LNG Infrastructure and Shipbuilding

Dipl.-Ing. Michael Kraack
Klaipeda, 10. Dezember 2015
GO LNG – Final Conference to the SBSR Project „MarTech LNG“
History of Marine Service

1958
Foundation of Marine Service GmbH by Dr. Karl-Heinz Kraemer

1959
Plan Approval and Construction Supervision of the first Dry Cargo Vessel

1969
Design, Plan Approval and Construction Supervision of the first LNG Carrier

since 1970
Technical Planning and Construction of more than 20% of the existing LNG Carrier Fleet worldwide

since 1974
Feasibility studies, planning of location, safety regulations, etc. for LNG Terminals worldwide

2009 – 2010
Approval in Principle of LNG fueling and bunkering systems for marine fuel supply

2010 – 2013
Type Approval – Design of an LNG Fuel Tank Container

Klaipeda, 10.12.2014
LNG Infrastructure and Shipbuilding
Supply of fuel gas within given pressure and temperature limits to:

- Main engines
  - Gas engines and dual-fuel engines: 5 to 6 bar
  - Slow speed engines with HP-injection: 300 bar
- Auxiliary engines: 5 to 6 bar
- Boilers: 0.5 to 2 bar
LNG TANK TYPES: TYPE “C”

- Cylindrical type-C Tanks
  - Pressure 6 to 10 bar
  - Vacuum, or PU panel insulated
  - Size up to about 500m³ per Tank

- Bilobe- type-C Tanks
  Pressure approx. 4 bar
  Panel or foam insulated
  Size up to about 10,000 m³ per Tank

- LNG Container
  - Type-C Tank and IMDG-Tank
  - Pressure 6 to 10 bar
  - Vacuum insulated
  - Size about 40m³ per Tank
LNG as Marine Fuel

LNG TANK TYPES: TYPE “C”

• Trilobe- Type-C Tanks
  Pressure approx. 4 bar
  Panel or foam insulated
  Tank size: volume improvement up to 30%
LNG TANK TYPES: TYPE “B” / “A”

- Type-A and B Tank
  - Pressure < 0.7 bar
  - Self-supporting construction with inner structure
  - Panel insulation with only partial second barrier Type „B“
  - Panel insulation without second barrier Type „A“
  - Size up to 10,000 – 45,000 m³ per tank
LNG TANK TYPES: MEMBRANE

• Membrane
  • Pressure approx. 0.3 bar max 0.7 bar
  • Foam or boxes with perlite filling with secondary barrier
  • Adapts to outer shell
  • Size up to 45,000 m³ per tank
LNG TANK INSULATION

### Insulation
- PU-Foam Insulation
- Vacuum Perlite Insulation
- Aerogel Mats
- Radiation Foil Vacuum Insulation

### Advantages
- Cost efficient
- Noninflammable
- Low thermal conductivity
- Simple processing
- Has a second barrier
- Remaining insulation after vacuum loss

### Disadvantages
- Risk of icing
- Inflammable
- Expensive waste disposal
- Needs a second barrier
- Risk of vacuum loss due to leakages
- High insulation costs with industrial vacuum
- High material costs
- Risk of icing
- Needs a second barrier
- Risk of vacuum loss due to leakages
- Highest insulation costs due to high vacuum, about 10 x more expensive
LNG as Marine Fuel

PANEL SYSTEM MOSS TYPE

Source: KAEFER
LNG as Marine Fuel

STRENGTH MOSS TYPE PANELS

LNG Skirt: Stress and deformation between 20 °C and −162 °C

Source: KAEFER

Klaipeda, 10.12.2014
Heat Input LNG Tank

- Bunker pressure 1.1 bar (a)
- Ambient temperature: 45°C
- LNG temperature: -161°C

Effective heat conductivity (W/mK)

- PU-foam aged: \( \approx 0.02 \)
- Vacuum perlite: \( \approx 0.0025 \)
- Aerogel mats: \( \approx 0.013 \)
Minimum possible insulation quality

Heat input into tank should not exceed 10 kW:

- PU-foam: \( \approx 260 \text{mm} \)
- Vacuum perlite: \( \approx 35 \text{mm} \)
- Aerogel mats: \( \approx 165 \text{mm} \)
To achieve holding times of 80 days or more for the fuel gas tank, a vacuum pressure of $10^{-4}$ mbar is necessary.
Vacuum space with perlite filling

Perlite filling compacted, blocking free movement of pipe expansion loops

- Remaining insulation effect if vacuum is lost
- Simple to implement
- Higher heat conductivity
- Risk of compacting under vibration

Source: Ziemann International
Vacuum space with radiation foil

- Low heat conductivity
- Free movement of pipes in vacuum space
- Small vacuum space
- Higher heat conductivity in case of lost vacuum
- Accurate installation necessary
LNG as Marine Fuel

LNG FUEL TANK LAYOUT

Source: motorship
How much energy is required?
- Operational profile
- DF or pure gas combustor

