Fermilab

GTT

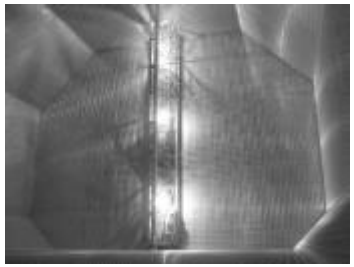
Expert in LNG

Membrane cryostats for large volume neutrino detectors

Workshop on Cryogenic Operations







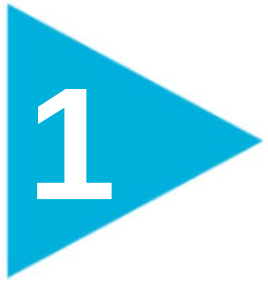
October 26th , FERMILAB

Safety | Excellence | Innovation | Teamwork | Transparency

Disclaimer

Agenda

- 1- Company overview
- 2- Membrane tanks - Design, Procurement, Construction
- 3- Membrane Status in International codes and standards
- 4- Membrane project references
- 5- Conclusion

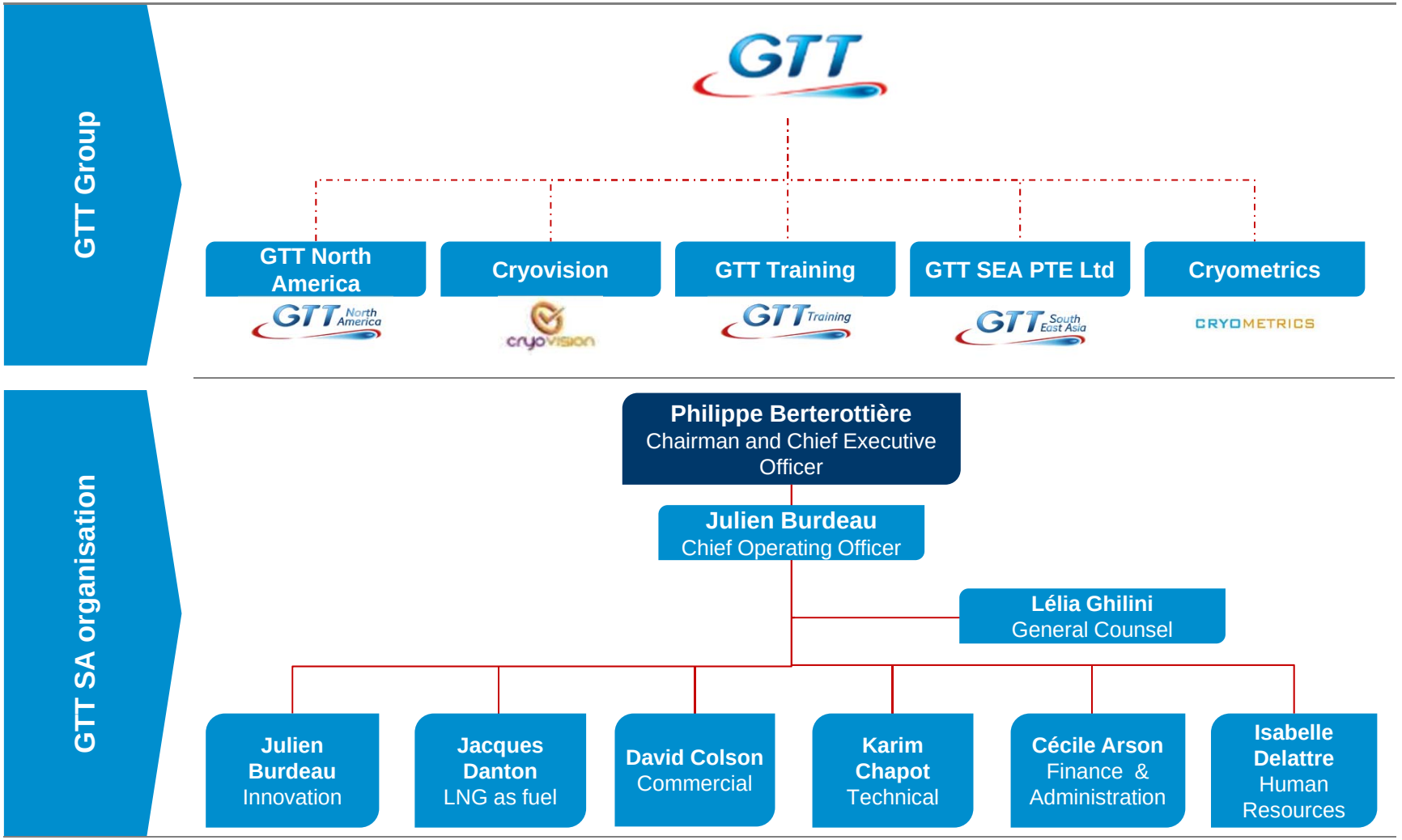


Company overview

GTT in brief

- An engineering company with more than 50 years of experience in the design of the Membrane Containment Systems for cryogenic liquids
- GTT is a public company listed on the Euronext Stock Exchange (Paris)
- About 110 ships and onshore tanks currently on order
- More than 33 onshore tanks and more than 390 LNG Carriers equipped with GTT's technology
- Around 380 highly qualified people, mainly at head office, but also present worldwide to assist our clients during construction

