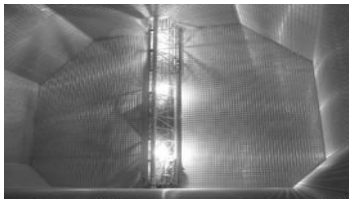
US DOT PHMSA LNG Workshop

Technology included since NFPA 59A-2001: Membrane LNG Storage Tanks

WASHINGTON, DC – May 18th, 2016







Greg Denton, Business Development Manager – Houston, TX

AGENDA

- **GTT overview**
- **LNG storage tank types**
  - Comparison between Membrane and 9% Nickel technology currently referenced in CFR
- **Status in International codes and standards**
- **Membrane onshore project references**

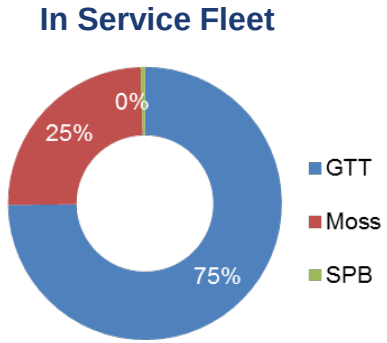
1 GTT overview

GTT Corporate Video

Membrane systems proven across markets

- **LNG Carrier Orders by Containment System Type:**

TANK TYPES	Number on Order	Number in Service *
MOSS	26	98
SPB	4	2
GTT MEMBRANE	107	297
KC-1	2	0



** End of March 2016, > 30k cbm*

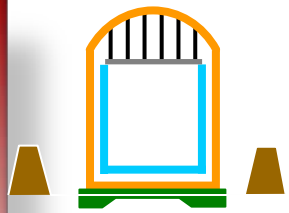
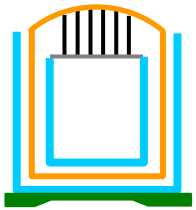
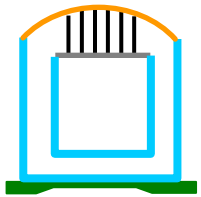
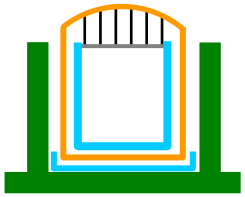
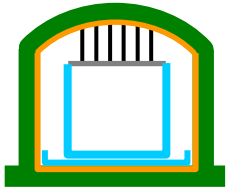
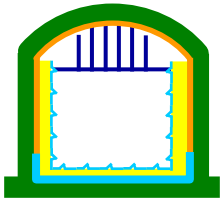
- **FSRU** *Floating Storage Regasification Units*
  - GTT Membrane used in **all 19 newbuilds in service** with **6 more on order**(1)
- **FLNG** *Floating LNG Units*
  - GTT Membrane used in **all 3 newbuilds** on order(1)
- **Onshore Storage Tanks**
  - **34 GTT Membrane storage tanks** in operation as far back as **1972**

Membrane onshore references

- About 100 Membrane Tanks in service today :
  - **34 GTT MEMBRANE TANKS**
  - Mainly LNG but also LPG, Ethylene
- First Membrane tank **commissioned in 1972** (and still in operation…)
- From **8,000 m³** to **250,000 m³** capacity
- Approximately **2,500 tank-years** experience in total (similar to 9% Ni)
- More than 150 LNG carriers (+600 tanks) using GTT Mark system are operated
- Two large Membrane tanks under construction (Philippines & Indonesia)

