LNG as Ship Fuel

Effects on Ship Design, Operations and Supporting Infrastructure

New Technologies for the Marine Highway
TRB – Marine Highways Committee (AW010(1))
January 14, 2013
LNG as a Ship’s Fuel

- Liquid Natural Gas (LNG) has characteristics that impact ship design and operation

  - It is liquid only at cryogenic temperatures (-163°C) so it requires special storage tanks, pipe systems, and handling
  - It will normally slowly evaporate when stored so a means to deal with boil off gas (BOG) is required – venting to air is not allowed
  - When in gas state it can be explosive in an enclosed space at the right mixture with air – ventilation system needed
  - It is clean burning so low SOx, Particulate, and NOx emissions can be achieved without add on hardware – emissions are compliant with ECA regulations
  - LNG has half the density of diesel fuel so larger storage tanks for the same range are needed – tanks are not at high pressure so can be stored below deck, unlike CNG
LNG Fueled Propulsion for Ships

➢ LNG as a ship fuel has great potential as fuel of choice for the future
  • Clean burning – meets all current and future emission standards
  • Existing Technology: Dual fuel engines in use on LNG carriers and coastal vessels/ferries in Europe
  • LNG Fuel has lower cost today - about 30% lower than diesel fuel
  • Vessel regulatory issues manageable
  • LNG can be stored in tanks internal to the hull
  • Variable Range Possible - Short Range on LNG (2,500 mi), Long Range with diesel fuel (dual-use)

➢ Major roadblocks
  • Lack of bunkering supply system
  • Higher cost for engines and fuel system & tanks
  • Mostly unfounded fear of LNG by some
  • Potential loss of cargo space on some ship types - RoRo & Container to make space for LNG Tanks
  • Possibility of no cargo operations during bunkering
LNG Propulsion Options

➤ Five LNG fuel propulsion options available
  • Steam boiler and turbine – high fuel consumption
  • Medium Speed Diesel Engine - dual fuel (LNG or diesel fuel)
  • Medium Speed Spark Ignition Diesel Engine – LNG fuel only
  • Low Speed Diesel Engine – dual fuel (LNG at high pressure)
  • Gas Turbine with Waste Heat Boiler – dual fuel, limited power availability

➤ Medium Speed Dual Fuel Diesel Engines most commonly selected
  • Existing, in use technology with good service history
  • LNG fuel is not under pressure so safer than high pressure required for low speed diesel engines
  • Full power operation with diesel fuel is possible
  • Wide range of available power sizes
LNG Fuel Tanks

Several Tank Options are available – IMO Tank Types

- Type A & B are structural tanks built into hull – low pressure requires constant consumption of boil off gas (BOG)
- Type C cylindrical pressure tanks – up to 10 bar pressure allows storage of BOG for up to two weeks

Type C are most widely used for fuel tanks because they allow retention of BOG so there is little wasted fuel

For ocean going vessels large volume of LNG tanks to achieve desired range can impact vessel cargo stowage

Tanks and tank compartment need special ventilation & tank vent piping to raised vent mast on deck

Fuel tanks are expensive because of the need for special materials (stainless steel) for the cryogenic temperatures, need to be pressure vessels, and gas control equipment
**LNG Fuel System**

LNG fuel system layout – (from Wartsila)

- **Tank Room** – space with equipment to gasify LNG located in vicinity of or attached to LNG Tanks
- **Double Wall Piping** – recommend double wall piping. With space between inner and outer pipes vented to atmosphere it allows LNG pipes to run through machinery spaces without creating hazardous areas.
- **Redundant LNG Fuel Supply** – recommend two supply pipes from Tanks to Engine for greater reliability
- **Gas Valve Units** – self contained units, one for each engine, fitted in engine room - contain gas flow control and shutdown equipment
- **Vent Riser Mast** – height is Beam/3 above weather deck, hazardous outlet

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LNG Bunkering

LNG bunkering by vessel

- Two Main Options for Bunkering
  - From Barges or Small Ships
  - From Shore by Truck or Pipeline

- No bunkering system in place at this time, but under development
- Barges or Small Ships – similar to fuel bunkering, at pier or anchorage
- Truck or Pipeline – Trucks have limited volume – 38 m³ so for small ships only, pipelines require dedicated LNG storage facilities and piers
- Major issue is whether can bunker during cargo operations

LNG bunkering by truck
Impact on Ship Operation

- LNG fuel use and bunkering require special crew training
- Complex fuel system can increase maintenance costs
- LNG capable medium speed diesel engines have some operational issues
  - 10% higher fuel consumption when operating on diesel oil compared to conventional engines
  - Some high GHG effect methane is emitted – methane slip
  - Operation on gas at low power (less than 15% MCR) is difficult and so may have to maneuver on diesel oil

- Significant safety issues with LNG use onboard
  - Especially with low speed diesel engines that require LNG gas to be raised to high pressure for direct injection into the engine

- Potential Port Regulations not allowing bunkering during cargo operations can impact vessel schedules
Suitable Ship Types

- LNG fuel is more suitable for some ship types than others
- Best for the following ship types
  - Ships & boats with a set route and short range (4,000 nm or less) – storage tank capacity is not overly large & fixed bunkering port can be established
    - Ferries
    - Coastal ships & tugs
  - Ships that operate mostly within an ECA – low emissions are required
  - Ships without high fuel consumption rates – required storage capacity is practical and bunkering time & frequency is not high
  - Ships that trade where a source of LNG is available
- Ships intended for cross ocean passages designed to use LNG in ECA only need a means to effectively utilize BOG when mid-ocean and heavy fuel is the primary fuel
Design 13 – Arrangement for LNG Propulsion (from CCDoTT Project)