A streamlined group and organisation



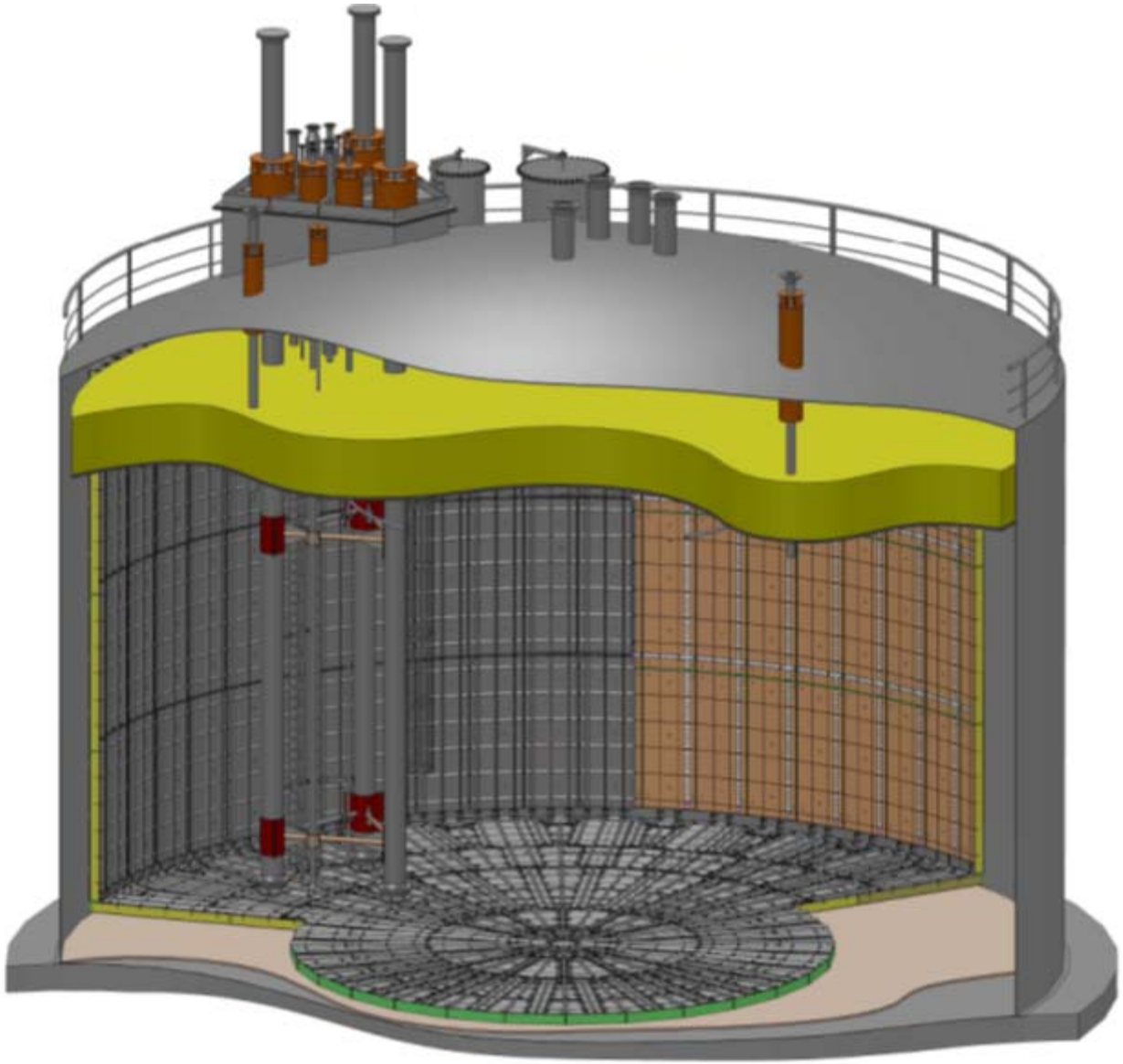
GTT offers broad exposure across the liquefied gas shipping and storage value chain

	Exploration & Production	Liquefaction	Shipping	Re-Gasification	Off Take / Consumption
Offshore clients: shipyards	 Platform / Installation	 Floating LNG Production, Storage and Offloading unit (FLNG)	 Liquefied Natural Gas Carrier (LNGC)  Ethane/ multigas Carriers	 Floating Storage and Regasification Unit (FSRU)	 LNG fuelled ship  Barge  Gas-to-wire
Onshore clients: EPC contractors		 Onshore storage liquefaction plant	 Onshore storage re-gasification terminal	 Tank in industrial plant	 Power plant