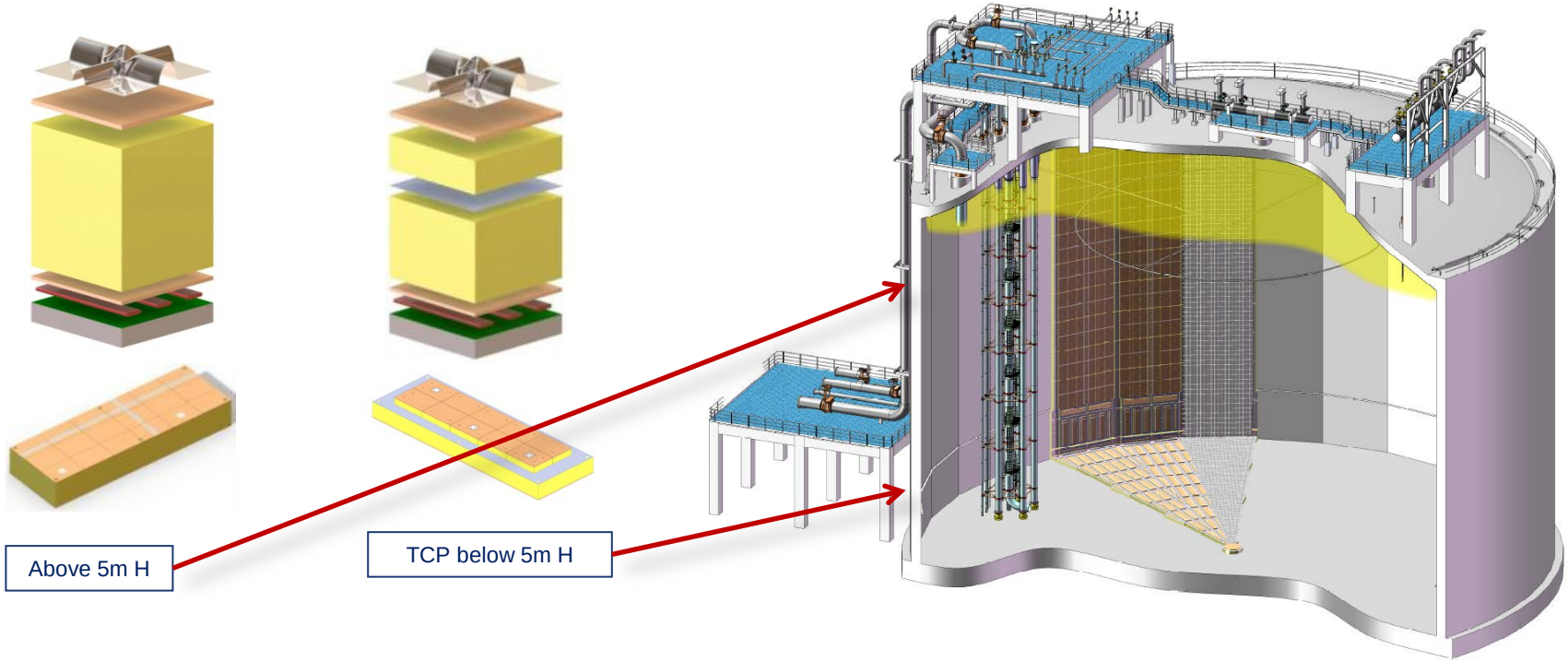
LNG storage tank types according to International Standards

Tank type according to EN 1473 and EN 14620

	SINGLE CONTAINMENT	DOUBLE CONTAINMENT	FULL CONTAINMENT 9% Nickel	FULL CONTAINMENT Membrane
Steel outer tank				
Concrete outer tank				
In case of leakage	Neither liquid nor gas are contained	Only liquid are contained by bund wall	Liquid and gas are contained	Liquid and gas are contained
Dike	REQUESTED	NOT REQUESTED	NOT REQUESTED	NOT REQUESTED

