Module 1: LNG Fuelled Vessels Design Training

‘Case Studies about New-building and Retrofitting LNG Fuelled Vessels’

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(University of Strathclyde)
M/S Viking Grace

**Ship type:** RoRo passenger ship (Cruise ferry)

**Built year:** 2013

**Length:** 218 m

**Beam:** 32 m

**Draught:** 6.8 m

**Gross Ton:** 57,565 GT

**Net Ton:** 47,600 GT

**Class:** Lloyd’s Register - LRS +100A1 Passenger/Vehicle Ferry, ShipRight SDA, CM, Ice 1AS FS, Movable Decks, +LMC, UMS, IBS, IWS, PCAC12, PSMR*, GF

**Speed:** 23.0 knots (max)

21.8 knots (service at 85% MCR)

**Capacity:** 2,800 passengers

1,275 lane meters for ro-ro cargo

1,000 lane meters for private cars

**Crew:** 200

**Flag State:** Finland

**Ship Owner:** Viking Line Abp

(M/S Viking Grace)

(Source: Stockholms Hamn AB)
Case 1

Technical Description:

- Two LNG tanks on board with 200 m³ each,
- A gas pipe drives the fuel to the machines with a ventilated double pipe,
- Propeller, propeller-shafts and bearings are made from Wärtsilä,
- Two dual fuel boilers from SAACKE,
- The alternators (4 x ABB AMG1120, each 8,191kVA),
- The electrical propulsion motors (2 x ABB AMZ1600, each 10,500kW),
- Four dual fuel engines on-board made from Wärtsilä (8L 50DF),
- The gas valve unit is made from SAACKE,
- Two bow thrusters of 2,300 kW each and one stern thruster of 1,200 kW

Complete system integration – example configuration for Ro-Pax ferry with diesel-electric propulsion
Design descriptions:

- Two tanks are placed on the main deck to save space for the gallery and crew recreation facilities spaces,
- Over the tanks, there is a water curtain system,
- Quite heavy,
- Each tank: 140 tonnes,
- The weight of LNG in each tank: 80-85 tonnes,
- The total rises more than 500 tonnes.

M/S Viking Grace - Gas storage and supply systems
(Source: Zoglia, P. (2013). Gas storage and supply systems. Wartsila)
Case 1

M/S Viking Grace-HVAC-Cold Recovery

(Source: Zoglia, P. (2013). Gas storage and supply systems. Wartsila)

HVAC
- Heating,
- Ventilating and
- Air conditioning

Co-funded by the Marco Polo Programme of the European Union
## Case 1

The differences between M/S Viking Grace and M/S Isabella; her predecessor to the Turku-Stockholm line. (Viking Line Abp)

<table>
<thead>
<tr>
<th></th>
<th>Isabella</th>
<th>Viking Grace</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT</td>
<td>35,100</td>
<td>57,700</td>
</tr>
<tr>
<td>Pax cabins</td>
<td>643 pcs</td>
<td>880 pcs</td>
</tr>
<tr>
<td>Installed power</td>
<td>31,180 kW</td>
<td>30,400 kW</td>
</tr>
<tr>
<td>Speed max</td>
<td>21.5 kn</td>
<td>23 kn</td>
</tr>
<tr>
<td>Annual fuel consumption</td>
<td>24,300 tonnes HFO</td>
<td>20,000 tonnes LNG</td>
</tr>
<tr>
<td></td>
<td>692 kg/GT</td>
<td>350 kg/GT</td>
</tr>
<tr>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>2.2</td>
<td>0.36</td>
</tr>
<tr>
<td>SO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>0.44</td>
<td>0.00</td>
</tr>
<tr>
<td>CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>132</td>
<td>81</td>
</tr>
<tr>
<td>PM</td>
<td>0.088</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Case 2

Case Study: Hamworthy Baltic Design Centre, Project No. 3103
## Case 2

### Main particulars:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length overall</td>
<td>193.20 m</td>
</tr>
<tr>
<td>Length between perp.</td>
<td>175.00 m</td>
</tr>
<tr>
<td>Breadth moulded</td>
<td>28.50 m</td>
</tr>
<tr>
<td>Depth to entrance</td>
<td>10.60 m</td>
</tr>
<tr>
<td>Depth to upper deck</td>
<td>23.30 m</td>
</tr>
<tr>
<td>Design draught</td>
<td>6.80 m</td>
</tr>
<tr>
<td>Scantling draught</td>
<td>7.00 m</td>
</tr>
<tr>
<td>Max. deadweight</td>
<td>9800 t</td>
</tr>
<tr>
<td>Lane length (2.90m width)</td>
<td>2400 sqm</td>
</tr>
</tbody>
</table>

- Main engines are made from Wartsila (4 x 9L50DF),
- The nominal output is 34,200 kW,
- Two controllable pitch propellers fitted,
- Service speed (90% MCR, 15% SM, PTO-off) is 22.5 knots.