- Suitable for Combined Service including both AMH and offshore Jones Act services
  - Provides good base load from offshore service to keep vessels full and cover costs
  - Large container capacity suitable for offshore services
- LNG Propulsion
  - LNG Storage Tanks on Lower Deck
  - Dual Fuel Medium Speed Engines – LNG or Diesel Fuel
  - LNG Range about 2,500 nm (1 round trip)
TOTE - New LNG Fuel Containership

**Vessel Profile**
- First cargo vessel to be built in the US with LNG fuel
  - First worldwide marine application of Low Speed Diesel engine with Gas Injection
  - Both main engine and diesel generators can use LNG fuel
  - Dual Fuel Engine allows use of LNG or Diesel fuel, depending on availability
- Intended for Florida to Puerto Rico service, Jones Act service
- Gas storage tanks located aft, some reduction in container stowage
- Gas Injection is at high pressure, 250 bar, so significant safety concern
- Limited range with LNG

**LNG Fuel System**

Construction Costs – LNG & Diesel Versions – Design 13

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Medium Speed Diesel - LNG Fuel</th>
<th>Low Speed Diesel - MGO Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBP (m)</td>
<td>187.000</td>
<td>187.000</td>
</tr>
<tr>
<td>Beam (m)</td>
<td>32.200</td>
<td>32.200</td>
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<tr>
<td>Depth (m)</td>
<td>18.900</td>
<td>18.600</td>
</tr>
<tr>
<td>Design Speed (knots)</td>
<td>22.00</td>
<td>21.85</td>
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<tr>
<td>TEU Capacity (Loaded)</td>
<td>1,314</td>
<td>1,208</td>
</tr>
<tr>
<td>Installed Power, MCR (kW)</td>
<td>23,400</td>
<td>21,060</td>
</tr>
<tr>
<td>No. of Propellers</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SSDG Installed Power (kW)</td>
<td>4,620</td>
<td>4,620</td>
</tr>
<tr>
<td>Lightship Weight (mt)</td>
<td>13,819</td>
<td>13,478</td>
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<tr>
<td><strong>US Construction Cost ($M)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ship Price (one of 3 ships)</td>
<td>$190</td>
<td>$160</td>
</tr>
<tr>
<td>Lower bound estimate</td>
<td>$171</td>
<td>$144</td>
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<tr>
<td>Upper bound estimate</td>
<td>$213</td>
<td>$177</td>
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<tr>
<td>Uncertainty (ROM)</td>
<td>-10%/+12%</td>
<td>-10%/+10%</td>
</tr>
</tbody>
</table>

- Tote Containership is comparable in cost – expected to be less than Design 13 LNG version because includes low speed diesel
- $10M in cost difference from change in propulsion from diesel fuel low speed diesel to 2 x LNG capable medium speed diesels with gearbox & CPP
- $20M in cost difference from LNG equipment and outfitting – see next slide
## Special LNG Equipment Costs – Design 13

### LNG Storage Tanks

<table>
<thead>
<tr>
<th>Item</th>
<th>Quant</th>
<th>Unit Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNGPac194 - Buy</td>
<td>6</td>
<td>$2,500,000</td>
<td>$15,000,000</td>
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<tr>
<td>Tank Install Cost</td>
<td>6</td>
<td>$625,000</td>
<td>$3,750,000</td>
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<tr>
<td>Total</td>
<td></td>
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<td>$18,750,000</td>
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### LNG Outfit - All In Cost

<table>
<thead>
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<th>Item</th>
<th>Quant</th>
<th>Unit Cost</th>
<th>Total Cost</th>
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</thead>
<tbody>
<tr>
<td>GVU Rooms</td>
<td>4</td>
<td>$100,000</td>
<td>$400,000</td>
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<tr>
<td>Double Wall Pipe</td>
<td>2</td>
<td>$100,000</td>
<td>$200,000</td>
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<tr>
<td>Vent Riser &amp; Mast</td>
<td>1</td>
<td>$200,000</td>
<td>$200,000</td>
</tr>
<tr>
<td>Bunker Sta &amp; Pipe</td>
<td>2</td>
<td>$100,000</td>
<td>$200,000</td>
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<tr>
<td>Ventilation</td>
<td>1</td>
<td>$300,000</td>
<td>$300,000</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$1,300,000</td>
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Conclusions

- LNG has great promise as a fuel for the future
  - Lower cost
  - Clean burning

- Its use impacts ship design and operation
  - Requires special, expensive propulsion machinery & storage tanks
  - Best when provided with a backup diesel fuel option to ensure fuel availability
  - Requires complex fuel system with added safety measures
  - Requires special crew training and higher maintenance costs

- Its use may not be feasible for some ship types
  - Best for short range ships on fixed routes so bunker supply can be arranged and storage tank size is practical
  - Tramp ships with long voyages and uncertain routes are not suitable in the near future
  - High powered ships may not have available space for the required large storage tanks

- The benefits and fuel cost savings can out weigh the higher costs for some ships, making LNG a very viable fuel option to consider