LNG – An Alternative Ship Propulsion Fuel

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In the wake of strict environmental norms and increased bunker prices, this article looks into LNG as a ship propulsion fuel used for a RoRo new building at Bharati Shipyard. It highlights the available regulations today for such ships and the benefits ship owners can derive in terms of environment, auxiliary machinery, engine room comfort and equipment maintenance.

1.0 Ship operations worldwide have been influenced by two visible changes in the last few years.

a) Increase in price of bunkers
b) Stricter environmental norms

1.1.1 On the first account, ship owners have seen soaring bunker prices. The bunker costs which remained at a steady 100$ plus per metric tonne between 2000 and 2005, has increased 6 folds in the last months.

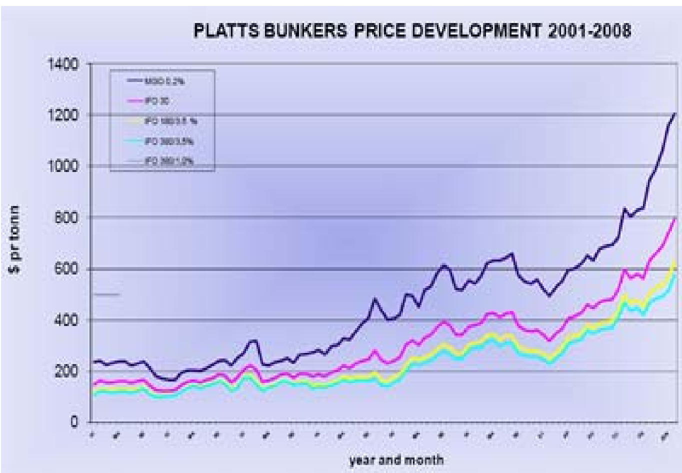


Figure 1

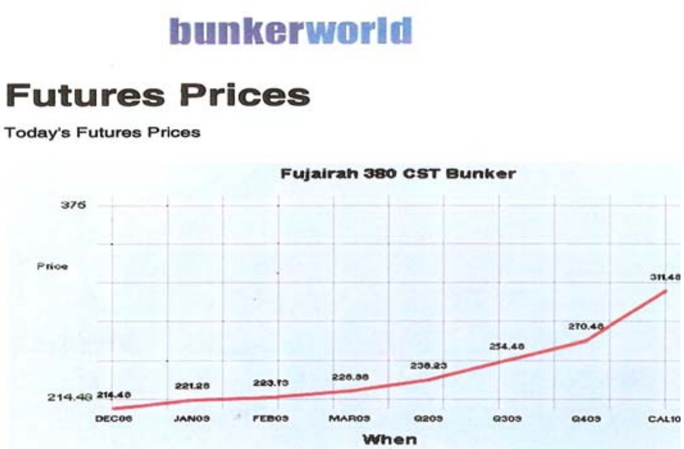


Figure 2

1.1.2 While present day prices are ruling at 200$ plus per metric tonne, the world outlook show that oil prices because of it's shear demand have to start climbing again. This will no doubt lead to increase in bunker prices. Some future trends in bunker prices have been shown in figure 2..

1.2 On the second account, the International maritime organization has been tightening the levels of Nox and Sox emissions from ships.

These requirements are more stringent for vessels plying in the SECA and owners are faced with various options on reducing emissions, by means of low sulphur fuels, catalytic converters etc. Tables 1 & 2 below, point out to challenges the ship owners have to face.

Table 1

Future control of sulphur oxide (SOX) and particulate matter (PM) emissions – revised MARPOL Annex VI.

For SOx Emission Control Areas (currently the Baltic Sea and the North Sea):

Date	**Maximum allowable sulphur content**
Before July 1, 2010	1.50% m/m
On and after July 1, 2010	1.00% m/m
On and after January 1, 2015	0.10% m/m

For all other areas:

Date	**Maximum allowable sulphur content**
Before January 1, 2012	4.50% m/m
On and after January 1, 2012	3.50% m/m
On and after January 1, 2020	0.50% m/m*

* A review, to be completed by 2018, will establish whether this grade of fuel oil will be available. If not, this implementation date may be changed to January 1, 2025.