Source: Company data

2 Membrane tanks
Design, Procurement, Construction

Full Integrity Membrane concept



Full Integrity Membrane concept

Primary Barrier

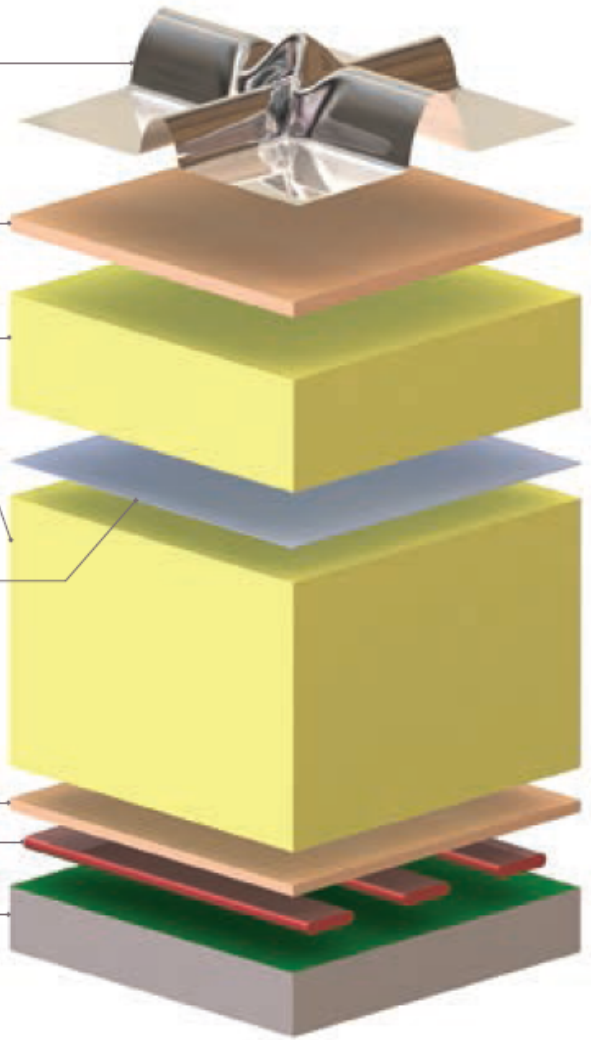
Flexible stainless steel corrugated membrane – 304 L – 1.2 mm.

The double network of corrugation absorbs the thermal contraction due to the very low temperature of LNG.

Secondary Barrier

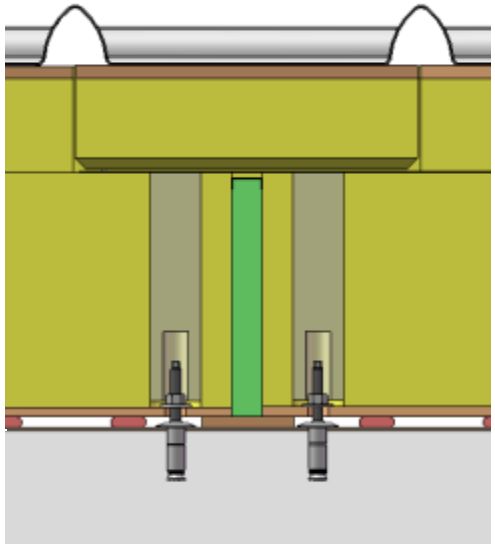
Composite material: a thin sheet of aluminium between two layers of glass cloth and resin.

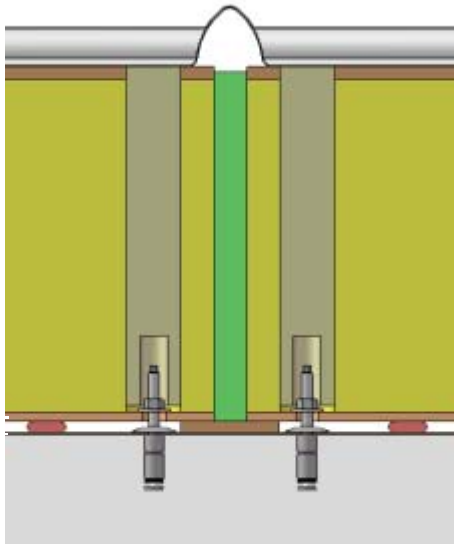
In the event of a failure of the primary membrane, it prevents the build-up of stress concentrations of the concrete corner and ensures the liquid tightness of the concrete wall, as required by European standards.



