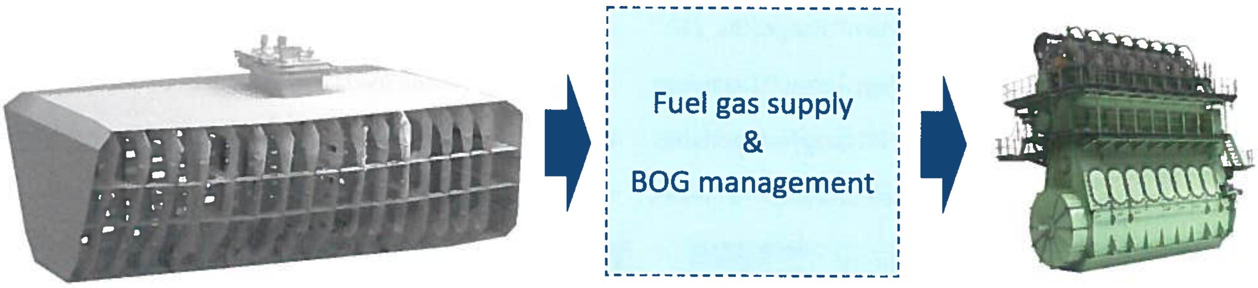

Figure 5. Boil-off gas (BOG) management is simpler with increased pressure.