Table 2

Future control of nitrogen oxide (NOx) emissions from marine diesel engines

For ships built between January 1, 2000, and December 31, 2010 (Tier I limits):

- 17 g/kWhr when *n** is less than 130 rpm
- 45.0 x $n^{(-0.2)}$ g/kWhr when *n* is less than 130 rpm or more, but less than 2,000 rpm
- 9.8 g/kWhr when *n* is 2,000 rpm or more

These are the current MARPOL Annex VI, Regulation 13 limits.
**n* = rated engine speed (crankshaft revolutions per minute)

For ships built between January 1, 2011, and December 31, 2015 (Tier II limits):

- 14.36 g/kWhr when *n* is less than 130 rpm
- 44.0 x $n^{(-0.23)}$ g/kWhr when *n* is less than 130 rpm or more, but less than 2,000 rpm
- 7.66 g/kWhr when *n* is 2,000 rpm or more

These figures represent a reduction in NOx emissions of about 15%, and are based on what engine manufacturers believe can be achieved through adjustments within the engine.

For ships built after January 1, 2016 (Tier III limits):

- 3.4 g/kWhr when *n* is less than 130 rpm
- 9.0 x $n^{(-0.2)}$ g/kWhr when *n* is less than 130 rpm or more, but less than 2,000 rpm
- 1.96 g/kWhr when *n* is 2,000 rpm or more

When operating outside a SECA, the Tier II limits will apply.

Operation within a designated SECA will require the use of exhaust gas treatment systems, such as selective catalytic reduction (SCR) devices.

2.0 One such fuel which fits the IMO levels for NOx and SOx is Liquefied natural Gas (LNG). Figure 3 below, shows where a gas engine is in terms of emissions against statutory requirements.

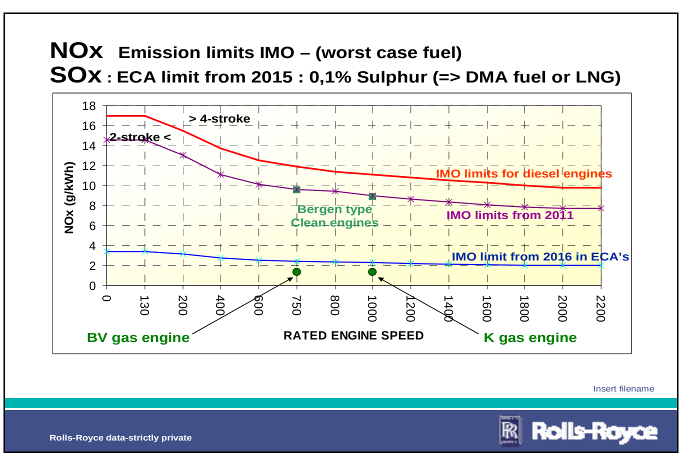


Figure 3

Similarly typical bunker consumption comparisons are highlighted in figure 4.

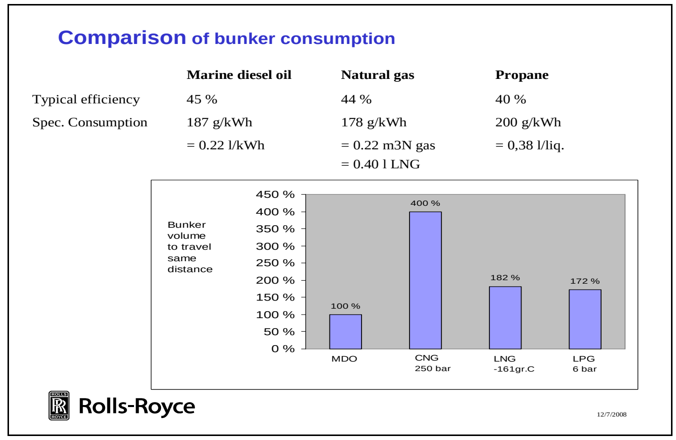


Figure 4

Emissions for CO2, SOx, NOx and Particulate are illustrated in the following graphs. It may be noted that CO2 emission reduction is at 23%, SOx and Particulate reduction at 100% and NOx reduction at 92% as shown in figure 5.

