TURNING BACK TIME

Kjetil Sjølie Strand, LNT Marine, Norway, considers how refurbishing insulation systems for spherical LNG carrier tanks can boost energy conservation and facilitate hassle-free operations.

The Moss fleet still represents a significant and important share of the global fleet of LNG carriers. The famous tank design has proven its reliability and performance for decades and is suitable for life extension as well as conversions. The insulation systems are, however, ageing and deteriorating over time, while the market expectations for boil-off gas (BOG) are decreasing. LNT Marine has taken on this challenge and developed a range of solutions and services to assist owners and operators of ageing Moss type LNG carriers.

Background details

At the 2nd LNG Congress in Paris in 1970, Kværner Moss presented the paper: 'The design of an 88 000 m^3 LNG carrier with spherical cargo tanks and no secondary barrier'. Subsequently, the *Norman Lady* was delivered from the Rosenberg shipyard in Norway in November 1973, becoming the first LNG carrier with spherical tanks – the Moss type. In the following decades, Moss type LNG carriers dominated the development of the LNG carrier fleet. Even though GTT membrane systems dominate the market today, Moss

type LNG carriers still represent a significant share of the world's LNG carrier fleet – some 125 units are listed in the Clarkson Ship Register.

With their independent spherical tanks, Moss type LNG carriers are known to offer high reliability and flexibility for transporting LNG at sea. The spherical and robust structure allows any filling level, with no concerns for sloshing problems. Since a spherical shape is the optimal geometric definition for a given volume relative to surface area, the tank system also has the potential to offer very attractive boil-off rates (BOR). As most of the existing Moss carriers were built some decades ago and with steam turbines which consumed large amounts of BOG, the vessels were typically designed and built with BOR in the range of 0.20 - 0.25% per day. Due to its simple configuration and robust design, the tank structure has proven to be in very good condition after decades of operation. However, the same is not always true for the insulation systems, which have a tendency to deteriorate over time. Consequently, many existing Moss vessels now have a BOR higher than the original specification and significantly higher than what the market typically would expect today.

Figure 1. Typical problems seen in the insulation systems.

Figure 2. Upgrade of a Moss type tank.

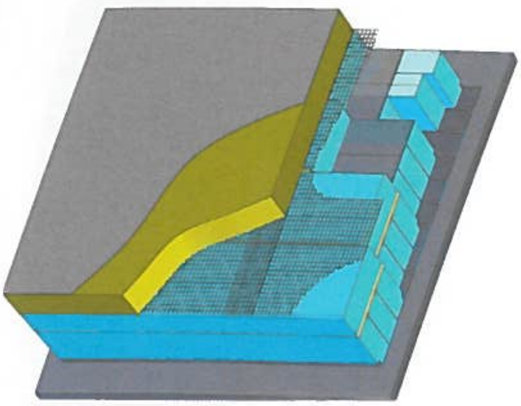

Figure 3. Moss upgrade section.

LNT Marine, a specialist in LNG containment systems and cryogenic insulation, has seen an increasing demand to repair and even upgrade insulation systems on Moss type spherical LNG tanks. Based on its experience with gas carrier insulation systems in general, and Moss type LNG carriers in particular, the company can provide a range of solutions and services to enable mature Moss type LNG carriers to offer competitive BOR in today's market.

Insulation systems for spherical tanks

Two methods have traditionally been used for the insulation of Moss spherical tank LNG carrier new-builds. These are panel systems and the so-called spiral generation.

In the panel method, insulating panels made of modified polyurethane foam, polystyrene, or a combination layer of phenolic resin foam and a layer of polyurethane foam are attached onto the spherical tank with studs. A vapour barrier of aluminium foil or composite coating is applied to the outer surface. In order to allow the necessary shrinkage in the horizontal and vertical directions, expansion joints are provided in each panel.

