A step towards more sustainable storage systems

Adnan Ezzarhouni, GTT China, and Fabien Pesquet, GTT France, outline the use of membrane full containment technology for LNG onshore tanks.

The significant increase in LNG supply and demand over the last few years, driven by the explosion of US exports and Chinese imports, along with further growth – 71 million tpy of final investment decision in new liquefaction plants have been taken in 2019, an all-time record – are likely to drive LNG land storage projects. Furthermore, decreasing LNG prices and air pollution challenges arising from coal-fired power stations should increase the market for LNG and consequently cryogenic storage tanks.

9% nickel (Ni) full containment system: the main onshore tank technology

Origin and market

The first 9% Ni full containment LNG tank was built in 1977 at the Abu Dhabi, UAE, liquefaction plant. Since the 1980s, almost all the large tanks built worldwide have been designed as 9% Ni full containment tanks. The evolution compared to double containment tanks consisted of integrating an outer concrete container, giving it a higher level of safety. This evolution allowed the contents of the inner tank to be protected against external aggression (projectiles, blast effect, adjacent fire, etc.), in order to withstand cryogenic conditions, to provide tightness for liquids, and to contain boil-off gas. The outer concrete container also provides the structural resistance to internal and external loads.

Characteristics

These tanks are composed of an inner tank made of special steel (9% Ni), able to contain refrigerating liquid under conditions of normal operation; an insulation system to control boil-off of tanks' fluid content; and a secondary container wall made of pre-stressed concrete with a roof which is usually reinforced concrete (although metal roofs are allowed).

The largest onshore tanks using the full containment system are 260 000 m^3 and located in South Korea and Singapore.

Figure 1. 130 000 m^3 membrane full containment tank in the Philippines.

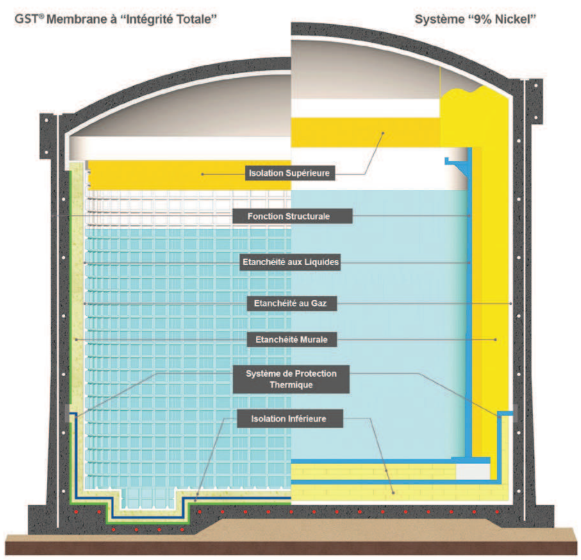

Figure 2. Left: Cross section of membrane full containment tanks. Right: Cross section of 9% Ni full containment tanks.

Membrane full containment system: an increasingly attractive solution

Origin and market

The surge in the demand for new LNG facilities or for readily available increased storage capacity, as well as the rising cost of raw materials (in particular Ni), make the selection of membrane-type full containment systems more and more attractive for LNG land storage. In this context, Gaztransport & Technigaz (GTT) has leant its extensive expertise of membrane containment systems both for LNG carriers and for land storage, to develop GST®, which is an updated solution of the membrane full containment dedicated to onshore storage.

38 membrane full containment tanks, in operation or in order as of 31 March 2020, have already been applied worldwide with GTT technologies. The first membrane full containment tanks were ethylene tanks, commissioned in 1972 in France, and still in operation after almost 50 years. The first two LNG membrane full containments are the ones operated by ENGIE in Montoir-de-Bretagne, with a capacity of 120 000 m^3 each. Following those, 10 tanks with a capacity of 100 000 m^3 were built for KOGAS in Pyeong Taek, South Korea.

Recently, GTT has been designing two membrane full containment LNG storage tanks, each with a net capacity of 220 000 m^3. The tanks are under construction by PetroChina EPC contractor Huanqiu Contracting & Engineering Co. Ltd (HQC). The tanks will be located in the Tianjin South Port Industrial Zone in China and are expected to be commissioned during the last quarter of 2022. They will be the world's largest above ground membrane full containment LNG storage tanks.