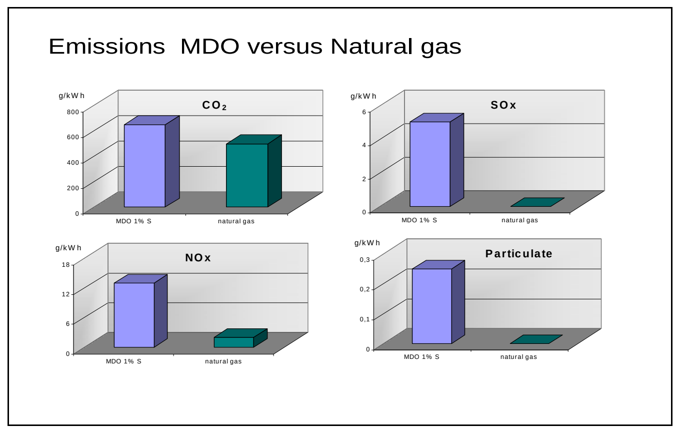


Figure 5

2.1 In addition to above facts, the following events now lead ship owners to seriously look at LNG as an alternative propulsion fuel for short endurance vessels.

a) Introduction of specific regulations for gas fuelled engine namely:
IMO International code of safety for gas –fuelled engine installation in ships: Interim guidelines on safety for gas-fuelled engine installations in ships dated 25 April 2007

b) Incentives from Governments especially in Europe to operate gas ships.

c) Ability of ship owners to clinch long terms contracts for providing bunkers from Gas operators.

2.2 At Bharati Shipyard, we have continuously looked at these opportunities and are now building this first ever gas propelled ship for Sea Cargo A/S, an operator of Ro Ro vessels in Norway.

2.3 These Ro Ro vessel, 138 m in length will ply within European routes and have endurances of about 10 days. The vessels typically have 3 cargo decks, namely
a) Tank top
b) Main deck
c) Weather deck
This is shown in the figures 6 & 7 below.

Figure 6

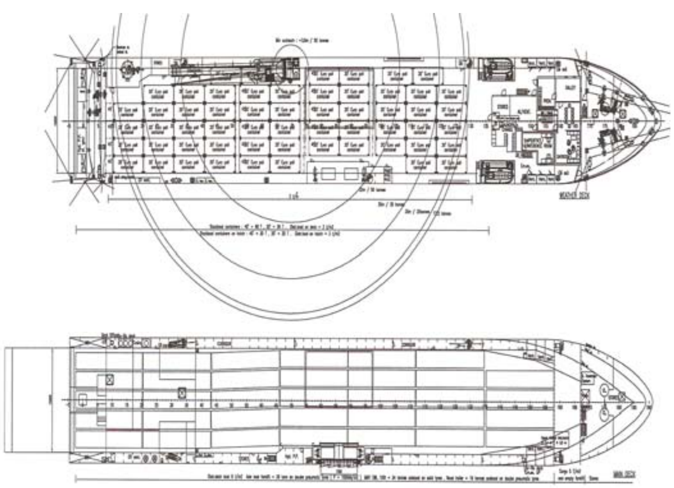


Figure 7

As can be seen Ro Ro cargo is driven through the stern ramp on the main deck and can be transported to the weather deck and tank top using fixed or hoistable ramps.

Similarly Pallet cargo can be loaded through the side ramp. The pallet elevators working together with Fork lift trucks position pallets at their respective location on either the tank top or main deck.

