LNG fuel tank – benefits and challenges -

Dr. Gerd-Michael Würsig, Business Director LNG fuelled ships
How to ignite a Methan/Air mixture?

- **Mindestzündenergie:**
  - H₂: 0,011 mJ; CH₄: 0,25 mJ (Erdgas)
  - statische Entladung eines menschlichen Körpers: ca. 10 mJ

<table>
<thead>
<tr>
<th>Flammability limits (vol. % in air)</th>
<th>Hydrogen</th>
<th>Methane</th>
<th>Propane</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower limit (LFL)</td>
<td>4</td>
<td>5.3</td>
<td>2.1</td>
<td>1</td>
</tr>
<tr>
<td>Upper limit (UFL)</td>
<td>75</td>
<td>15</td>
<td>9.5</td>
<td>7.8</td>
</tr>
<tr>
<td>Minimum ignition energy (mJ)</td>
<td>0.02</td>
<td>0.29</td>
<td>0.26</td>
<td>0.24</td>
</tr>
</tbody>
</table>
The close relation between temperature and Pressure for liquids

Cooker
- 100 °C, 1 bar
- 900 °C
- 6 min

LNG Tank
- -162 °C, 1 bar
- -152 °C, 2 bar
- -138 °C, 5 bar
- 20 °C

Pressure Cooker
- 120 °C, 2 bar
- 900 °C
- 3 min
Tank design principle: prevent LNG spill from fuel tanks

- What to do with the gas from a tank leak?
  - Type C → leaks possible only from valves
  - Type A and Membrane Tank → gas release has to be handled in case of large leaks
  - Type B Tank → limited gas release from leaks has to be handled
Tank Types and their Safety Principles

- **Type C (min p >2 bar g)**
  - leakage free tank
  - leaks possible only from valves

- **Type B Tank (max p<= 0,7 bar g)**
  - only minor leaks of the tank structure possible
  - limited liquefied gas release has to be handled

- **Type A and Membrane Tank (max p<=0,7 bar g)**
  - complete first barrier failure not excluded
  - Liquefied gas release has to be handled

Protect the hull from so much cold gas or you risk the ship!
Cryogenic spills always cause cracking in the hull structure
Summary - Prevent gas from entering safe spaces

- Gas tight secondary barrier or hold space: Type A-, Membrane- and Type B-Tanks
- Thermal insulation: Type A- and Membrane-Tanks. Type B-Tanks → consideration of low temperatures needed (from gas of the drip tray)
- Type C tanks without pipes into the hold space:
  - No low temperature protection because no leaks in the shell assumed. Nevertheless small amounts of gas should be able to be handled!
  - Watertight hold space with differential pressure between adjacent spaces. Pressure in hold space lowest
  - Gas detection in the hold space

- Type C tanks with pipes into the hold space:
  - Leaks from pipes assumed → gas tight, low temperature resistant secondary barrier.
    (existing vacuum tank design for ships)

Safe release of gas in case of tank failure must be considered
Membrane tanks: hull is supporting structure
- Mark V: General description -

Primary membrane identical to Mark III

No perforation of membrane

Metallnic and flexible secondary membrane

Anchoring to the hull with mastic
Cargo and spray pumps & level gauges, cables etc are mounted in the tank tower.

Protect membrane in the area where work is taking place.

Rubber mats with thick plywood on top.

Source: GTT
Membrane tank with gas handling room above tank

Prefabricated ship section for fast integration into the ship

Source: GTT
Independent tanks: tank exists without ship’s hull
- IHI-Self supporting system: Type B -
Moss LNG tank: Type B
Pressurized Tanks: Type C tanks

Ethylene- and LPG carriers: 1000 to 10000 m$^3$ per tank
LNG fuelled ships:
- currently 30 to 500 m$^3$ per tank
- Near future: up to 1000 m$^3$ per tank
- Expected: 2000 to 10000 m$^3$ per tank
New Type-B tank from NLI

- Company: NLI Innovation AS:
- Tank containment system type-B prismatic (0.7 bar)
- AiP issued by DNV June 2013
New designs for pressure tanks