GST® Design philosophy

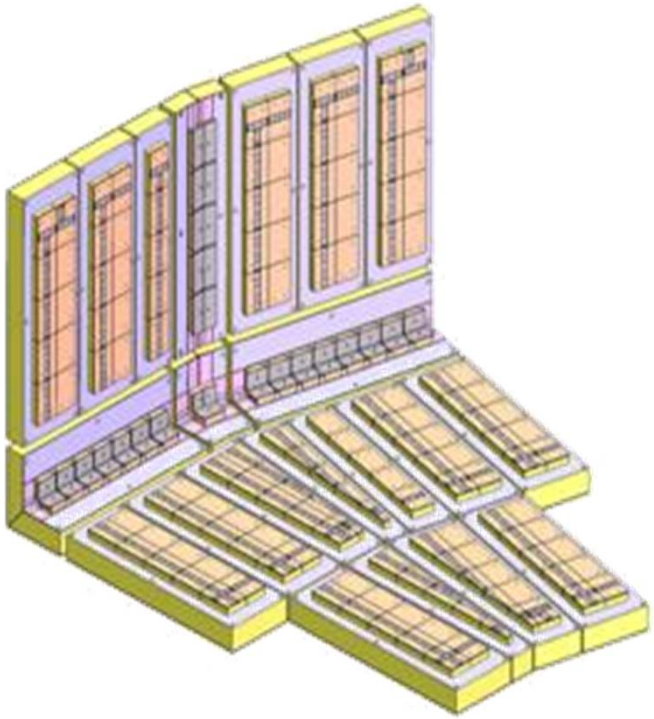
- Prefabricated elements with or without secondary membrane
- Insulation thickness defined according to boil-off rate requested
- Maximum size 3m * 1m - Max weight about 150kg
- Density of foam optimized according to design loads
- Used in LNG industry since 1993

