Agenda

1. GTT Highlights

2. Brief overview of membrane technology

3. GTT’s Applications for Commercial Vessels

4. Main Advantages of Membrane Technology

5. Addressing the main concerns
GTT in brief

- An **engineering company** with more than **50 years of experience** in the design of the Membrane Cargo Containment Systems

- Independent company with **strong shareholders**

- A 370 people company constantly working on **on-going projects** and **new developments**, aiming at proposing technologies for the development of the LNG market

- **NO96** and **Mark III** are the leading systems for LNGCs and offshore units
- **GST system** for on-shore tanks
- **PLUTO II** subsea cryogenic pipeline

March 25th 2013
Current Order Book – Standard LNGC & Off-Shore

Split by Product:
- 87 LNGCs
- 9 FRSU/RV
- 2 FPSO

Split by Shipyards:

Split by Technology:

Source: GTT, 18th March 2013
2. Brief Overview of Membrane Technology
Common Characteristics of membrane

- Complete **double hull** vessels (bottom, sides, deck)
- Transverse cofferdams between tanks
- Containment system **anchored to the inner hull**
- Two membranes (second able to hold LNG for at least a fortnight as per Int. Gas Carrier Code)
- Two layers of insulations (secondary able by itself to keep temperature above design parameters of steel grades in worst conditions)
- Insulations spaces **inerted with Nitrogen**
Primary Invar membrane
Invar tongue
Coupler
Secondary Invar membrane
Inner hull
Secondary insulation box
Primary insulation box
Mark III

Primary stainless steel membrane

Corner panel

Hardwood key

Top plywood

Primary insulation layer (RPUF)

Composite secondary membrane (Triplex)

Secondary insulation layer (RPUF)

Back Plywood

Top bridge pad

Metallic insert

Inner hull

Insulation panel

Resin ropes
GTT’s Applications for Commercial Vessels
The Ship-owner’s Dilemma

Complying with new regulations regarding gas emissions reduction and remain competitive...

+ 

for those operating nearly exclusively in ECA zones, the decision must be taken rapidly

- The alternatives are known:
  - Running on HFO + scrubber + SCR
  - Running on MDO / MGO
  - Running on LNG

- Parameters of the business plan equation:
  - Technical feasibility (retrofit, newbuilding), reliability, CAPEX, OPEX, loss of earnings...
Why LNG?

- **Ecological** benefits are obvious; straight compliance with any environmental rules.

- **Economic** benefits still to be demonstrated but in Europe one can reasonably expect a price at an intermediate level between HFO and MGO (energy equivalent).

- Other alternatives are either not completely proven ecologically (Scrubbers + SCR) or much too costly in OPEX (MDO/MGO).
LNG Fueled ship

Parameters of the economic equation for the ship-owner:

- Price of LNG fuel;
- Cost of supply chain infrastructure;
- CAPEX;
- OPEX;
- Reduced available cargo space on an LNG fuelled ship as compared to the equivalent conventional ship.
Small scale LNG infrastructure development

Early Days (since 2000 abt)

- **Initiation of LNG used as fuel** for ships initiated by Norway
- **Small LNG terminals and local storage** on the coast line
- **Small volumes** (on ferries and PSV < 500 m3)
- **Very local and dedicated logistics** (trucks, very small LNG ships, e.g: Knutsen Pioneer)
- **Type-C tanks** (pressurized tanks all along the supply chain)
Small scale LNG infrastructure development

Next phase (starting 2015 and onwards)

- Infrastructure building up in US and Europe (various drivers for that)
- Volumes getting larger and larger: more ships and larger ships using LNG as fuel (not only ECA areas depending on the LNG price trend)
- Larger tank capacities
- Need for better efficiency in the supply chain

Greater use of low pressure containment system
Particularly membrane technologies
Membrane Type Bunkering Solutions

Retrofit of a Container vessel

New section includes:
- a 5,000 m³ LNG tank,
- a gas preparation room and
- additional 100 TEU

Newbuild Ropax vessel

- 1,700 m³ LNG tank
- Gas preparation room
Membrane Type Bunkering Solutions

Small Land Storage Tanks

Offshore storage & bunker station

Ship-to-Ship transfer system
Small and Mid-scale LNG Carriers

**In Service**

- **Aman Sendai**

**Under development**

- **32,000 m³ LNG Feeder**
- **16,500 m³ Shallow Draft LNGCs**
Main advantages of membrane technology
Main advantages of membrane technology
Cargo space reduction on LNG fuelled ships

Rules imposing constraints on location of LNG tank onboard:
- Distance from side shell (B/5 as basis from IGF code);
- Requirement for cofferdams;
- No LNG directly underneath passenger accommodation space.