**Class:**
Det Norske Veritas +1A1 ‘Car Ferry’, gas fuelled, ICE 1A, E0, NAUT-OC, RP, LCS-DC, clean design, BWM-TP, TMON.
## Case 2

### Tank capacities (m³):

<table>
<thead>
<tr>
<th>Material</th>
<th>Capacity (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquefied natural gas</td>
<td>1500</td>
</tr>
<tr>
<td>Marine diesel oil</td>
<td>780</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>220</td>
</tr>
<tr>
<td>Fresh/technical water</td>
<td>1200</td>
</tr>
</tbody>
</table>

### Cruising range:

<table>
<thead>
<tr>
<th>Type</th>
<th>Range (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only on LNG</td>
<td>3500</td>
</tr>
<tr>
<td>Only on MDO</td>
<td>3200</td>
</tr>
<tr>
<td>LNG and MDO</td>
<td>6200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passengers</td>
<td>400</td>
</tr>
<tr>
<td>Crew</td>
<td>86</td>
</tr>
</tbody>
</table>
## Case 3

Case study for a generic Cruise ship

### Main Particulars

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Gross Tonnage</td>
<td>63,000 GT</td>
</tr>
<tr>
<td>LOA</td>
<td>238 m</td>
</tr>
<tr>
<td>Breadth</td>
<td>32.2 m</td>
</tr>
<tr>
<td>Passengers/ Crew</td>
<td>2050 + 570 Crew</td>
</tr>
<tr>
<td>Engines</td>
<td>Dual fuel (2 x 6 MW; 2 x 8 MW)</td>
</tr>
<tr>
<td>Fuel</td>
<td>2x1000 m3 LNG/ 800 m3 MGO</td>
</tr>
<tr>
<td>Class notation</td>
<td>Unmanned Engine Room (EC0), Redundant Propulsion (RPS), SRTP</td>
</tr>
</tbody>
</table>
Case 3

Cruise ship GA

(Source: Meyer Werft, 2013)
Case 3

Cruise ship GA

(Source: Meyer Werft, 2013)
**Case 3**

- Ventilation of gas dangerous spaces is 30 air changes per hour
- Vent mast outlet 10m above uppermost deck
- All ventilation of rooms with gas equipment (GVUs, GHR) is lead through double walled venting duct

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**Gas Handling Room (GHR) Schematic**

(Source: Meyer Werft, 2013)
Growth of worldwide passengers carried.

(Source: cruisemarketwatch.com)
DNV GL Study

Fleet size variation

- Vessels in operation
- Orderbook up to 2016
DNV GL Study

Average age variation

- Less than 40,000: 25.8
- 40,000 to 69,000: 19.2
- 69,000 to 93,000: 13.4
- 93,000 to 143,000: 7.7
- More than 143,000: 5.6
Technical Consideration

• The ‘Crazy Idea’ outlined in the title involves the conversion of a cruise ship to run on LNG by lengthening it (Figure).

• A new prefabricated part, containing LNG tanks and all the required LNG systems, is added to the ship.

• Every ship is different,

• All the required technical modifications are outlined and presented from a hull and structural perspective,

• The machinery point of view and

• Finally the operational side

Constraints for Tier I-II-III regarding emissions NO₅

(Source: DNV, Shipping 2020)
Benefits

- Most likely improved revenue
- Increased number of passenger and crew cabins
- Improved environmental footprint
- Energy efficiency may be increased by installing low-improving appendages during dry-docking
- Additional public space and retail capacity
- Additional open deck spaces
- Reduction of main engine maintenance hours
- Less engine crew required
- Cheaper lubricants
- Cleaner engine room
- No soot on decks – less cleaning and wash water needed
- No need for exhaust cleaning devices or catalytic reactors
- Slightly lower noise level in engine room
Current challenges

- Design & retrofit cost compared to switching to distillates
- Time required for ship to be taken out of service for the retrofit operations
- Elongation may reduce the range of ports of call
- Bunkering challenges
- Statutory challenges
- LNG fuel cost pricing challenges
- LNG infrastructure challenges
- More tank space required to accommodate enough LNG to cover all the itineraries
- Onshore bunkering logistics are still under development
- Rules still under development
- More sophisticated fuel equipment is required
- Public perception not fully known
DNV GL Study

Elongation concept with prefabricated LNG tanks
Lengthening characteristics

- The minimum elongation limit is half a main vertical fire zone (approximately 22m), maximum (approximately 43m),
- Technical feasibility study has shown that, in a 23m compartment, the maximum possible volume of LNG is approximately 1500m$^3$ due to design and structural constraints,
- The addition of new cabins will increase the total number of cabins by approximately 10%,
- Cylindrical pressure type C tanks were used - the most feasible option,
- A prismatic low-pressure tank, type B, is an alternative, increasing the LNG capacity by about 30%,
- For a type B tank - a controllable fatigue crack may occur as the worst-case leakage scenario,
- The low max tank pressure of 0.7 bars for a type B tank results in limited flexibility for the tank operation and bunkering
- A high-level study showed that, with 1,500m$^3$ of LNG, approximately 70%-80% of all existing cruise itineraries can be operated,
- A potential new mid-body section of 43m will be able to accommodate approximately 3,000m$^3$ of LNG in total.
Hull and structure