Cargo/ containers on weather deck can be loaded by a 50 T crane.

2.4 Considering the above, a ship owner aims at optimising cargo space, in terms of the following

a) Stack loads,
b) Stack heights
c) Deck area.

The engine room heights and steering gear heights below the main deck are therefore significantly reduced to cater for the required stack heights.

Similarly spaces for engine silencers, boilers, exhaust pipes are severely restricted, to cater for larger deck width in the Ro Ro decks as can also be seen in figure 7.

2.5 While it would seem, that advantages with respect to a LNG propelled engine version would only be in terms of improved emissions, the advantages gained from reduction in number of engine room equipments and engine room tanks would lead to comfort in working in such engine rooms.

3.0 The following paragraphs, highlight the effect of changes on the design and construction of the vessel because of a LNG propelled engine.

3.1 Propulsion: The propulsion comprises of Non-reversible, turbocharged in line marine medium speed natural gas engine. The engine is connected to a gearbox and controllable pitch propeller and obtains fuel from LNG tank installation.

As of now, gas as a fuel in ships other than LNG carriers is not yet covered by International conventions and such installations will need additional acceptance by flag authorities.
However IMO has issued Interim rules, stated as **"Interim guidelines on safety for gas fuelled engine installations in ships"** and apply to internal combustion engine installations in ships using natural gas as fuel. The engines may use either a single fuel (gas only) or dual fuel (gas and fuel oil) and the gas may be stored as compressed natural gas (CNG) or liquid natural gas (LNG)

3.1.1 Two alternative system configurations are referred to by IMO and Class Societies:

a) ESD (emergency shutdown) – protected machinery spaces: Arrangements in machinery spaces are such that the spaces are considered non- hazardous under normal conditions, but under certain abnormal conditions may have the potential to become gas hazardous.
b) Inherently safe – gas safe machinery spaces: Arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions i.e. inherently gas safe.

3.1.2 As far as gas tank storage both gases of the compressed (CNG) and the liquefied type (LNG) are accepted for storage above deck level. The storage tanks or tank batteries shall be located at least B/5 from the ship's side.

For vessels other than passenger vessels a tank location closer than B/5 from the ship side may be accepted and approved by classification society, on a case by case basis.

For Gas fuel storage below deck the following regulations exist :

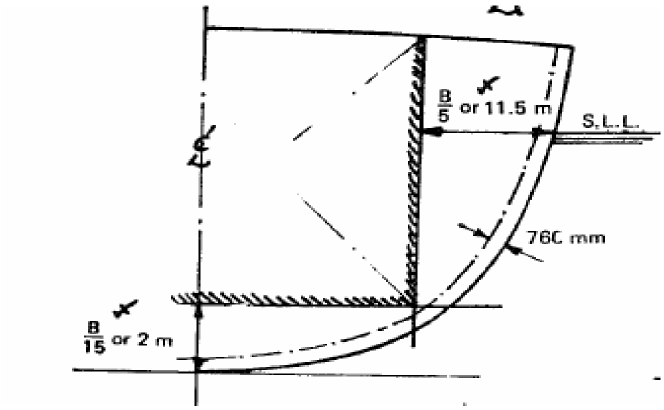


Figure 8

- Minimum, the lesser of B/5 and 11.5 m from the ship side
- Minimum, the lesser of B/15 and 2 m from the bottom plating
- Not less than 760 mm from the shell plating. This is illustrated in figure 8 above.

3.1.3 For single main engine installation configurations *"Inherently gas safe machinery spaces"* requirements must be followed. As a result

a) All gas supply piping within machinery space boundaries and elsewhere in closed spaces must be enclosed in a gas tight enclosure, i.e. double wall piping or ducting.

b) In case of leakage in a gas supply pipe, having shutdown of the gas supply is necessary, and a secondary independent fuel supply must be available.

c) For single fuel installations (gas only) the fuel storage shall be divided between two or more tanks of approximately equal size.

d) For "Gas Only" engines, the two fuel gas supplies shall be independent all the way from the storage tanks to the engine.

e) For "Gas Only"- engines if completely segregated gas supplies to the main engine is not possible, a secondary power either 40% of installed power or according to classification rules can be provided. The emergency propulsion system power capacity shall be such that it, as recovered after any failure will enable the vessel to maintain a speed of not less than 7 knots except for single failures in acceptable common components.