The spiral generation system has been employed for the insulation of Moss tanks since 1974. With this system, extruded polystyrene foam with glass fibre mesh cloth reinforcement is rapidly applied in spirals using rotation booms to a thickness of approximately 250 mm. Panels of insulation are fitted to the dome's north and south poles and along the cargo tank's equator skirt. The spiral generation method is highly automated and offers advantages that include: reduced manpower, rapid application, continuous monitoring, and uniform quality. An aluminium foil (used as vapour barrier) is sealed by heating and pressing an overlap to the previously applied material. Straps and steel springs secure the insulation to the lower hemisphere.

A notable safety feature of the Moss containment system is the purging of the space between the tank surface and the insulation. Thus, in both insulation methods, the insulation is not bonded to the tank surface and the inter-barrier space is purged with nitrogen gas, in order to enable: continuous monitoring for possible small cargo vapour leaks; maintenance of a non-flammable atmosphere around the tank; and to act as a spray shield for the hull, directing any leak downward to the drip tray that forms the secondary barrier. The tightness of the vapour barrier is therefore a key element of the design philosophy.

The challenge

LNT Marine's team of insulation specialists has experience dealing with both LNG carrier new-builds as well as the maintenance and repair of Moss type LNG carriers, and has first-hand experience with the typical deterioration and failures in the insulation systems.

Glued and foamed joints between insulation panels, or between the extruded polystyrene for spiral generation system, are weak points prone to leakage after years of service. The aluminium surface does not expand and extract thermally as the underlying insulation material. Aluminium surface flexibility is therefore based on corrugation lines, allowing the aluminium to bend inwards during contraction. After decades of operation and hundreds of thermal cycles, the glue used in the system has experienced the effects of ageing and thus has lost some of its flexibility. Moreover, by this point the aluminium is prone to cracking due to fatigue. When the spherical tanks on old vessels are inspected, minor deficiencies on the external surface are often found. The most obvious finding is often cold spots, especially on the lower hemisphere, but the underlying reason is usually that the vapour barrier is leaking due to loose sealing tape, delaminated or cracked aluminium foil, and sometimes cracking in the panels.

When the vapour barrier is no longer tight, the result is reduced thermal performance and increased inert gas consumption. It also becomes difficult to maintain the required pressure in the annular space for leak detection.

Solutions

Local spot repairs

If the extent of cold spots and deficiencies are not too extensive, and the vessel can still offer an acceptable BOR, local spot repairs are possible. In such cases, LNT's specialists typically board the vessel during a cargo voyage for a detailed inspection of the

Figure 4. Removing of foil.

insulation surfaces in cold condition to determine the extent of repairs needed. Subsequently, the local insulation spot repairs are carried out during the next dry docking of the vessel. It shall be noted, however, that when the insulation system has reached a point where the vapour barrier fails, it must be expected that this process will continue. Indeed, even with local repairs being carried out, it is normally just a matter of time before new failures emerge. Consequently, it would not be possible to guarantee the long-term performance of the insulation or the prevention of any further operational damages occurring if this option is chosen.

Full refurbishment and upgrade

Alternatively, and rather than adopting a piecemeal approach, it is possible to refurbish the complete insulation on the upper and

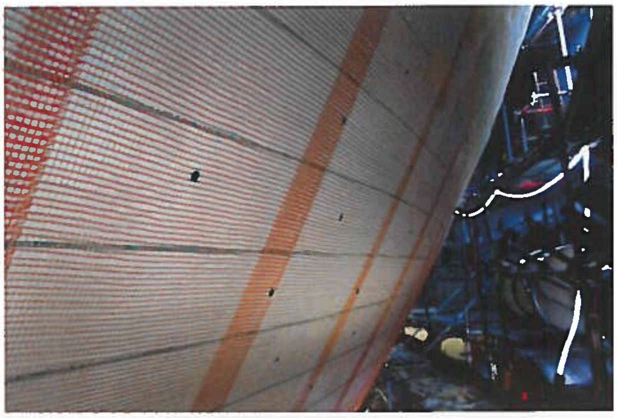

Figure 5. New crack arrester.

Figure 6. Application of new PU foam.

lower tank hemispheres, as well as attend to any defects found in the panel insulation at the equator skirt and poles.

