WHAT IS DRIVING THE REVIVAL OF INTEREST IN THE MEMBRANE SYSTEM FOR LAND STORAGE LNG TANKS?

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I. ABSTRACT

Recent worldwide growth in natural gas consumption has led to a significant change in LNG supply and storage requirements. To meet the new demand, a broad range of innovative solutions including small and mid-scale developments to meet regional requirements, and large LNG Hubs are under consideration.

Membrane technology has become the most popular system for the storage of LNG, with more than 1200 tanks servicing the LNG seaborne trade since 1969. In addition, since 1972, membrane technologies have been used for onshore applications, with more than 100 tanks in service.

However, over the course of the past ten years, the 9% Ni Full Containment system has become the most common technology employed for above ground LNG tank applications, satisfying the requirements of existing projects. Confronted to a lack of viable alternative the industry had to limit its needs to the maximum capabilities of this containment system.

Today, there is a revival of interest in GTT’s Membrane Full Integrity technology for above ground LNG tanks which can be seen by an increasing demand within project specifications.

This paper will highlight the main differences between the Membrane Full Integrity and the 9%Ni Full Containment. An explanation as to why over the past decade there has been a lack of interest in the use of above ground Membrane systems will be given. Nowadays, there is a heightened interest in the Membrane Full Integrity technology as a strong contender in new project specifications. The paper will also explain what is now attracting global markets and end users toward the GST® Membrane Full Integrity system for LNG storage tanks for upcoming projects.

II. MARKET REQUIREMENT

Market requirements are varied and cannot be met with one simple solution.

As a first example, for large importing countries, the size of LNG projects has been increasing steadily. At the same time, we can observe a discrepancy in the capacity evolution between LNG Shipping and LNG onshore storage. It is a fact that the LNG carrier capacity has seen a significant increase up to 266,000 m³ in order to maximize commercial benefits. Conversely, the unit capacity of onshore storage tanks could not follow this trend as the nickel-type tank has reached the limit of technical development for very large containment. Due to lack of an alternative, LNG terminal capacity has increased by multiplying the number of nickel-type tanks rather than increasing each storage unit capacity. End users have expressed satisfaction despite the fact that there were no real alternative solutions.

As the Membrane Full Integrity system has no theoretical limit of capacity, LNG tanks larger than 250 000m³, 320 000m³ or even larger can be considered. Consequently, the required number of tanks on a specific project can be reduced:
As a second example, construction of an LNG tank in a remote area encounters a number of constraints. One of the constraints is the availability of human resources to build a good quality LNG tank. Indeed, it is very difficult and expensive to find high qualified and experienced welders for the 9%Ni thick plate welding as well as capable workers for placing the brittle bottom insulation. In some places, and depending on the concurrent 9%Ni Full Containment LNG tank construction, it is very difficult and expensive to find people, as resources amount of are scarce.

Owners would like to mitigate project risks. Among other risks is the variability in the cost or even availability of 9% Nickel steel. This risk is removed by implementation of 304 SS Membrane systems.

### III. MAIN DIFFERENCES BETWEEN THE MEMBRANE FULL INTEGRITY SYSTEM AND FULL CONTAINMENT

The Membrane Full Integrity and 9%Ni Full Containment systems have some similar attributes:

- They both ensure the same primary functions: containing LNG and the associated Gas phase under normal and abnormal conditions.
- They are both equipped with a robust pre-stressed outer concrete tank, which is the key point as concerns external safety hazards.
- They both integrate thermal corner protection in the design, as per industry standards requirements (see below).
From a conceptual point of view however, the philosophy of the Membrane Full Integrity system, which is to separate each function of the elements, is very different from 9%Ni Full Containment. The structural function is ensured by an outer pre-stressed concrete tank, which affords structural resistance to the inner hydrostatic load and outer hazards. The tightness function is provided by a primary corrugated stainless steel membrane which is liquid and gas tight. The membrane is 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. In addition, a moisture barrier applied to the inner surface of the concrete structure prevents any water migration from the concrete to the insulation space. The insulating function is ensured by “load bearing” reinforced PUF insulating panels, secured onto the concrete wall with anchoring elements (mastic and studs), and permanently maintained under nitrogen atmosphere.