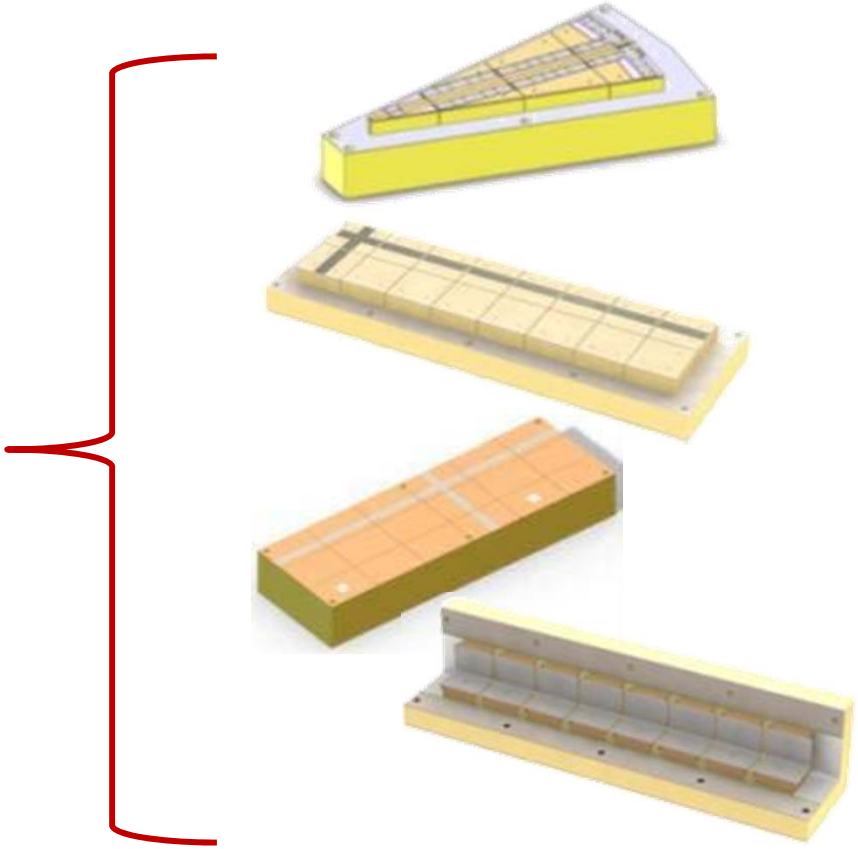




Design - Insulating Panels

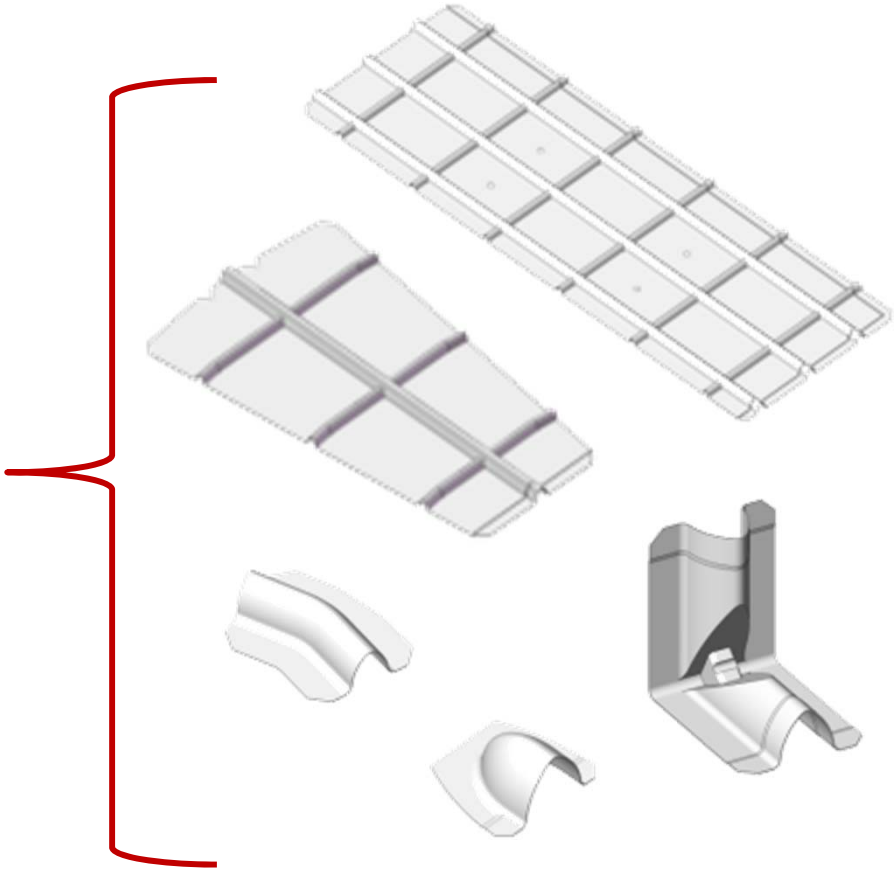
Modular Insulating Panels





- Standard components whatever the tank capacity.
- Prefabricated by independent industry-recognized suppliers.

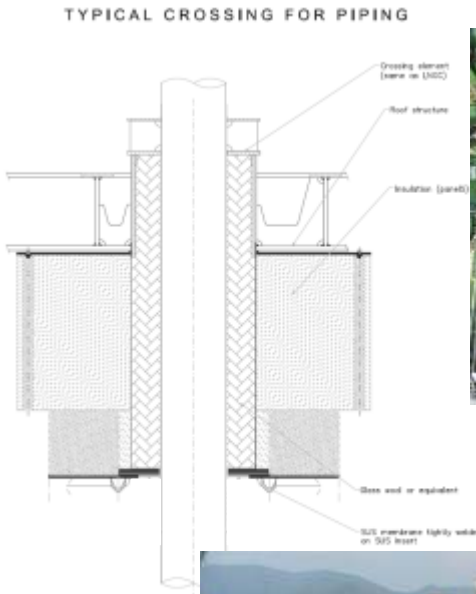
Design - Stainless steel membrane



- Standard components whatever the tank capacity
- All pieces have been fatigue tested in laboratory and through FEA

Design – Typical possible connections

From Top



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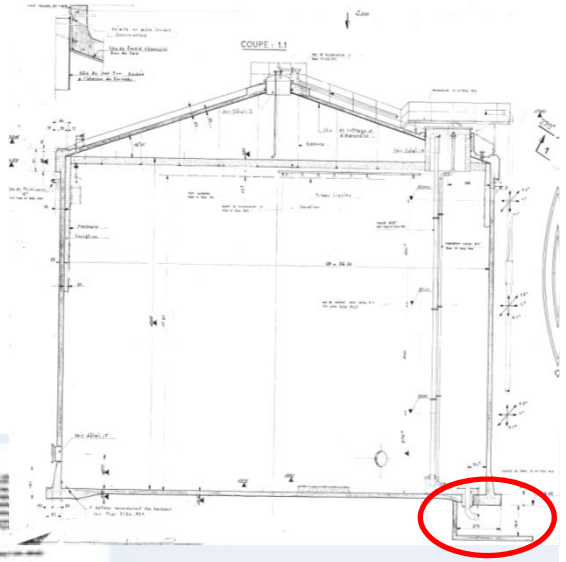
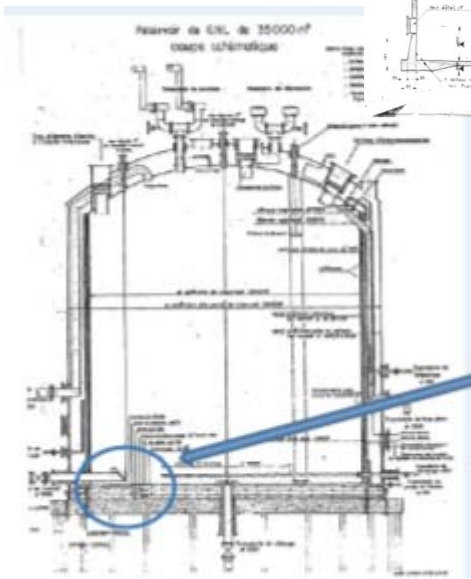
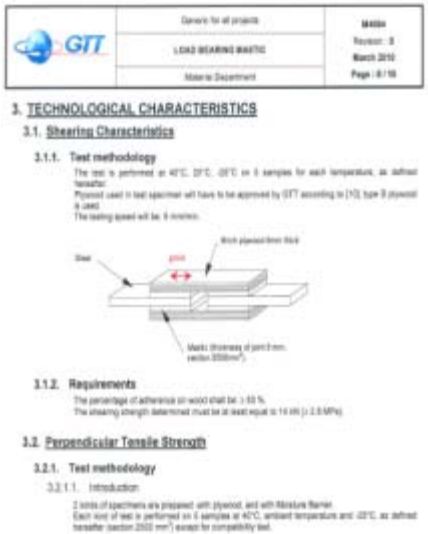




Procurement

- Panels and membranes made according to GTT's specifications

- Assistance provided by GTT during auditing of chosen material suppliers specific to their project(s);