Increased volume of required liquid
- To achieve same autonomy as conventional ship;
- Equivalent onboard energy stored;
- Requires 1.6 to 1.7 more liquid volume compare with HFO or distillates.

Space for:
- insulation
- inspection
- Fuel Gas handling and supply system (FGHSS).

The larger the ship and/or the storage tanks, the smaller the relative loss of cargo space
Example of loss of cargo space

LNG fuelled 16000 TEU mega container ship

Loss of 450 TEU

Source: GTT
- **Main assumptions**: Tanks integrated inside hull; same energy equivalent stored (same autonomy) for a typical passenger ferry.

- **In reality**, if running on DF engines, some HFO/MDO capacity + associated systems shall remain onboard increasing further the wasted space.
## Weight Advantage

**Bunker ship**
4000 m³ LNG; 1000 m³ MDO

<table>
<thead>
<tr>
<th></th>
<th>Type C design</th>
<th>Membrane design</th>
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<tbody>
<tr>
<td>LOA</td>
<td>106 m</td>
<td>90 m</td>
</tr>
<tr>
<td>LBP</td>
<td>99,9 m</td>
<td>95,9 m</td>
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<tr>
<td>Breadth</td>
<td>16,5 m</td>
<td>15,7 m</td>
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<tr>
<td>Depth</td>
<td>9,0 m</td>
<td>9,4 m</td>
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<tr>
<td>Design Draught</td>
<td>5,1 m</td>
<td>5,0 m</td>
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<tr>
<td>Cb</td>
<td>0,75</td>
<td>0,77</td>
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<tr>
<td>Lightship weight</td>
<td>3520 t</td>
<td>2410 t</td>
</tr>
<tr>
<td>Design DWT</td>
<td>2900 dwt</td>
<td>2919 dwt</td>
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<tr>
<td>V LNG cargo tanks (100%)</td>
<td>4080 m³</td>
<td>4080 m³</td>
</tr>
<tr>
<td>Max filling level in LNG tank</td>
<td>98%</td>
<td>98%</td>
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<tr>
<td>V MDO cargo tanks (100%)</td>
<td>1000 m³</td>
<td>1000 m³</td>
</tr>
<tr>
<td>Service speed (85% MCR, 15% sea margin)</td>
<td>12,0 knots</td>
<td>12,0 knots</td>
</tr>
<tr>
<td>MCR (propulsion only)</td>
<td>2740 kW</td>
<td>2420 kW</td>
</tr>
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16,500 m³ LNG

16,500 m³ Shallow Draft LNG carrier

Less Draft = Less Dredging
« More Access »
Other Advantages of Membrane solutions

- **Lighter and smaller ship means cheaper ship** (for same cargo capacity in volume and deadweight)

- **Cheapest solution per m³ for large tanks (> 1.000 m³)** either as cargo tank or fuel tank

- **Unrivaled track record** for LNG transportation at sea

- Possibility to **create quite complex shape** to better fit the available space on board

- **Low pressure means also low temperature of LNG**: Because membrane is operating at low pressure (<700 mbarg), temperature is kept low (around -160°C) which is of utmost importance at delivery to end user.
Addressing the main concerns
Sloshing

- Membrane system can withstand very high loads

- Extensive model testing is carried out for each project by GTT using specific test facility (Hexapod)

- For small LNG carriers which trade will mainly be coastal, the potential mass of liquid in tanks in case of partial filling will not be sufficient to generate:
  - significant sloshing loads
  - loss of stability beyond acceptable limits (IMO criteria)

- Not even speaking about river or port activities for LNG river barges or LNG bunker ships/barges
Pressure Build-up; BOG management

- **Natural Boil Off if not consumed** accumulates in the upper part of the tank

- **For atmospheric pressure tanks** (membrane, type A, B), this boil off has to be handled

- **Increased thermal performance of insulation** and **higher pressure** (up to 700 mbar) allows for a **reasonable autonomy in most of cases**
Case study 32k: Pressure-build-up

Consumption: 150 kg/hr (Case 2: idle condition)

• Full cargo
• Idle consumption

Pressure Rise Evolution 32K

0.25 Barg
120 hrs / 5 days

0.7 Barg
Over 400 Hrs
Before reaching 0.7 Barg
= 17 days

Over 400 Hrs
Before reaching 0.7 Barg
= 17 days
Conclusion

Membrane technology is well adapted to all storage application all along the small scale supply chain:

- LNG feeder
- LNG river barges
- LNG bunker ships / barges
- Small – medium LNG land storage

Very efficient solutions (compact and optimized ships) are expected using membrane technology for the upcoming development of the small scale infrastructure development
Thank you for your attention

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