The liquid tightness and structural functions on the bottom part of the 9%Ni Full Containment tanks are same as the Membrane Full Integrity. However, on the wall part, the 9%Nickel wall shall ensure two main functions: being structural and liquid tight. This requires performing thick and structural welds which, in some areas, can be exposed to stresses greater than 250MPa.

Complementing the above listed attributes, the Membrane Full Integrity has interesting competitive advantages:

- **Safety (Earthquake, Tsunami):** The Membrane Full Integrity tank copes more easily with seismic-induced loads than the 9%Ni Full Containment technology, thanks to its design philosophy. During an earthquake, the primary container of a 9% Ni Full Containment tank is exposed to lateral and vertical accelerations. Thus, the inner tank (self standing steel shell) needs to be anchored into the slab to resist the up-lift. During a tsunami, the Membrane Full Integrity is less susceptible to the impact of a major tsunami wave thanks to the internal loading of the tank.

- **Carbon Footprint:** Membrane Full Integrity allows a significant reduction (about 25%) of the impact on the environment thanks to material types and weights.

- **Cost & Schedule:** The Membrane Full Integrity is expected to provide a 10% to 35% reduction in cost and a 3 to 4 months reduction in construction schedule. The exact and final benefit will of course depend on the number and capacity of tanks, the location, and the competitive environment.
- Operational Flexibility: Constraints for thermal cycling of Membrane Full Integrity tanks are minimal.
- Local content: Procurement and Construction of the Membrane Full Integrity system can be made with a high ratio of local labor rather than calling upon specialized foreign companies.

IV. WHY THIS LACK OF INTEREST?

More than 100 LNG onshore tanks have been built using Membrane technology. The first inground Membrane tanks were commissioned in 1972 in Japan, and one of those has recently been decommissioned with promising feedback. The Membrane tank is very popular in Japan, Korea and Taiwan for use, in inground configurations. Today, inground Membrane tank technology has been selected for the largest tank ever conceived: 250,000m³.

Similar to inground type tanks, the first above ground Membrane tanks were also commissioned in 1972, in France. Above ground membrane tanks were also built in Korea. However, for a decade, interest in the technology diminished for above ground tanks. To try to understand and identify the reasons behind this trend, the following questions will be addressed:

a) Were there any safety issues?

b) Were there any issues related to standards?

c) Were there any Design, Procurement or Construction weaknesses/uncertainties?

d) How was the Membrane technology positioned commercially?

a) Safety:

The membrane technology is advantageous in that we have more construction and operational feedback compared to other technologies, via experience obtained on LNG tanks and tankers, but also on LPG and ethylene tanks. Moreover, many Quantitative Risk Assessments have been performed by Korean, British, French and US entities, for comparison of the Membrane and 9%Ni Full Containment systems. Each of them came to the same overall conclusion: both technologies provide the same risk profile and same level of safety, with some advantages for the Membrane Full Integrity in some events such as Seismic, Tsunami, Overfilling, etc...

Additionally, further confidence in regard to the robustness of Membrane technology comes from the existing fleet and orders for LNG ships; where more than 95% have selected Membrane technology. This technology is designed to resist loads experienced in shipping that far exceed those experienced in a static tank.

1 Tokyo-Gas, TEPCO and IHI published a paper during the LNG 15, in Barcelona, 2007 : “Encouraging report : Membrane type LNG inground storage tank removed after 32 years of operation”.

2Many QRA & Risk assessments have been performed over the past 15 years:
- Korean Journal of Chemical Engineering, Vol.22, No.1, 1-8, 2005 :Risk Assessment of Membrane Type LNG Storage Tanks in Korea-based on Fault Tree Analysis, by Hyo Kim, Jae-Sun Koh and Youngsoo Kim from Department of Chemical Engineering, University of Seoul Korea, and Theofanious G. Theofanous from Center for Risk Studies and Safety, University of California, Santa Barbara, CA, USA.
b) **Standard issues**

It is a fact that Membrane technology for inground applications was covered sufficiently in Japanese recommended practices but was inadequately addressed for above ground configurations. Over recent years the Standard situation has taken an important toll on project development. [This is a chicken and egg issue - lack of market interest caused low motivation to standards bodies, except in Europe & Korea.]. The lack of references in international Standards or local acceptance demotivated project development teams from consideration of Membrane technologies.