- Company: Aker Engineering
- Aker Design (ADBT)- approx. 10 bar pressurised tank (double walled)
Independent type A tanks for LNG

- Company: LNG New Technology
- A-type tank design for LNG (insulation on ship’s hull forms secondary barrier)
- AiP issued by DNV 2013
Space needed for different tank types

CS=Containment System, HS=Handling System

Source: GTT
Vacuum insulations are most effective

<table>
<thead>
<tr>
<th>Type of Insulation</th>
<th>W/(m K)</th>
<th>% of Polyurethane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyurethane</td>
<td>0,033000</td>
<td>100,00</td>
</tr>
<tr>
<td>perlite (gas filled)</td>
<td>0,026000</td>
<td>78,79</td>
</tr>
<tr>
<td>evacuated powders: p &lt; 0.13 Pa at 300 K (1.3*10^-6 bar)</td>
<td>0,001425</td>
<td>4.32</td>
</tr>
<tr>
<td>multilayer vacuum insulation; p &lt; 0.0013 Pa at 300 K (1.3*10^-8 bar)</td>
<td>0,000046</td>
<td>0.14</td>
</tr>
</tbody>
</table>

![Graph showing the thermal conductivity of insulations]
Small tanks need efficient insulations

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>A</th>
<th>fl</th>
</tr>
</thead>
<tbody>
<tr>
<td>(m**3)</td>
<td>505</td>
<td>1018</td>
<td>0,95</td>
</tr>
<tr>
<td>(m**2)</td>
<td>461</td>
<td>735</td>
<td>0,95</td>
</tr>
</tbody>
</table>

VLNG: 480 m**3, MLNG: 202949 kg

BOR %/d: 0,30

BOG: 609 kg, QBOG: 311120 kJ/(d)

Q0: 3,60 kW, q0: 7,82 W/m**2

eta: 0,45

P (with BOG): 331 kW, 668 kW

LNG fuel tanks below approx. 500 m**3 will stay with vacuum insulation
A system to bring the LNG out of this tank - Low pressure gas supply to engine -

- A) compressor supply
- Boil Off to low to meet engine gas demand

This is a motor but could be any engine which is happy with relatively low pressure gas:
Low pressure gas supply to engine

- A) compressor supply
- B) direct supply from tank
- Boil Off to low to meet engine gas demand
Low pressure gas supply to engine

- A) compressor supply
- B) direct supply from tank
- C) supply by pump
- Boil Off to low to meet engine gas demand
High pressure gas supply to engine

- A) bottom line from tank (exclude loss of tank content in case of pipe failure)
- Boil Off must be handled separately
High pressure gas supply to engine

- A) bottom line from tank (exclude loss of tank content in case of pipe failure)
- B) in-tank pump (redundancy required)
- Boil Off must be handled separately

This is a motor but could be any engine which is happy with relatively high pressure gas.
Engine Arrangement M/S Stavangerfjord

- 1) Bergen marine gas motor; 4 pcs B35:40V12PG with GRU
- 2) LNG fuelling system; 2 pcs 300m3 LNG tanks with cold boxes, 2 pcs bunkering stations, associated piping
- 3) ACON LNG control and monitoring system

All existing vessels use Type C tanks. This will change for large amounts of LNG!

Source: Rolls Royce Bergen
‘LNG Ready’ for all who like to built a oil fuelled ship today
- Service Process -

1. STRATEGY – FUEL DECISION
   - High level technical feasibility
   - Fuel consumption estimates
   - Financial feasibility
   - Cost, pay-back time and sensitivity analysis
   - Fuel availability

2. CONCEPT CAPTURE
   - Detailed technical feasibility study
   - Machinery and tank evaluation and optimization (evaluation of performance)
   - Concept Design Review (Statement - class acceptance)
   - HAZID

3. INITIAL DESIGN
   - Approval in Principle
   - HAZID or Risk Assessment

4. RISK ASSESSMENT
   - Gas fuel Safety Risk Assessment (mandatory by IMO)

CLASS APPROVAL (after vessel is ‘LNG Ready’)

Decision Points. Proceed with the LNG option or not.
Safeguarding life, property and the environment

www.dnv.com