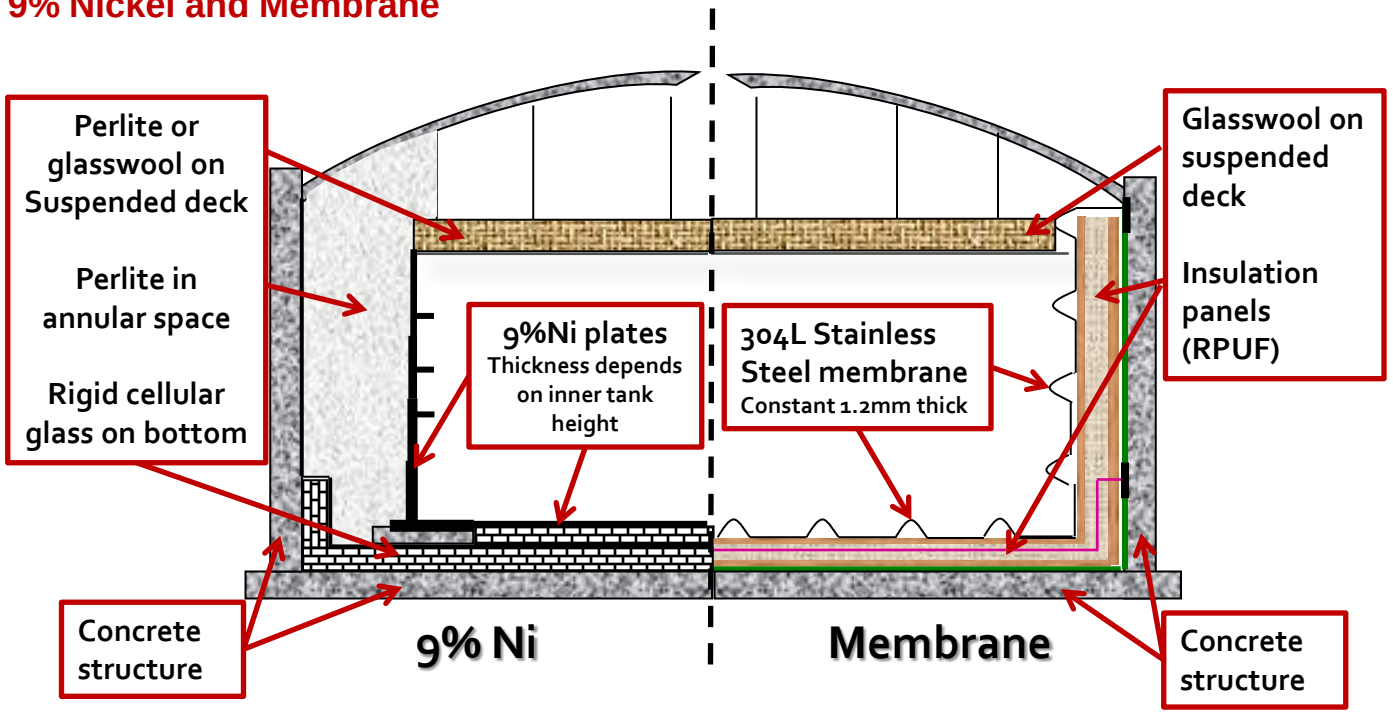
Note: solutions with concrete inner tank and buried tanks are not represented here.

Membrane GST Full Integrity storage tank



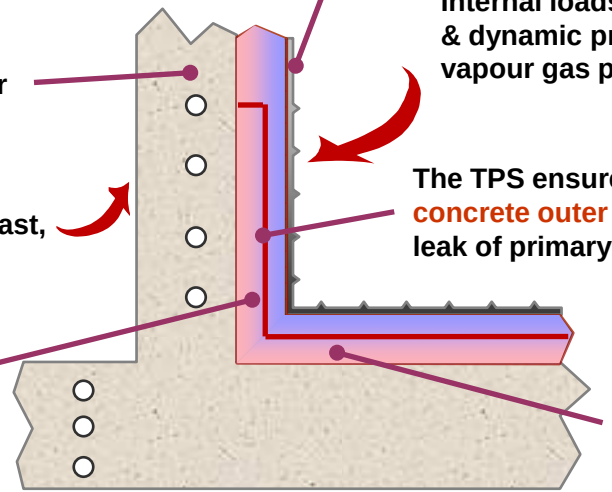
Cross-sectional comparison of elements

Between 9% Nickel and Membrane



Membrane design philosophy

"… tightness and structural functions are separated which allows optimization of each function and avoids simultaneous multiple failures …"



