The LNT A-BOX features self-supporting IMO Type-A tanks mounted within an insulated hold space to be installed in a 45 000 m³ vessel under construction in China.
Patrick Janssens, ABS, China, looks at how LNG containment systems are continuing to push the boundaries of innovation.

The evolution of containment systems employed in LNG shipping has been driven by multiple factors. While vessel designs have seen some dramatic size increases, containment system design has been mainly driven by lower boil-off requirements resulting from more efficient propulsion systems, the development of small and mid-scale LNG carriers and a desire of new players to enter the market, with a resulting pressure to reduce barriers to entry.

This dramatic growth has created numerous challenges for owners, designers, shipyards and classification societies, but it has also been instrumental in fostering innovation, while enabling the industry to grow safely and sustainably.

For many years, both LNG and liquefied petroleum gas (LPG) carriers were built using a handful of well understood technologies supplied by established designers. More recently, designers have begun to develop and present new technologies for construction in leading shipyards in both China and South Korea, which are gaining experience in such newbuilding projects.

ABS has played a key role in the development of these new technologies through its assessment and approvals process, and has been requested to class many of the containment systems and vessel designs.

Some notable milestones for ABS include classification of the first LNG carrier featuring the new KC1 membrane containment system, a pair of LNG carriers using an integrated membrane-hull structure technology, and an LNG carrier employing self-supporting Type-A tanks.

The traditional approach by class societies to approval in principal (AIP) and general design approval (GDA) would have been to comment on drawings submitted from shipyards or designers and to provide comments and amendments at the end of the review process.

The increasing number of new players entering the market means that the class role is increasingly to provide AIPs on system designs that reflect emerging shipping projects and new vessel designs.

**Regulatory background**

The very first LNG carriers built from the late 1950s onwards were constructed before a dedicated regulatory framework had been developed. Today, the industry relies on the Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, better known as the IGC Code.

The IGC Code, which is part of the International Maritime Organization's (IMO) Safety of Life at Sea Convention, has been adopted by almost all maritime nations and written into the rules of classification societies, which are approved to perform statutory surveys and issue Certificates of Fitness on behalf of flag administrations.
ABS participated in both the development of the original IGC Code and the updated and revised Code which entered into force in 2016, contributing experts to the Steering Committee and working groups and chairing the Group reviewing Chapter 4 of the Code, which deals with design and construction of cargo containment systems.

Gas carriers, and LNG carriers in particular, have excellent safety records, but with the increase of gas transportation by sea and the number of players in the sector, it is essential to ensure that this record is maintained and that measures are taken to use accumulated knowledge when assessing new technologies.

The philosophy of the IGC Code is to be less prescriptive than previous iterations and focus more on goal-oriented development. Some detailed requirements for achieving these goals are left, where appropriate, to organisations including flag administrations and classification societies.

Risk analysis has become an important tool for assessing new designs, concepts and also for verifying overall safety of existing designs and practices. The Code introduces new requirements for advanced analysis of sloshing, fatigue, vibration and dynamic loads, buckling considerations and crack propagation.

**New approaches**

Some years ago, South Korean energy major Kogas began an ambitious project to design a new membrane cargo containment system for large LNG carriers in collaboration with Hyundai Heavy Industries (HHI), Samsung Heavy Industries (SHI) and Daewoo Shipbuilding & Marine Engineering (DSME).

The Kogas KC-1 cargo containment system adapts an approach already used by Kogas in some onshore LNG storage tanks of primary and the secondary barriers constructed of 1.5 mm thick stainless steel corrugated plates.

ABS was involved since the beginning of the KC-1 project and granted AIP in 2012 and GDA in 2014. SK Shipping subsequently ordered the first two 174 000 m³ LNG carriers to be built with KC-1 system to ABS class at the Samsung shipyard.

Kogas believes that this arrangement results in increased flexibility, while the anchoring system is designed only to prevent the detachment of the insulation and to allow some horizontal movement.

The spherical design of the Moss-type containment system is one of the industry’s most characteristic and was a familiar sight during the early growth of LNG trades.

For the first time in many years, a non-Japanese owner, Malaysia’s Petronas, ordered vessels with a Moss-type containment system from a non-Japanese yard. The four LNG carriers of 155 000 m³ capacity were built at South Korea’s HHI, two of them to ABS class.

For these vessels, the traditional Moss-type configuration was modified in accordance with a design known as the Integrated Hull Structure (IHS). The principal feature of the IHS is the new type of tank cover integrated to the hull structure as a longitudinal member. This continuous cover is highly effective in increasing the longitudinal strength of the vessel and also in simplifying the construction process.

However, this concept is not completely new, as approximately 10 years ago Kværner Moss presented a concept drawing for a Moss ship with an integrated cover.

ABS is classing eight Moss-type Sayaringo STAse LNG carriers under construction in Japan. The Sayaringo tanks are apple-shaped, with an upper half which has more of a bulge than the lower half and a cover integrated with the tanks.