How is the bunker frequency?
- Dependent on routes
- Dependent on filling stations

How much of the tank volume can be used?
- Bunker temperature
- Tank design and safety valve adjustment
LNG as Marine Fuel

LNG FUEL TANK TYPE C

10 t LNG at -162°C, 1 bar absolute
Volume = 237 m³

10 t LNG at -121°C, 11 bar absolute
Volume = 278 m³

17% Volume Increase
LNG as Marine Fuel

LNG FUEL TANK TYPE C

<table>
<thead>
<tr>
<th>Case</th>
<th>Temp. (°C)</th>
<th>Pressure (bar absolute)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading temperature</td>
<td>-162,0</td>
<td>1,00</td>
<td>422,6</td>
</tr>
<tr>
<td>Reference temperature</td>
<td>-121,0</td>
<td>11,00</td>
<td>359,6</td>
</tr>
<tr>
<td>Relative density, reference, PR</td>
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<td></td>
<td>359,6 kg/m³</td>
</tr>
<tr>
<td>Relative density, loading: PL</td>
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<td></td>
<td>422,6 kg/m³</td>
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<tr>
<td>Loading part</td>
<td></td>
<td></td>
<td>98%</td>
</tr>
<tr>
<td>Volume load: VL</td>
<td></td>
<td></td>
<td>83% of total tank volume at -161,6°C</td>
</tr>
</tbody>
</table>

In this case < 80% of the volume can be used!

Safety Valve Adjustment

Minimum liquid level

Maximum liquid level

Available Volume ~ 78 %

Room for Vapour Phase ~ 17%

Minimum Remaining Volume ~ 5 %

\[ VL = 0.98 \times \frac{PR}{PL} = 83\% \]
Functions:

- Supply of fuel gas within given pressure and temperature limits
- Control of storage tank pressure
- Handling of boil-off
- Bunkering support
- Gas freeing capability
Most simple design with pressure build-up (PBU) vaporizer to raise tank pressure. The vaporizer is used for regasification and fuel gas temperature control. If vapor is withdrawn from the tank to reduce the pressure, the vaporizer is used as a heater for the vapor.
The separation of the vaporizer function and the gas heating function improves the pressure and temperature stability of the fuel gas.
If the fuel gas shall also be used during bunkering, an LNG fuel pump is necessary. This pump can also be used in case of heavy weather if the tank pressure collapses due to sloshing in the tank. The LNG pump is installed in a vacuum insulate drum.
If the bunker pipe is long, a pre-cooling is required. A line cool-down is required. The pump can also be used to spray the LNG tank prior to bunkering to reduce the back pressure and by this speeding up the bunkering.

The pump can also be used for discharging the tank (gas freeing).
• **ISO LNG Tank Container:**
  - IMDG hazardous goods container
  - IGC compliant Type C Tank (pressure tank) to allow use onboard as shipboard fuel bunker
  - Vacuum insulated to ensure extra long holding time up to 80 days
  - Dry coupling system with break-away device to avoid LNG leakage
40' ISO LNG Tank Container developed by Marine Service for external loading with LNG within a safe environment.

LNG as Fuel

with the Marine Service LNG Tank Container onboard a feeder ship
• Up to 6 LNG fuel tank containers in one stack
• LNG container hose connections in cell guides
The dry coupling developed by Marine Service has a break-away device and is TÜV certified with more than 1000 trial couplings with nearly no leakage ($10^{-5}$ mbar * l / sek).
LNG DRY COUPLING

Coupling under pressure
Installation of permanent tanks with vertical layout for a project on the Great Lakes
A GVU (Gas Valve Unit) is used for a retrofit installation of an LNG propulsion. Additional explosion protection equipment in the engine room is therefore not needed, which would be very expensive and difficult to install.
LNG TANK SYSTEMS: FSRU

Offshore Livorno, Italy

LNG FSRU “FSRU TOSCANA”
Source: Marine Service
FSRU MOORING SYSTEM

LNG FSRU “FSRU TOSCANA”
Source: Marine Service

Turret and Swivel
Source: LMC
• Truck-to-ship
• Shore-to-ship
• Ship-to-ship
  – Barge
  – LNG carrier
High flexibility: Trucks can drive to the jetty of the vessel to be supplied
Limited amount of fuel: The amount of LNG which can be delivered by trucks is very limited or many trucks have to be used.

Risky security chain
  e.g. emergency stop

Security zone: barrier

MS “Viking Grace” in Finland
The infrastructure onshore has been prepared, however, not all vessels are equipped with loading arms.

Many terminals are only laid out as import terminals where no fueling can be done.
LNG SHIP TO SHIP

LNG bunker vessels have a relatively large capacity and are flexible with regard to the bunker location.

Bunker procedure is similar to today’s oil / diesel procedures.

Regulations are currently not yet applied uniformly.
Soot Cloud over Hamburg, 4 October 2014

Foto: News Art

Thank you for your kind attention

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