In addition, the emergency propulsion system power capacity shall be such that it, as recovered after any failure, will enable the vessel to remain in position in wind speed of 17 m/s (33 knots) and significant wave height of 4.5 m (15 ft) with 7.3 seconds mean period, both of which are acting concurrently in the same direction, except for single failures in acceptable common components.

3.2 Accordingly on the vessel being built the following configuration has been provided:

- LNG tanks : Hamworthy LNG tanks 2x216 m³. Length:17m and Diameter:5 m
- Main Engine: RR Bergen Engine B35:40 12P-G, MCR 5250 kW / 750 rpm
- Reduction gearbox: RR 3000 AGHC K 560
- Shaft generator/motor: ABB 1400 kW / 1800 rpm
- Propeller system : RR Kamewa CPP with prop diameter 4,2 m /4 bladed.
- Rudder : RR FM 3000x4100
- Steering engine : RR SV430-2FCP

A diagrammatic illustration is shown in figure 9 below.

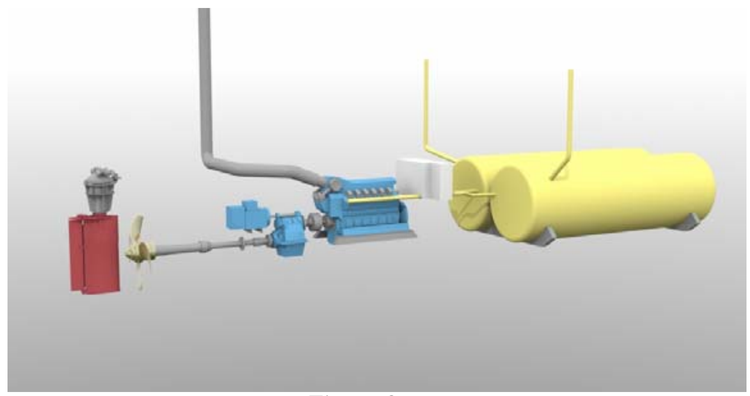


Figure 9

3.3 To meet the requirements of emergency propulsion, the auxiliary engine capacity has been enhanced to 720 KW and the shaft generator has a PTI capability, enabling the vessel to have a speed of over 7 knots, when propelled with such emergency power.

This additional generator capacity can be used for additional reefer containers to be carried.

4.0 Gas System: The LNG system as a whole comprises of 2 independent fuel system including 2 tanks, 2 tank room and 2 bunkering stations.

The LNG being used comprises of Methane (94%), Ethane (4.7%), propane (0.8%), Butane (0.2%) and Nitrogen (0.3%). It may be noted that no definite standard exist as per IMO Interim Guidelines on Safety for Natural Gas Fuelled Engine Installations in Ships.

Methane characteristics are as under:

Liquid density	: 430 kg/m3
Gas density at 1 barg, - 163 deg C	: abt. 1.6 kg/m3
Gas density at 1 barg, 40 deg C	: abt. 0.6 kg/m3
Boiling temperature at 1 barg	: - 163 deg. C
Boiling temperature at 10 barg	: - 130 deg. C
Volume reduction from gas to liquid	: 600 to 1
Critical temperature	: - 82 deg. C

4.1 Relative to heavier hydrocarbons (HCs) it has wider flammable range (5 – 15 vol.%), higher ignition temperature (540 deg C), less CO_2 emission (one mole CO_2 per mole methane) and is less reactive.

Each system includes the LNG tank, heat exchanger and control valves working independently of the other and designed in a way that failure of one of the two system would enable to run the ship on the other one.

