LNG Propulsion System as Shipyards Perspective

LNG Fuel Forum
20 Sep. 2011

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INTRODUCTION
DUAL FUEL ENGINES
LNG FUEL STORAGE TANKS
FUEL GAS SUPPLY SYSTEM
LNG BUNKERING
SAFETY ISSUES
CONCLUSIONS
**Background**

**Emission Regulations**
- **SOx Regulation by IMO** (MARPOL Annex VI, Regulation 14)
<table>
<thead>
<tr>
<th>Tier</th>
<th>Construction date on or after</th>
<th>g/kWh (RPM&lt;130)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1 January 2000</td>
<td>17.0</td>
</tr>
<tr>
<td>II</td>
<td>1 January 2011</td>
<td>14.4</td>
</tr>
<tr>
<td>III</td>
<td>1 January 2016</td>
<td>3.4</td>
</tr>
</tbody>
</table>

- **NOx Regulation by IMO** (MARPOL Annex VI, Regulation 13)

**Fuel Price**
- **Recent Gas & Ship Fuel Price (06 May 2011)**

**Global LNG Fueled Ships (small size)**

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Storage</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>A few small ships with CNG</td>
<td>CNG (Compressed Natural Gas)</td>
<td>1982 – 1990s</td>
</tr>
<tr>
<td>Glutra (car &amp; passenger ferry)</td>
<td>LNG (2 x 32m³)</td>
<td>2000</td>
</tr>
<tr>
<td>Viking Energy (platform supply vessel) (+ 1 sister ships)</td>
<td>LNG (1 x 234m³)</td>
<td>2003</td>
</tr>
<tr>
<td>Bergensfjord (car &amp; passenger ferry) (+ 4 sister ships)</td>
<td>LNG (2 x 125m³)</td>
<td>2007</td>
</tr>
<tr>
<td>Kystvakt (coast guard ship) (+ 2 sister ships)</td>
<td>LNG (1 x 234m³)</td>
<td>2009</td>
</tr>
<tr>
<td>Moldefjord (car &amp; passenger ferry) (+ 2 sister ships)</td>
<td>LNG (2 x 125m³)</td>
<td>2009</td>
</tr>
<tr>
<td>Viking Queen (platform supply vessel) (+ 1 sister ships)</td>
<td>LNG (1 x 234m³)</td>
<td>2009</td>
</tr>
</tbody>
</table>
For Large Ships

- Large ship requires totally different technologies to utilize LNG as its fuel.

<table>
<thead>
<tr>
<th></th>
<th>Small Ships</th>
<th>Large Ships</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propulsion</td>
<td>4 Stroke Gas or D/F Engine &amp;</td>
<td>2 Stroke D/F Engine &amp; Mechanical</td>
<td>Large Propulsion Power (Bore 90 or 98)</td>
</tr>
<tr>
<td></td>
<td>Electric Propulsion</td>
<td>Propulsion</td>
<td></td>
</tr>
<tr>
<td>FGS</td>
<td>LNG/NG Supply by Tank Pressure</td>
<td>New Concept FGS</td>
<td>High GI Pressure</td>
</tr>
<tr>
<td>Fuel Tank Type</td>
<td>Type C Pressure Vessel</td>
<td>New Concept Fuel Tank</td>
<td>Huge Tank Volume</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CAPEX, Volume Efficiency</td>
</tr>
<tr>
<td>BOG Management</td>
<td>Not Critical</td>
<td>Careful Attention</td>
<td>MARVS</td>
</tr>
<tr>
<td>Fuel Tank</td>
<td>Complying with B/5 distance from</td>
<td>Difficult to meet B/5</td>
<td>Cargo Loss, Collision</td>
</tr>
<tr>
<td>Arrangement</td>
<td>side hull</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bunkering</td>
<td>Not Critical</td>
<td>Critical in Method &amp; Time</td>
<td>Tank Volume &amp; Operation Schedule</td>
</tr>
</tbody>
</table>

LNG Fueled Propulsion System

- LNG Fueled Propulsion System for Large Commercial Ships

*NG : Natural Gas  
*ME-GI : MAN Electronic – Gas Injection  
*BOG : Boil-Off Gas