In the meantime, another membrane full containment LNG tank is under construction in Heijan City, in the Hebei Province in China, by another EPC contractor of PetroChina group, China Petroleum Engineering and Construction Corp. North China Company (CPECCNC). The tank will have a capacity of 29 000 m^3 and is expected to be commissioned during 2021.

A new containment system

GST technology is derived from the well-known Mark III system. It is made of a corrugated stainless steel membrane (304 L) with a thickness of 1.2 mm, which is the primary membrane. The double network of corrugation absorbs the thermal contractions, in both directions, resulting from the very low temperature of the LNG. This makes the membrane insensitive to thermal loads.

The primary membrane is made of standard prefabricated membrane sheets, welded onto the insulating panels and lap welded over each other. The thickness of the panels can be adjusted to provide a large range of boil-off rates according to the owner's requirements (typically 0.05% per day).

The outer concrete container provides the structural resistance to internal and external loads. A moisture barrier, applied on its inner side, prevents moisture from entering the tank.

GST also includes a thermal corner protection as required by European standards. Like Mark III, it consists of a thin sheet of aluminium inserted between two layers of glass cloth and

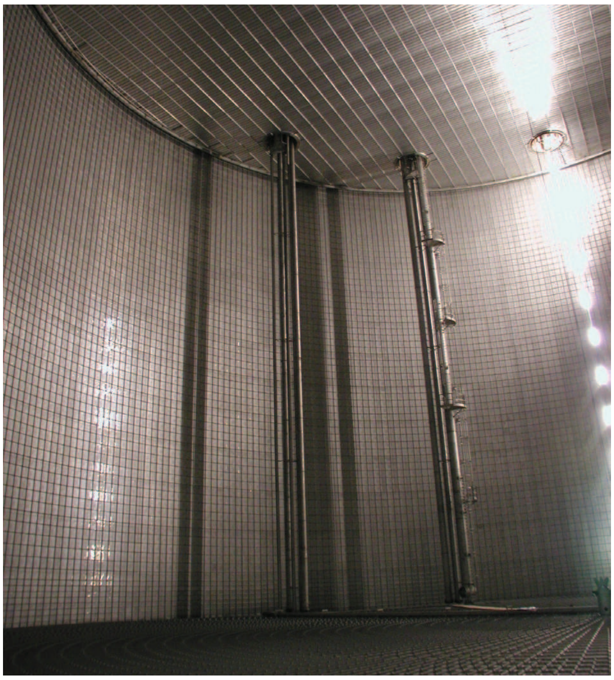

Figure 3. Inner view of a membrane full containment tank.

Figure 4. Completed fondation of the 220 000 m³ membrane full containment tank in Tianjin, China.

resin. In the event of a failure of the primary membrane, the secondary membrane ensures liquid tightness.

Separation of the main functions

The GST membrane full containment system is based on a clear separation of the three main functions required for a land storage tank: tightness, thermal insulation, and structural resistance. The tightness function is provided through the two membranes: primary and secondary. The primary corrugated stainless steel membrane is then tightly welded to the carbon steel liner on the inner side of the dome roof and therefore ensures a total gas tightness of the containment system, thus preventing any water migration from the concrete to the insulation space.

The insulating function is ensured by insulating panels, secured onto the concrete wall with anchoring elements (mastic and studs).

The structural resistance function is ensured by an outer post-tensioned concrete tank, which grants structural resistance to the inner hydrostatic load and outer hazards.

Prefabricated modular elements

Another characteristic of the GST technology is a concept that relies on prefabricated modular elements composing the membrane sheet layer as well as the insulating panels. They are prefabricated with basic shaped components that can be manufactured by normal industrial processes used from the shipping industry, affording the benefit of a short lead-time for supply as well as streamlining cost of supply. These prefabricated elements are very similar to the ones already fitted on LNG carriers. The size of these elements makes them easy to handle and fit together on site. Their design simplifies the construction and, therefore, makes it possible to use local workforce.

Membrane and 9% Ni full containment systems

Similar attributes

Membrane full containment and 9% Ni full containment tank systems have some similar positive attributes. Both technologies contain both liquid and vapour under normal and accidental conditions. Under abnormal (spill) conditions, both tanks use a robust pre-stressed concrete outer tank for containment of LNG and vapour. Moreover, both tanks incorporate thermal corner protection in the design, as per industry standards requirements.