3. TECHNOLOGICAL CHARACTERISTICS

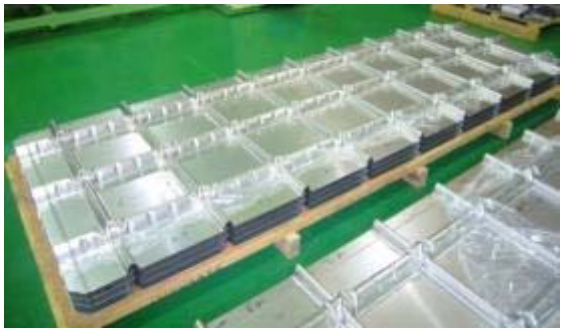
3.1. Shearing Characteristics

3.1.1. Test methodology

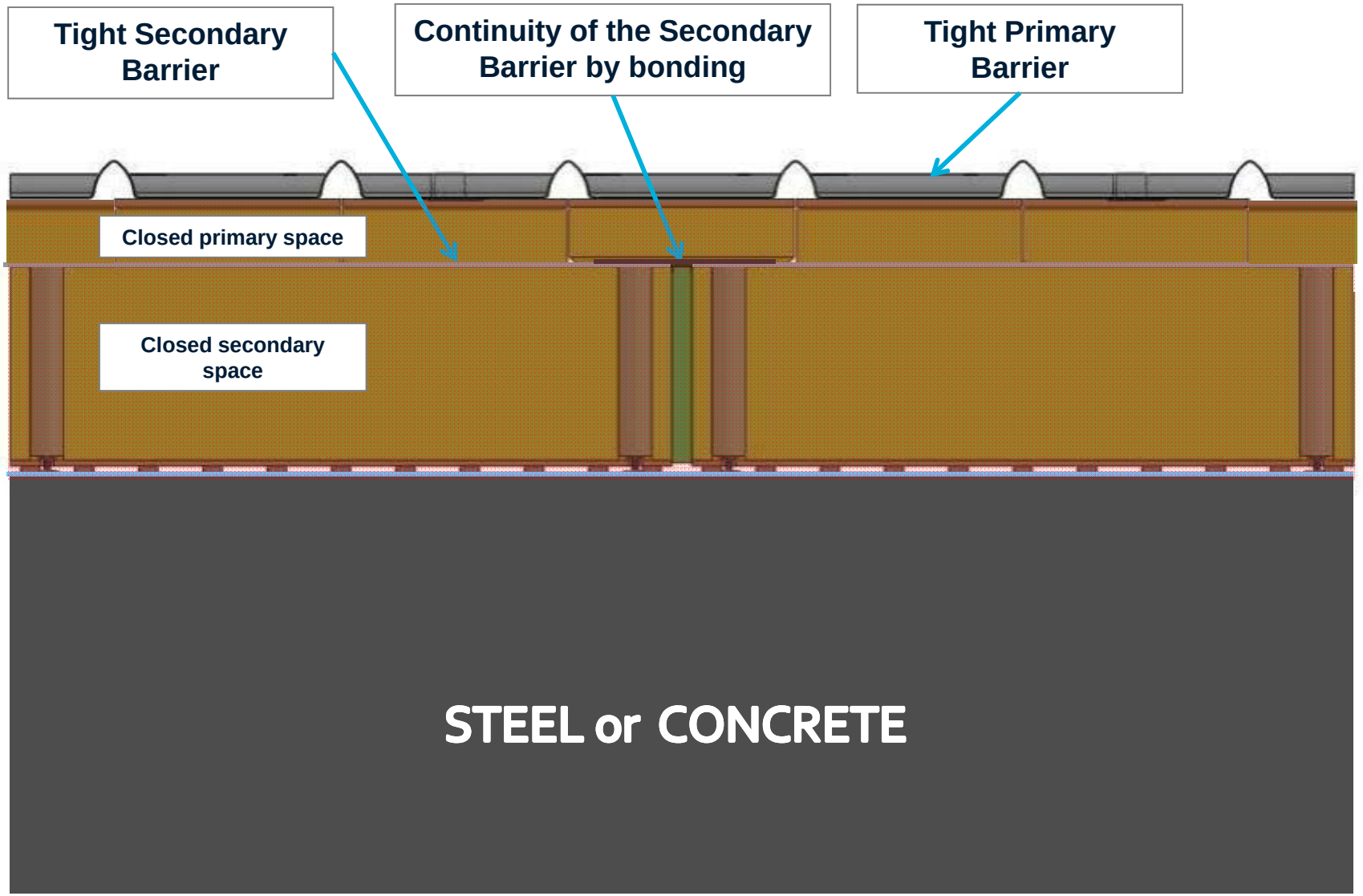
3.1.2. Requirements

3.2. Perpendicular Tensile Strength

3.2.1. Test methodology



Construction sequences



Video of the 17m³ tank construction at CERN

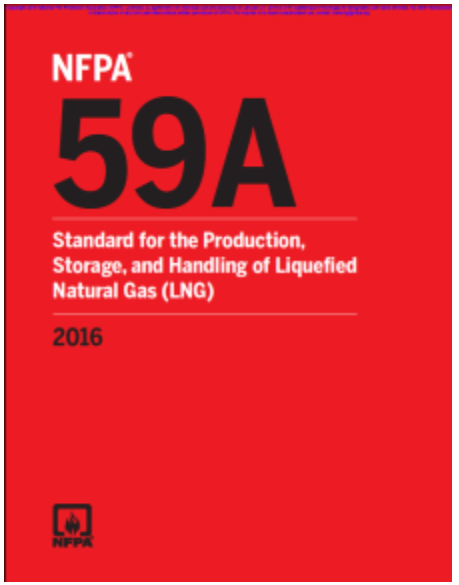
3 Membrane Status in International codes and standards

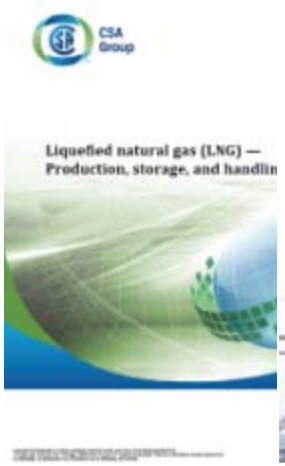
Membrane references in worldwide standards

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;*
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.*
India	PNGRB T4S (ongoing)	2016	*Regulation for LNG Facilities*	*Full definition of Membrane containment tanks in line with other tank technology requirements.*

GTT support to permitting/ regulation

- **Support of GTT to get approval from National/regional authority**
  - GTT supports the client during its discussions with the local authorities
- **Support of GTT on National Standards**
  - Example : Membrane inclusion in US and Canadian Standard
  - Ongoing discussions with FERC/PHMSA





Safety

- **Many comparative QRA over the past 15 years:**
  - 1996, *LNG 12 Perth*, Quantification and Comparison of the Risks of LNG storage concepts – Membrane and full containment.