**Membrane systems evolve**

Of the major membrane containment systems available today, Gaztransport & Technigaz (GTT) launched the Mark III Flex design five years ago in order to meet two specific criteria. The first is to reduce boil-off by increasing insulation thickness; the second is to reinforce the containment system by applying higher density foam for applications such as floating LNG (FLNG) where partial filling is required.

As the mechanical characteristics of foam insulation can deteriorate when the thickness is increased, secondary insulation is fabricated by joining together two thinner foam boards. The
resulting design is similar to the original Mark III, but can achieve a boil-off rate of less than 0.10%.

More recently, GTT presented its Mark V insulation system, which includes a metallic secondary barrier made of Invar sheets, which have small corrugations with reverse orientation to the primary barrier sheets.

The Mark V system has received ABS AIP and GDA, with one vessel featuring the system currently under construction to ABS class.

GTT still offers the No 96 system in various configurations. In particular, the No 96-LO3 features a modified design of the secondary Insulation boxes, which are split into two layers. One is a typical No 96 insulation box of lower thickness, filled with glass wool, and the other a polyurethane (PU) foam panel secured on the bottom.

The size of the new boxes and the installation principle is the same as for the standard No 96 and this setup maintains much of the simplicity of the system, but greatly increases efficiency, reducing the nominal boil-off rate from 0.15% to nearly 0.10% without increasing the total thickness of the insulation.

GTT also recently revealed a new No 96 system design, where the bulkhead reinforcement arrangement has been replaced by reinforced wooden pillars, which increase the strength capacity of the boxes, while reducing boil-off to lower than 0.10%.

Emerging technologies

A particular challenge of transporting LNG is that large tanks cannot easily handle high pressures, while the use of multiple lower pressure tanks is inefficient in terms of storage volume.

An alternative approach is suggested by the developers of the Lattice Pressure Vessel (LPV), which was designed and developed with the goal of providing a solution for prismatic pressure vessels which fully combine the space efficiency of the prismatic shape of non-pressure tanks with the load-carrying capability of cylindrical pressure vessels.

Commercial development was largely sponsored by South Korean steelmaker POSCO, which regards the LPV as a future sales channel for its cryogenic high manganese steel material. ABS granted AIP to the LPV in 2016.

By employing an internal lattice structure for balancing pressures on opposite walls, the outer shell, which acts as the gas barrier, is less stressed than in a normal shell design. The internal structure has repetitive redundancies, which can redistribute forces in case of component failure and also effectively dampens liquid motion and virtually eliminates sloshing.

ABS has also supported the development of another new technology in LNG containment, granting AIP for a system of self-supporting IMO Type-A tanks mounted within an insulated hold space and classing the 45 000 m³ vessel under construction in China.

The ‘LNT A-BOX’ has been developed by Landmark Capital affiliate LNG New Technologies (LNT), which is providing engineering services for the project and will market the containment system to third-party shipyards looking to enter the LNG sector.

LNT has attempted to reduce the cost of entry for owners and yards to construct mid-size LNG carriers by designing a containment system that could fill the gap between smaller ships with Type-C tanks and those with larger membrane type containment systems.

The vessel design features a complete double hull with the independent Type-A tanks located in the holds. The tanks themselves are not insulated, as this will be arranged on the internal surface of the inner hull of the vessel and sealed in a way similar to membrane vessels.

A further concept designed to lower the cost of construction for LNG and LPG carriers while also providing a solution for the small scale transport of gas received AIP from ABS in 2015. Designed in Norway by Brevik Technology, the containment system uses a series of independent, cylindrical Type-B tanks and was designed for application in a 30 000 m³ gas carrier.

In granting this AIP, ABS assessed the concept against the requirements of the IGC Code, ABS Rules and Guide for Liquefied Gas Carriers with Independent Tanks. Since the tank design was a novel concept, a hazard identification (HAZID) study was also performed.

ABS has completed more than a dozen assessments on new concepts in gas containment in recent years and, as always, the focus during the AIP process is on assessing a system’s compliance with the intent of ABS Rules and other applicable standards, such as the IGF Code for newbuilding projects.

Enabling the future

The development of LNG containment systems – just like the ships on which they are installed – has followed a path defined first by the need for scale and then by specialisation, but always marked by innovation. The demand for bigger and bigger volumes of gas for transport has seen systems constructed to serve long distance, large scale trades in safety.

As LNG trades have evolved, so has the design of systems which address new ship types and smaller cargo volumes. Crucially, these new containment systems have enabled new players to enter the market alongside the established names by creating new ideas as well as reviving existing concepts to address changing needs.

In all of these projects, ABS leverages the experience of its Global Gas Solutions team to provide industry leadership and guidance in LNG, floating structures and systems, gas fuel systems and equipment, gas carriers, and regulatory and statutory requirements. The team also offers specification reviews, risk and hazard assessments, bunkering suitability reviews, project management for new construction and feasibility studies.