Primary barrier ensures the liquid and vapour tightness

Internal loads: LNG hydrostatic & dynamic pressure and vapour gas pressure

The outer tank provides the structural resistance to inner and outer loads

The TPS ensures the design of concrete outer tank in case of leak of primary barrier

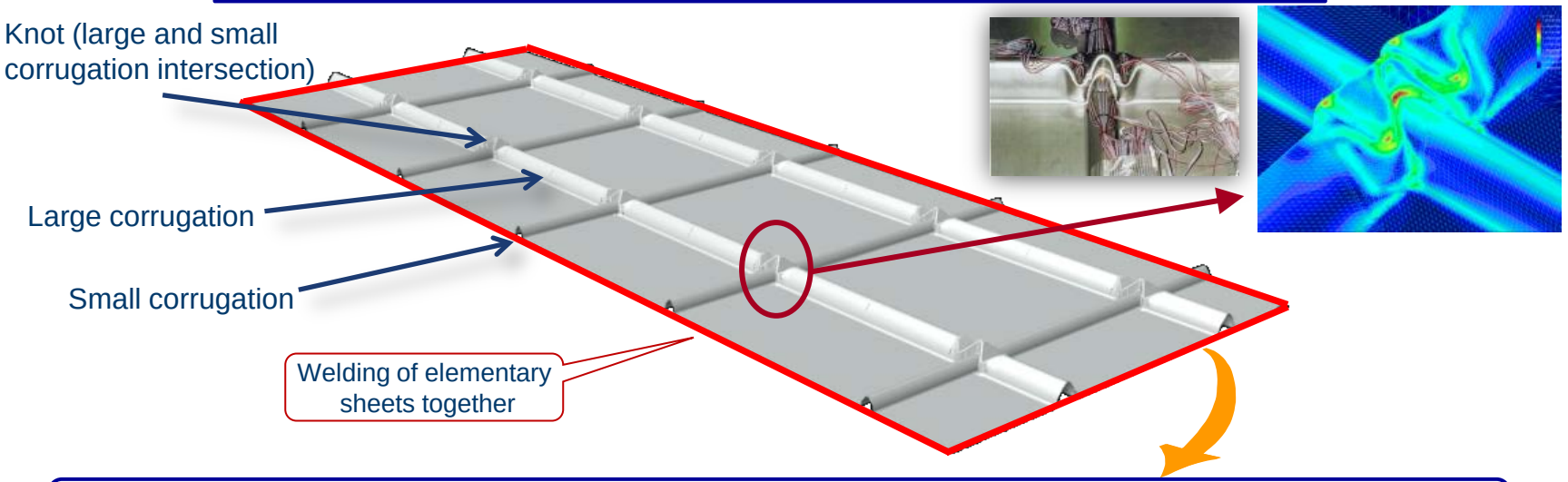
External loads (eg Impact, Blast, Fire,...)