  - 2005, *Korean Journal of Chemical Engineering ,* Risk Assessment of Membrane Type LNG Storage Tanks in Korea-based on Fault Tree Analysis
  - 2006, *23rd World Gas Conference*, Safety Comparison of LNG tank designs with fault tree analysis
  - 2011, by ESR Technology, Comparative QRA of the GST® Membrane and Full Containment LNG storage tanks
    - ESR Technology: formerly Engineering Safety and Risk Business of AEA Technology (privatized from UK government Atomic Energy Authority)

Membrane project references

Membrane references Worldwide

- About **100 MEMBRANE TANKS** in service today :
  - 32 GTT Membrane tanks
  - Mainly LNG but also LPG, Ethylene, Argon.
- First Membrane tank **commissioned in 1972** (and still in operation…)
- From **17 m³** to **200,000m³** capacity
- Approx. **2500 years-tanks** experience in total (same as FC)
- 2 large above ground Membrane tanks under construction (Indonesia & Philippines) and 2 smaller in Europe

- More than 110 LNG carriers (+500 tanks) using GTT Mark system are operated.
  - First built in 1993

Pagbilao, regasification terminal – 130,000 m³ net

Containment system pre-production underway

Sengkang, liquefaction plant – 90,000 m³ net

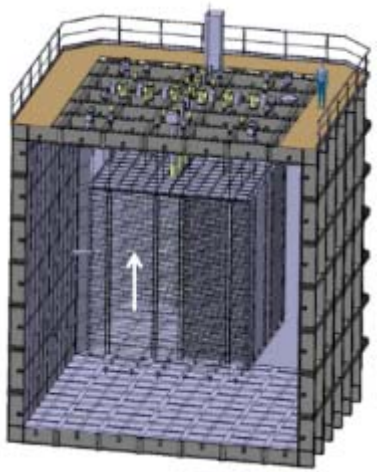
Concrete completed, moisture barrier soon

Geneva, Liquid Argon storage for research

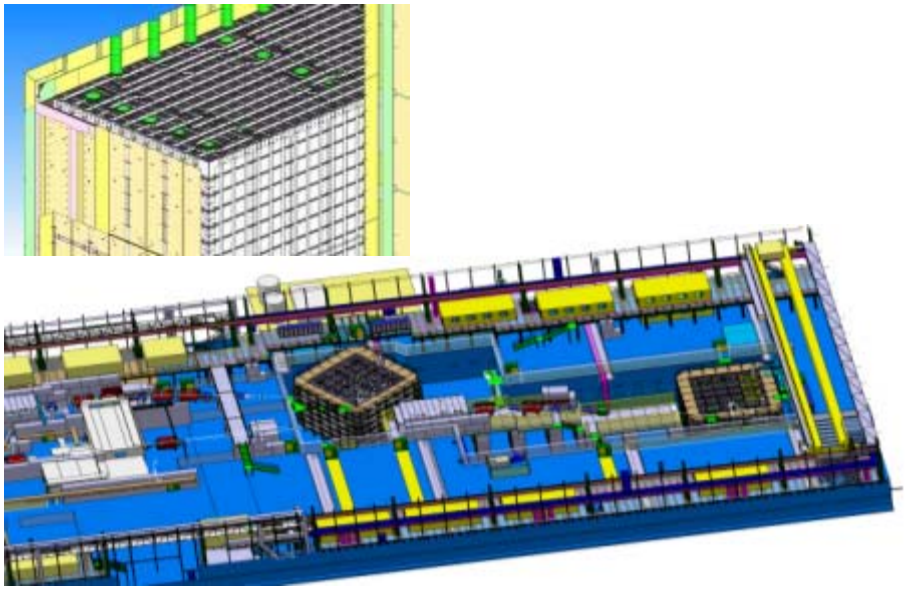
Containment system completed, commissioning soon