LNT's upgrade package is intended to improve the structural and thermal performance of the insulation and vapour barrier to a long-lasting level equivalent or better than the original insulation system – often referred to as 0-hour condition.

In order to achieve gas and vapour tightness of the insulation system, the existing aluminium foil will be completely removed from the tanks. The surfaces will be cleaned and checked for deficiencies and, for the lower hemispheres, this will require the partial removal of the strap bands. A glass fibre mesh will then be applied to the top of the original insulation prior to foaming to act as a crack arrester. The mesh will be secured with plastic plugs and bridged to panel surfaces by a two-component polyurethane glue. Following this, polyurethane foam, comprised of two main premixed polyol and isocyanate components, will be applied by means of a spray gun until a required total foam thickness is achieved. This process will provide a continuous surface with no joints and an overall tank insulation thickness of more than the original 250 mm. The polyurethane foam is flexible and can cope with the thermal contraction and expansion of the cargo tank and underlying original insulation. The foam, as applied, will have a typical density of 36 - 50 kg/m^3 with a closed cell content in excess of 90%. Finally, a hybrid polyurea/polyurethane coating will be sprayed onto the foam surface to a thickness close to 2 mm as a homogeneous, continuous protective layer. This coating, developed by LNT Marine for cryogenic temperatures, will replace the aluminium foil and function as a spray shield. The coating has been tested for compatibility with cargo as required in the IMO IGC code and approved by class societies. The outer layer will, in addition to functioning as a spray shield, serve as a vapour barrier, as well as providing mechanical protection for the insulation against impact. In addition, the coating is flexible enough to follow any thermal movement in the insulation. The completed insulation will provide an improved partial secondary barrier and spray shield for 15 days in the case of a small leak through the primary barrier.

This approach will result in long-term operational cost savings in three key areas. By reducing nitrogen gas leakage and restricting heat ingress due to the extra insulation it is providing, there will be not only an improved retention of inert gas in the annular space, but also a reduction in cargo BOG. Finally, the hull structure will have additional protection against extreme temperature changes.

An example of a project where such a solution was selected, was when the former *Golar Frost* was converted to become the *FSRU Toscana* for OLT in Dubai Drydocks World back in 2011. LNT Marine (former MGI) carried out the full refurbishment and upgrade of the insulation of all four of the vessel's spherical tanks – with a total surface area of some 20 000 m^2 – in approximately 10 weeks.

BOR reduction

As already indicated, the refurbishment and upgrade methodology does also have the potential to reduce the BOR from the tanks, as the insulation system thickness is increased with additional polyurethane foam. Subject to an owner's requirements, the additional polyurethane foam layers on top of the new crack barrier mesh can be increased to reach specific BOR targets.

LNT has analysed a number of potential projects for BOR reductions, and results show that quite significant improvements can be achieved. A traditional vessel with original BOR in the range of 0.25% per day can, for instance, be improved to some 0.15% per day. For more modern vessels with design BOR of 0.15% per day, performance can be improved to approximately 0.08 - 0.10% per day. As the lower hemisphere is somewhat sensitive to additional weights, the majority of the new polyurethane foam will be added to the upper hemisphere. Coincidentally, this is also where the majority of the heat ingress comes from and therefore it is a very efficient option. Furthermore, lighter insulation materials may be added to the lower hemisphere to maximise thermal performance and minimise boil-off.

Conclusion

Considering the general good quality of Moss type LNG carriers still sailing and being used, or considered for use as floating infrastructure (i.e. as FSUs, FSRUs, or FLNGs), there is a good business case for refurbishment and upgrade of the insulation systems on the spherical tanks of these vessels. Shipowners and operators with such vessels in their fleets seeking hassle-free operation and minimised operational costs could benefit from these solutions, as they can reduce BOR – which is becoming increasingly important – and avoid random faults which would require short-term fixes. A fully upgraded insulation system has the potential to minimise the need for expensive shutdowns for spot and quick-fix repairs, as well as to lower the energy consumption of a vessel as boil-off is reduced. **LNG**