In addition, there are two evaporators installed in each tank room which are designed for redundant operation, a larger one feeding directly the fuel line, and a smaller one designed to hold the pressure and acting as a pressure build up unit (PBU) in the tank.

During normal operation the two systems are independent from each other. The pressure holder has to supply vapor to the tank to ensure that pressure will be kept constant, while the main evaporator produces the vapor that is sent to the heater and from the heater to the engines.

4.2 Storage of LNG: LNG is stored in an Independent tank type C and has a pressure of 7-10 Bar G. However in line with DNV Rules & Regulations for Gas fuelled engine installation and based on it’s location, the tanks are located within a secondary barrier.

The annulus space between the inner and outer tank is filled with perlite and maintained at vaccum. However at 0.25barg pressure, the pressure transmitted monitoring the annulus pressure shall activate shut down of all tank valves and activate depressurizing of the inner tank down to atmospheric pressure.

Figure 10 below highlights the arrangement of the tank, secondary barrier and the associated equipment.

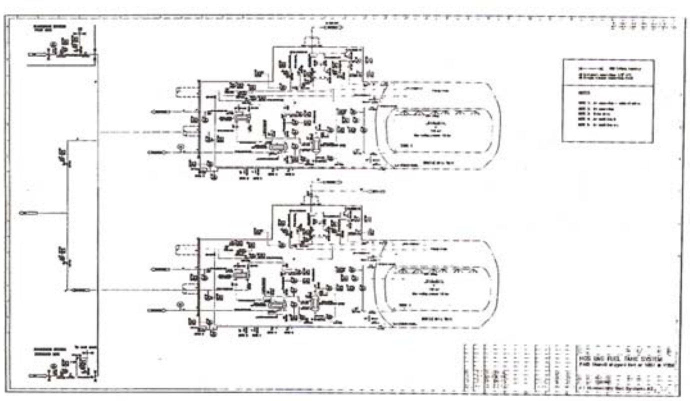


Figure 10

4.3 Any gas leakages can be detected in a relatively short time. A leakage from the inner tank will result in a pressure build up in the outer shell that is designed to stand up to 4 bar pressure. Both inner and outer tanks are build from SS 304 to withstand low temperatures. In such a event the surrounding tank top structure will also cool down, because of which the tank top structure in way of the saddles is to be made of fully killed aluminium treated fine grain carbon-manganese steel.

Similarly leakages from LNG/ NG lines in the tank room, and internal leakage through any of the 3 heat exchangers can be detected.

Since the two fuel systems are completely independent up to the engine gas regulation unit, in the event of a fuel leakage in either gaseous of liquid state, the operator will be able to identify which of the two fuel systems is affected.

At first, the two regulating valves will be closed and will ensure that the evaporators will stop operating and the tank will be completely isolated from the rest of the system and will only be connected to the Pressure Safety Valves.

4.4 Other LNG fuel tank system functions include:

4.4.1 Bunkering of LNG from both bunkering stations to both tanks through on shore terminals (See figure 11 & 12).

Figure 11

Figure 12

At the end of the filling, correct pressure in the tank must be established by running the pressure build up unit. The bunker lines must be inerted after bunkering operations, with Nitrogen bottles, available on the ship. The location of the bunker stations on the ship are shown in figure 13 & 14.