The insulation system limits the heat exchange between the concrete and the LNG

The insulation system transmits loads to the outer tank

Design philosophy of stainless steel metallic primary membrane

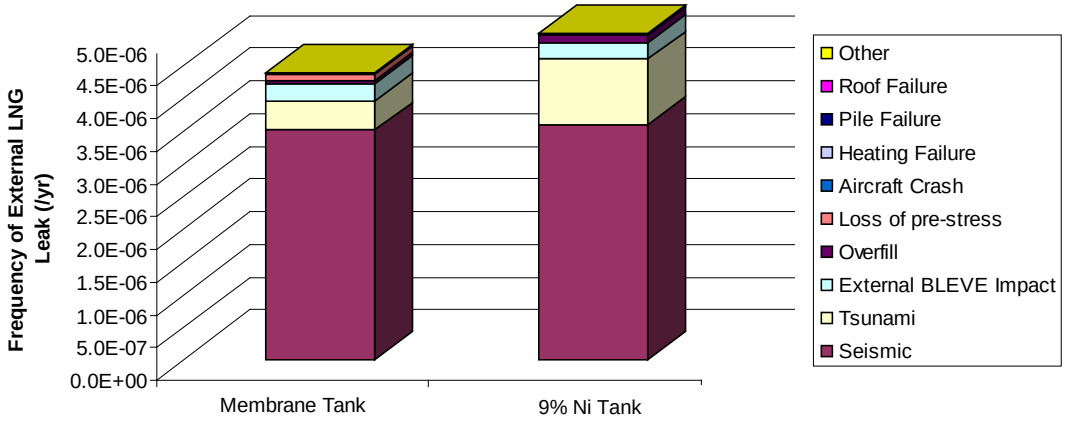
CORRUGATIONS MAKE THE MEMBRANE INSENSITIVE TO THERMAL LOADS



The membrane flat portions operate at ZERO STRESS LEVEL which results in an almost unlimited resistance to fatigue and prevents any risk of crack propagation and therefore catastrophic failure.

Predicted external LNG release frequencies

Qualitative Risk Assessment (QRA) conducted by ESR Technology in 2011



- **Main conclusions:**
  - The Membrane and 9% Ni tanks are predicted to pose very similar levels of risk from external LNG leaks
  - It is the design of each tank against specific events that is more important than whether it is Membrane or 9% Ni tank

Status in International codes and standards

Membrane references in worldwide standards

Country	Standard	Edition	Title	Comments
Europe	EN 14620 parts 1 to 5	2006	*Design and manufacture of site built, vertical, cylindrical, flat bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0˚ C and -165˚ C*	*Addresses the full design of membrane tanks.*
Japan	JGA RP 107-2		*Recommended practice for LNG in-ground storage*	*Deals only with in-ground storage tanks; No English version exists for this Japanese standard.*
Europe	EN 1473	2007	*Installation and equipment for liquefied natural gas - Design of onshore installations*	*Addresses definition and equipment relative to membrane tanks.*
Korea	KS B 6943	2007	*Standard for Membrane type inner tank*	*Design of membrane type inner tank.*
USA	ACI 376	2011	*Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases*	*This Code is not applicable to membrane tanks. However, it says that with appropriate additional engineering analysis and justification, portions of this Code may be applied.*
Canada	BCOGC	2014	*Oil & Gas Activity act; LNG Regulation*	*This regulation integrates Membrane tanks with reference to EN14620 for parts exclusive to membrane, ACI376 for concrete outer tank, and API625 as general codes.*
Canada	CSA Z-276	2015	*Liquefied Natural Gas (LNG) Production, Storage and Handling*	*Full inclusion of requirements for Membrane containment tanks in line with other tank technology requirements.*
USA	NFPA 59A	2016	*Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*	*Full inclusion of requirements for Membrane containment tanks in line with other tank technology requirements.*

Latest update of International standards

- **NFPA 59A incorporates Membrane as of 2016 revision :**

  Membrane and 9% Ni are recognized at the same level of safety and therefore the same requirements are valid for both technologies.

  In this latest revision, Membrane and 9% Ni are designed without dike and the outer concrete wall shall be able to contain the liquid in case of major leak and shall be able to withstand external fire.

Other relevant standards:

- **Canadian Standards**

  CSA Z276 updated in 2015 and Membrane is now included in this standard with Membrane and 9% Ni recognized at the same level of safety, with no dike required for either technology.

- **Korean Standards**

  KS standards recognize Membrane and 9% Ni as equivalent technologies.