- The longitudinal strength of the candidate ship has to be evaluated. The maximum allowable bending moment can become a showstopper if the hull is already designed to its optimum and cannot sustain any additional length.
- A damage stability study needs to be performed in order to determine the location of the new part.
- Fire boundaries and the evacuation arrangements need to be sorted out when planning the inserted arrangement.
- Machinery spaces need to be appraised and re-arranged as necessary.
- The location of the bunker station might create some challenges as balconies, openings and lifeboats cannot be within a safety distance of the bunker station.
- The location of the vent mast needs to be considered in order to avoid disruptions on the upper decks.
Operational requirements

- A major nautical aspect that needs to be investigated is the slow speed manoeuvring capability in port of the now longer ship
- The addition of new cabins requires an increase in potable black and grey water capacity
Machinery requirements

- The possibility of converting the main engines to dual-fuel needs to be investigated. Engine suppliers are continuously developing retrofit packages for different engine types.
- A longer ship will also require an increased thruster capacity. New bow and stern thrusters might be necessary.
- The ship’s power supply will need to be recalculated due to the increased hotel load. On the plus-side, exploiting the properties of LNG such as utilising LNG cold recovery for cooling and a higher waste heat recovery potential, both of which make the engine room more energy efficient, might balance out the need for additional hotel power.
Machinery requirements

- Removing the ship’s entire HFO capability, including fuel treatment systems and tanks, could also be investigated. This will free up space in the engine rooms for new LNG tanks. However, this will leave the ship with MGO as its second fuel and thus have a slight effect on the fuel cost if MGO is consumed instead of HFO.
- Cutting the ship in half involves severing and splicing all the coordination systems, including cables, pipes and ducts. This is a job not to be underestimated.
DNV GL Study

Financial assessment

- LNG tanks
- Gas supply system
- Retrofit of engines
- Modification of machinery systems
- Prefabrication of new section & transportation
- Cabins/common spaces etc.

CAPEX

LNG System

Mid-body Section

Engine Room
Financial assessment

- Lubricants
- Gas supply system
- Engine maintenance intervals
- LNG supply system
- Maintenance maintenance maint
- Fuel cost advantages of LNG

DNV GL Study
A ship with the following characteristics was assumed:

- New mid-body section length: 23 m
- New LOA of ship: 300 m
- Beam of ship: 32 m
- Ship GT: 75,000
- Added staterooms with new mid-body section: 120
- Total staterooms after elongation: 1,120
- Engines before retrofit: 4 x MAN 12V48/60 at 12,600 kW
- Engines after retrofit: 4 x MAN 12V51/60 DF at 11,700 kW

The total weight was assumed to be 5,000 mt and the required steel was assumed to be 3,000 mt, which includes the outfitting, hull structure and required reinforcement.

The LNG system includes all the necessary equipment from the bunker station to the engine.
High Level Cost Estimate of Retrofit
The parameters that have not been included in the cost estimate:

- The cost of having the ship off-hire as the daily income per passenger is a very case-specific parameter and depends upon each company’s business strategy.
- For simplicity, the operational cost of the LNG system has been assumed to be equal to that of the diesel equivalent version of the ship.
- The transportation cost of the equipment (LNG tanks and systems and scrubber system).
- It is assumed that refit is used for energy optimisation. Therefore the energy consumption is reduced to a level which can be covered by the DF engines.
Assumptions:

- LNG Price: $14/MMBtu (12.5% below HFO price)
- MDO Price: $25/MMBtu ($1,000/ton)
- HFO Price: $16/MMBtu ($614/ton)
- Discount rate applied: 8%
- No price increase over time is assumed
- 100% gas mode operation when operating
- The thermal efficiencies of diesel and gas engines are assumed to be identical
- All engines running at the same load point (assumed average load of 50% MCR)
DNV GL Study

ESTIMATES ONLY

NPV of Cumulative added Cost [Million USD]

Indicates payback time of LNG investment compared to Fuel Switch (MGO)

Co-funded by the Marco Polo Programme of the European Union
The pricing of the LNG used above is based on the following rationale.

<table>
<thead>
<tr>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Henry Hub price:</td>
<td>$3-4/MMBtu</td>
</tr>
<tr>
<td>US liquefaction cost:</td>
<td>$5/MMBtu</td>
</tr>
<tr>
<td>Distribution cost:</td>
<td>$3-6/MMBtu</td>
</tr>
<tr>
<td>Total final price spread of LNG:</td>
<td>$11–15/MMBtu</td>
</tr>
</tbody>
</table>
Thank you