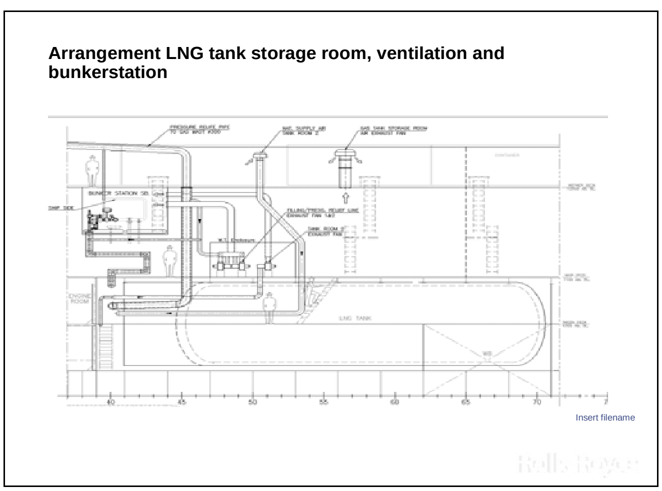


Figure 13

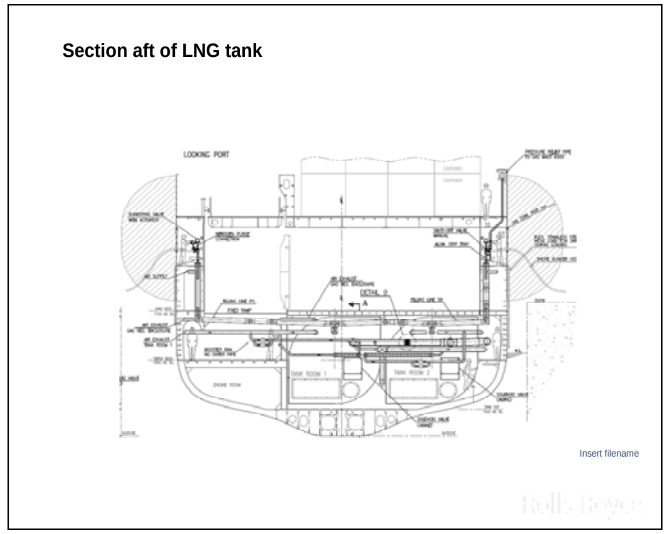


Figure 14

4.4.2 Evaporation, Heating and Supply of LNG to main engine: The pressure in the LNG tank is kept constant at approximately 7.5 bar despite the amount of liquid stored in the tank. During normal operation this is achieved by a dedicated heat exchanger that evaporates LNG and feeds NG back to the top of the tank. This evaporator will be called "pressure build up unit"
In parallel and independently from the pressure build up unit, a second evaporator produces enough vapour flow to feed the engine gas control unit. From this evaporator, gas is brought to a heater that increases vapour temperature to a level acceptable for the engine (approximately 30 C).

Control of the mass flow to the engine is achieved in the gas regulation unit (GRU). The GRU regulates the gas feed to the engine and therefore also the flow through heater and main evaporator.

A block diagram explaining the above is as shown in Figure 15 & figure 16.