Competitive advantages of the membrane full integrity system

Although both technologies have similar attributes, 9% Ni full containment and membrane full containment tank systems are different in many ways that can make a difference.

GST technology benefits from over 55 years of LNG experience – with more than 500 LNG carriers (in operation or in order as of 31 March 2020) using the technology. Secondly, GST technology benefits from a strong experience in land storage systems in aboveground as well as in-ground: 38 tanks have already been built worldwide. Thus, the reliability of the GST membrane system is proven by its inheritance.

The separation of the main functions of membrane full containment allows the optimisation of each function, permitting individual and global testing, and avoids simultaneous multiple failures. This is designed to enhance the reliability and efficiency of the membrane system.

GST has a flexible design and is suitable for very large tank capacity. In fact, as it is constituted of standard modular elements, GST technology can be adapted to every structure, whatever its form or size, without any major changes in the design and dimensions. So far, tank construction or feasibility studies made by GTT have covered sizes ranging up to 320 000 m³.

As a result of the simplified design and modular elements, the erection of the containment system is optimised.

In terms of safety, many quantitative risk assessments have been performed by Korean, British, French, and US entities – for comparison of the full containment technologies of both membrane and 9% Ni. Each study arrived at the same overall conclusion: both technologies provide the same risk profile and same level of safety, with some advantages for the membrane full containment in a variety of events such as seismic, tsunami, overfilling, etc. The membrane represents an inherently safe system for preventing LNG leakage. The membrane is not highly stressed compared to 9% Ni steel inner tanks and, as such, is not subject to sudden progressive failure modes. Instead, any failure of the membrane will result in a slow leakage of LNG, which will vaporise in the insulation space and be detected in the nitrogen purge stream.

The membrane full containment tank is a more robust cryogenic storage tank concept for high seismic areas. The 9% Ni full containment tank is susceptible to inner tank sliding, which is difficult to accommodate in areas of high vertical ground motions even with seismic isolation. The thin wall of the inner tank can uplift, increasing compressive buckling stresses. The membrane full containment tank transfers all seismic demands to the outer concrete tank, permitting a more robust design and less complex solutions to prevent sliding. Furthermore, during a tsunami, the membrane full containment tank is less sensitive to the impact of a major tsunami wave as a result of the internal loading of the tank.

The international EPC contractor Bouygues TP has investigated the carbon footprint of membrane full containment compared to 9% Ni. The study concluded that the membrane tank represents a significant reduction (approximately 25%) in carbon footprint due to material types and weights.

There is a lower-skilled labour requirement on-site for membrane full containment tank than 9% Ni full containment tank. Welding of thick 9% Ni steel plate is a specialised welding qualification with limited resources leading to increased costs. The membrane full containment technology transfers much of the skilled labour off site, leaving the placing of prefabricated components to site and the welding of the stainless steel liner. Most of this welding has been automated, further reducing the demand for manual on-site welding. Offsite manufacture of insulation panels and membrane fabrication can significantly reduce on-site manhours, resulting in higher productivities, higher quality, and reduced labour rates, leading to an overall reduction in unit costs.

The simplified modular technology, the industrial prefabrication of the containment elements, and the easiness of the erection make the GST membrane system cost-competitive and schedule effective, compared to 9% Ni full containment. Membrane full containment technology is designed to ensure cost and schedule stability in contrast to 9% Ni. In fact, 9% Ni is influenced by the cost of nickel, and the delivery times for 9% Ni steel plate also became a significant driver of schedule on LNG tanks. The membrane full containment tank generally provides a reduction in cost and a two to four month reduction in the construction schedule.

Conclusion

The membrane full containment technology has received little attention for many years because of the absence of competition among EPC contractors, inadequate references in international standards, and a reluctance by owners to adopt a technology for onshore tanks that had relatively little recent track record compared to the traditional 9% Ni full containment technology. Recent revisions and developments of design standards, and international and national regulations, have now incorporated provisions covering the membrane full containment technology. As the technology is now accepted by most oil and gas majors and large utility companies, such as Beijing Gas Group, it is likely to reshape the tank market – volume and technology wise – thereby driving further innovation, which can lead to reductions in unit costs and schedules for LNG storage tanks and also to lower carbon footprint. LNG