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Propulsion Engine: 2-Stroke Dual Fuel Engine

ME-GI Engine (MAN Electronic – Gas Injection)
- 2-stroke dual fuel engine made by MAN Diesel
- Highest efficiency among existing propulsion systems
- Simultaneous Dual Burning (HFO + FG)
- Low CAPEX & OPEX compared to other dual fuel engines
- CO2, NOx, SOx emission reduction

* Emission Comparison between ME and ME-GI in gas mode
(Refer to "ME-GI Dual Fuel MAN B&W Engines". Graph by DSME)

* Variable Gas Operation Mode of ME-GI
Gas / Dual Fuel Generator Engine

- 4-stroke, medium speed gas or DF engine
- Oil mode (HFO or MDO, DF engine only) or Gas mode (NG + 1% MDO pilot oil)
- SOx, NOx emission is negligible
- Working gas pressure: 5 ~ 8 bar
- Constant speed (RPM) designed

Generator Engine: 4-Stroke Gas / Dual Fuel Engine

• SOx, NOx emission is negligible
• Working gas pressure: 5 ~ 8 bar
• Constant speed (RPM) designed


DUAL FUEL ENGINES

INTRODUCTION

LNG FUEL STORAGE TANKS

FUEL GAS SUPPLY SYSTEM

LNG BUNKERING

SAFETY ISSUES

CONCLUSIONS
IMO Independent Type B

- Independent LNG tank – Prismatic type
- PUF (Poly-Urethane Foam) panel type insulation
- Inherent increased pressure design

Membrane Tank

- IGF interim guideline is expected to amended to allow membrane tank for LNG fueled ships

<table>
<thead>
<tr>
<th>GTT NO 96 system</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary membrane</td>
<td>0.7 mm Invar (36% Ni-Fe)</td>
</tr>
<tr>
<td>Primary insulation material</td>
<td>Plywood with Perlite</td>
</tr>
<tr>
<td>Secondary membrane</td>
<td>0.7 mm Invar (36% Ni-Fe)</td>
</tr>
<tr>
<td>Secondary insulation material</td>
<td>Plywood with Perlite</td>
</tr>
<tr>
<td>Insulation thickness</td>
<td>530 mm (230 + 300)</td>
</tr>
<tr>
<td>Insulation tightening</td>
<td>Securing device set</td>
</tr>
<tr>
<td>Note</td>
<td>Anti-sticking treatment between secondary insulation box with hull</td>
</tr>
</tbody>
</table>

- Internal view of NO96 CCS
- Result of sloshing in 2 raw arrangement of NO 96 CCS
**Fuel Gas Supply System - DSME HiVAR**

- **Conceptual Process Flow Diagram**
  - DSME HiVAR FGS
  - *1 LNG Storage
  - *2 HP Pump
  - *3 HP Vaporizer
  - *4 BOG Engine

- **Features**
  - HP Pump + HP Vaporizer
  - 300 bar Design Pressure
  - BOG Recondensing
  - Compact Size
  - Low Power Consumption
  - Low Noise & Vibration
  - Easy Maintenance

- **Power Consumption Comparison**
  - (for reference)
  - HP Compressor System
  - HiVAR
  - 1400 kW
  - 70 kW

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DSME Proprietary Technology

DSME HiVAR system

- International Patent Application
  - Several patents applied since June 2008
  - Designated States: EP (Granted), Singapore (Granted), China, United Arab Emirates

- United States Patent
  - Several patents applied since Dec 2008

- Patented or Patent Application in Korea
  - Several patents applied since May 2007
  - 20 patents granted or pending

EP: United Kingdom, Norway, Sweden, Germany, Belgium, France, Denmark, Greece, Switzerland, Finland

- High pressure fuel gas supply using HP pump and HP vaporizer is subject to intellectual and industrial property rights protected by national and international legislation.
- Registered to many countries including US and EU. (Previous arts have been exhaustively checked before registration.)