Membrane project references

Existing/under construction LNG tanks (on www.gtt.fr)

GTT LNG STORAGE TANKS REFERENCES					
DATE	***TYPE***	***CAPACITY(m3)***	***Qty***	***LOCATION***	***STANDARDS***
1981	Above ground	120 000	2	Montoir de Bretagne, France	Technigaz standards & RPIS (Recommended Practice for In-ground Storage tanks)
1981	In ground	95 000	1	Negishi, Japan	
1984	In ground	60 000	4	Ohgishima, Japan	
1985	In ground	130 000	1	Sodegaura, Japan	
1987	Above ground	100 000	4	Pyeong Taek, Korea	
1987	In ground	90 000	1	Futtsu, Japan	
1990	In ground	100 000	3	Kaohsiung, Taïwan	
1995	Above ground	100 000	3	Pyeong Taek, Korea	
1996	In ground	35 000	2	Fukuoka, Japan	
1996	In ground	200 000	2	Negishi, Japan	
1997	In ground	80 000	1	Sendai, Japan	
1998	Above ground	100 000	3	Pyeong Taek, Korea	
2003	In ground	200 000	1	Ohgishima, Japan	
2003	In ground	35 000	1	Nagasaki, Japan	
2016	Above ground	90 000	1	Sengkang, Indonesia	EN14620
2016	Above ground	130 000	1	Pagbilao, Philippines	EN14620

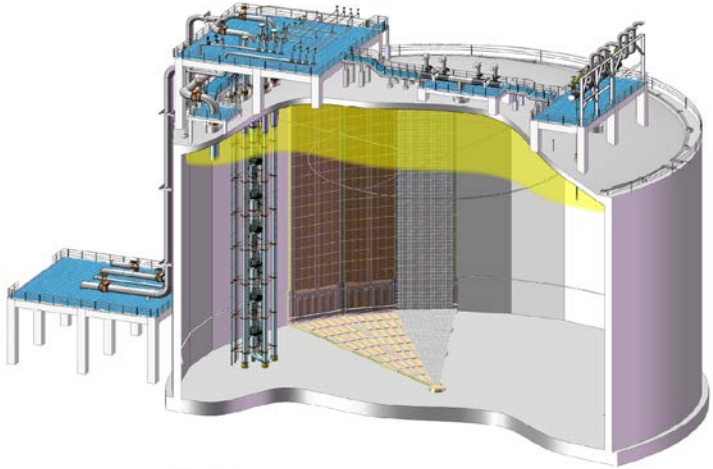
Pagbilao, regasification terminal – 130,000 m³ net

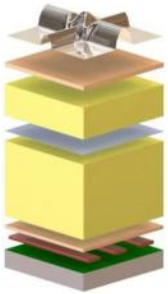
Containment system pre-production underway

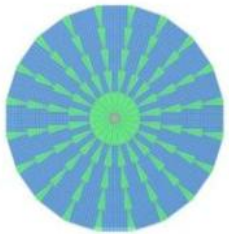
Sengkang, liquefaction plant – 90,000 m³ net

Concrete completed, moisture barrier mid-2016

Why is the Industry requesting Membrane tank technology?







- Is **Proven** with 34 tanks in service since 1972 with 2 large tanks and 2 very small tanks on order
- Is **Reliable** (no dyke is required according to European, Korean, North American Std)
- Is **Similar to MARK III technology** used for LNG Carriers (synergy and feedback on harsher dynamic environment)
- Is **a Cost saver** with up to 20% less CAPEX compared to other technology (160k m3)
- Is **a Schedule saver** with a gain of 3+ months in over all construction (160k m3)
- **Only requires trained operators** instead of highly skilled welders
- **Can be locally produced** with GTT assistance
- **Same design** whatever the capacity

Conclusion: Membrane Full Integrity storage tank

- Now broadly recognized by all International standards
- Poses similar safety level as 9% Ni
- Concrete outer structure for Membrane is more robust than for 9% Ni
- Benefits from 40+ years of onshore tank performance feedback
- Benefits from feedback of 150+ LNG Carriers in operation with similar Mark technology in much harsher environment
- Testing program ensures tank integrity after each step of erection
- Membrane provides commercial advantages and marketplace competition to Project Developers

Thank you for your attention

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