2007 was an important year for Membrane above ground tanks, since for the first time, the CEN (European committee of Standardization) published the Standard for Installation and equipment for liquefied natural gas which includes flat bottom cryogenic tanks. The additional Standard published the same year also provided requirements for Design and manufacture of flat-bottomed steel tanks for the storage of liquefied gases between 0 °C and – 165 °C. Both European Standards 1473 & 14620 address the Membrane technology alongside the 9%Ni Full Containment.

Korean Standards were also released in 2007 "Standard for Above Ground LNG Tanks" (KS B 6941), where both Membrane and 9%Ni types are addressed on the same basis as in the European standard.

c) **Engineering, Procurement and Construction aspects**

One of the main advantages of the Membrane Full Integrity technology is the modularity of the rectangular components. However, arranging rectangular components on a cylindrical shape is a tricky matter, especially for the bottom area. Historically, each tank needed a specific customized design according to the specifications. Additionally, procurement was also customized with dedicated suppliers and specific production, which does not favor cost competitiveness. In construction, which predated automatic welding, all Membrane above ground tanks were manually welded.

Nowadays the situation has been substantially improved for a variety of reasons. Extensive experience of LNG carrier construction which enabled the development of reliable, fast and competitive automatic welding machines. Moreover, Membrane Full integrity technology enables the use of a high ratio of local labor rather than calling upon specialized foreign companies. The technology has been substantially optimized to enhance competitiveness as described above.

Only two shapes are used over 95% of the tank surface area, simplifying procurement and installation significantly.
d) Positioning of the Membrane technology

Before 2006, the technology was owned by SN Technigaz. The company promoted the technology on an EPC basis, along with the 9%Ni system. In this arrangement, SN Technigaz was able to clearly give the client an alternative offer of its conventional technology with a cost and schedule saving. However, the client could not get any comparative bids for the Membrane Full Integrity option as no other EPC bidders had access the technology. Clients were thus comfortable with a technology where there was competition between bidders rather than a technology offered only by one bidder.

To solve this issue, in 2006, GTT re-acquired the technology through an agreement with SN Technigaz. Now, the technology is available on the same basis as ship containment through shipyards, based on a Standard & Non-exclusive License to interested contractors.

In 2009, GTT started the commercialization of the Membrane Full Integrity technology for land storage tanks with the same business model as LNG carrier model, including the latest optimization in Design, Procurement and Construction.

V. NEW POSITIONING OF THE MEMBRANE FULL INTEGRITY PRODUCT

The situation, past and present, of the Membrane Full Integrity technology for above ground tanks, is summarized in the table below:
Summary of Membrane features past and present

The business model and lack of reference in standards seem to have been the weakest points and principle cause-and-effect of diminished interest. Today, the opportunity of Membrane Full Integrity technology in the market allows a real and stronger competition between bidders.

V. CONCLUSIONS

The Membrane Full Integrity system offers breakthrough advantages some of which are described in this paper. The main reasons why there was diminished interest in the Membrane Full Integrity system for above ground tanks were the weak references in International Standards and the absence of competition among EPC contractors.
Evolution of Licensed EPC contractors since 2000

The above graph shows how the interest in EPC contractors to become licensed for the construction of GST® Membrane Full Integrity system has evolved since 2000. The number of EPC contractors doubled between 2010 and 2011 and doubled again between 2011 and 2012.

The EPC contractors which have current License agreements for the construction of Membrane Full Integrity are referenced hereafter:

List of Licensed EPC contractors in January 2013

The main changes motivating the revival of interest in Membrane Full Integrity system are:

- Membrane Full Integrity is a Credible & Viable option
- Membrane Full Integrity is now referenced through International Standards
- Membrane Full Integrity is now a Streamlined & Optimized technology
- Membrane Full Integrity is a Cost & schedule saver
- Membrane Full Integrity is now Generalized through licensed contractors

Currently, two projects are under construction using GST® Membrane Full Integrity system for above ground LNG tanks, and a dozen projects are considering the technology based on its competitive advantages. Today there is no reason why the Membrane Full Integrity system should not be considered as an equally valid solution alongside the 9%Ni Full Containment system.