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DSME HiVAR FGS Test Skid (at Copenhagen)

- SUCTION DRUM
  - Design press.: 11.5 barg
  - Design temp.: -186 °C
  - Volume: 0.68 m³

- GW SYSTEM
  - Temp. range: from 50°C to 60°C
  - Heating power: 330 kW (Max)

- HP PUMP
  - Type: Reciprocating
  - Discharge press.: 315 barg
  - Design capa.: 1.6 m³/h

- HP VAPORIZER
  - Type: Shell & Tube
  - Working press.: 315 barg (Max)
  - Heating power: 300 kW

- SILENSOR
  - Ref. noise: 80dB
  - Performance: > 20dB
  - Material: Sus 304

- PULSATION DAMPER
  - Pipe size: 40A
  - Length: 24m
  - Volume: 0.02 m³
LNG Bunkering Scenarios

- Tank lorry for small ships
- Existing LNG import or Export Terminals
- Launching local LNG Liquefaction Facilities for bunkering business
- Ship to Ship Transfer utilizing small LNG Bunkering Ships in
  - Container terminals, or
  - Open sea areas

Zeebrugge LNG Receiving Terminal w/ Re-Export in Belgium
LNG Bunkering Vessel Concept
- Pre-requisite for LNG fueled containerships and tankers
- Safe mooring
- Manifold mating
- High speed LNG pumping
- Returned flash gas treatment
- Safety monitoring and interface systems

* Side by Side Mooring

LNG Bunkering Vessel

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Overall Safety Design

- IGF* compliant design
- HAZID/HAZOP for LNG fuelled commercial ship
  - Gas existing physical spaces:
    LNG fuel tank space, FGS room, E/R, vent mast, bunkering station, passage way, etc.
  - Gas operations:
    LNG bunkering, FG supply at normal seagoing, drying, inerting, aeration, initial cool down, warming up, etc.


FGS Room

FGS Room Safety
- Explosion proof equipments (motor, etc)
- Ignition source inhibited
- Ventilation systems (30 air change / hour)
- Gas detection & ESD (Emergency Shut Down) system
- Structural integrity against dropping object (container ships)
**LNG Fuel Tank Space**

**LNG Fuel Tank Safety**
- Tank pressure control by BOG Management
- Emergency venting systems
- Inerting with N2 outside of tank
- Gas detection systems
- Drip Trays below tank bottom (Secondary Barrier)
- Eductors for drip trays
- Structural integrity against possible collision (container ships)

**Engine Room**

**Engine Room Safety**
- Double wall pipe connections
- GVU (Gas Valve Unit) for each gas fueled engine
  - Double block and bleed valves
  - Enclosed GVU room with ventilation
- Ventilation systems
- Gas detection systems
- ESD (Emergency Shut Down) system

- Gas Explosion Study in E/R
Considerations for LNG Fueled Ship

- **Ship owner**
  - Economic Benefit
  - Environmental Benefit

- **LNG Supplier**
  - Stable & Predictable LNG Price Setup

- **Shipyard**
  - Reliable, Robust and Safe Design
  - Verification during Commissioning and Sea Trial

- **LNG Bunkering**
  - Long-term Contract base Stable Supply
  - Safe Bunkering Procedure
Summaries and Conclusions

- **LNG Fueled Large Commercial Ship Design**
  - Dual fuel engines + Fuel storage tank + FGS system
  - LNG bunkering infrastructure
  - Safety design & operation procedures
  - Development of various LNG fueled ship design

- **Environment Friendly Operations**
  - Reduction of exhaust emission (CO2, SOx, NOx)

- **Cost-Effectiveness of LNG Fuel**
  - Environment and operation cost saving

<table>
<thead>
<tr>
<th>Ship Type</th>
<th>Annual Fuel Cost Saving</th>
</tr>
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<tbody>
<tr>
<td>Typical Large Container Ship</td>
<td>Approx. 12 ~ 20 mil. USD per year</td>
</tr>
<tr>
<td>Typical VLCC</td>
<td>Approx. 6 ~ 12 mil. USD per year</td>
</tr>
</tbody>
</table>

*Based on fuel prices of HFO($630/ton), MGO($930/ton) and LNG($8 ~ $12/MMBTU)