Geneva, NP02 and NP04 for Dune experiment

- **NP02 tank :**
  - Double phase TPC (Time Projection Chamber) as a prototype for the DUNE experiment



- **NP04 tank :**
  - Single phase TPC as a prototype for the DUNE



Design completed, construction ongoing

One 2,200 m³ LNG barge

Main parameters:

LOA : 64.6 m
B: 14.8 m
Draft: 2.6 m
Tonnage: 1,440 GT
Speed: up to 8 knots

Cargo:

2.200 m³ (100%)
2.066 m³ deliverable volume
4.5 hour full transfer time

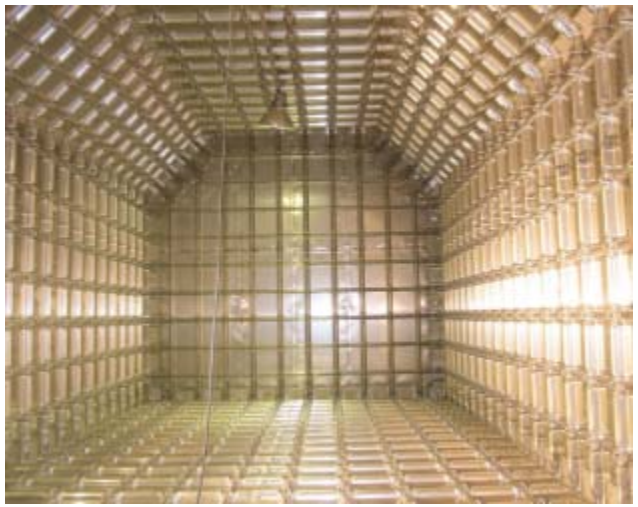
Power for Operations:

On board diesel generators for simplicity

Commissioning expected end 2016

Korea, 110m³ Pilot Cavern

- To demonstrate the underground storage feasibility for cryogenic gases
- 20m below ground level



Commissioned in 2004

Track record – GTT membrane onshore tanks

DATE	TYPE	CAPACITY(m3)	Qty	LOCATION	Standards	Type of gas
1972	Above ground	8 000	1	Lavera, France	Technigaz standards & RPIS (Recommended Practice for In-ground Storage tanks)	Ethylene
1981	Above ground	8 000	1	GonfrevilleLavera, France		Ethylene
1981	Above ground	120 000	2	Montoir de Bretagne, France		LNG
1981	In ground	95 000	1	Negishi, Japan		LNG
1984	In ground	60 000	4	Ohgishima, Japan		LNG
1985	In ground	130 000	1	Sodegaura, Japan		LNG
1987	Above ground	100 000	4	Pyeong Taek, Korea		LNG
1987	In ground	90 000	1	Futtsu, Japan		LNG
1990	In ground	100 000	3	Kaohsiung, Taïwan		LNG
1995	Above ground	100 000	3	Pyeong Taek, Korea		LNG
1996	In ground	35 000	2	Fukuoka, Japan		LNG
1996	In ground	200 000	2	Negishi, Japan		LNG
1997	In ground	80 000	1	Sendai, Japan		LNG
1998	Above ground	100 000	3	Pyeong Taek, Korea		LNG
2003	In ground	200 000	1	Ohgishima, Japan		LNG
2003	In ground	35 000	1	Nagasaki, Japan		LNG
2004	Cavern	110	1	Deajon, Korea		LN2
2016	Above ground	17	1	Geneva, Switzerland	Based on EN14620	LAr
on going	Above ground	90 000	1	Sengkang, Indonesia	EN14620	LNG
on going	Above ground	130 000	1	Pagbilao, Philippines	EN14620	LNG
on going	Above ground	600	1	Geneva, Switzerland	Based on EN14620	LAr
on going	Above ground	600	1	Geneva, Switzerland	Based on EN14620	LAr

33 tanks already built and 4 under construction

5 Conclusion

Conclusion: Membrane Full Integrity tank

- Now adressed in International standards
- Many QRA performed demonstrating that membrane offers the highest safety level for cryogenic containment
- No theoretical limit of capacity
- Modular system prefabricated by homologated companies
- Benefits from 40+ years of onshore tank performance feedback
- Benefits from feedback of 150+ LNG Carriers in operation with similar Mark III technology
- A continuous support from GTT from birth of project up to commissioning, also proposed during tank life

Thank you for your attention

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