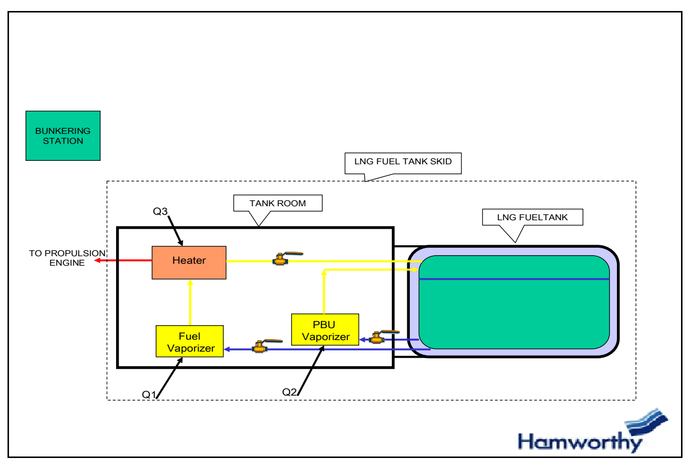


Figure 15

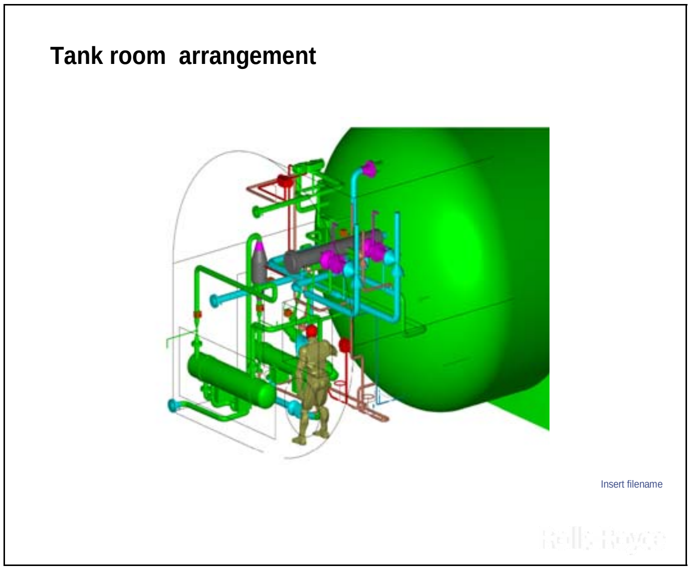


Figure 16

4.4.3 Relief from tank and associated piping: Pressure safety valves for tank inner and outer shell, main evaporator, fuel gas lines, bunkering line have been identified to be protected against pressure build up. Since the complete fuel system includes two independent fuels tanks, each fuel tank system will have a separate but identical set of pressure valves. The two systems will however share a common vent mast.

An arrangement of the gas equipments and engine room arrangement is shown in figure 17 & 18.

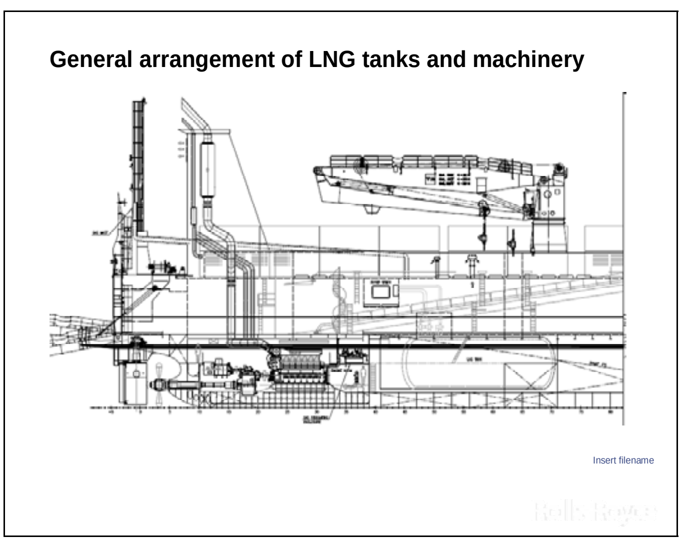


Figure 17

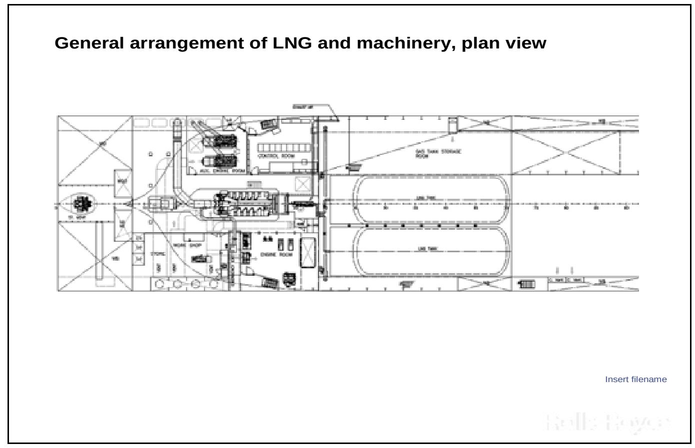


Figure 18

4.5 Thus ship system interfaces would comprise of LNG from tanks, Fuel gas (NG) to Engine Room, Bunkering lines, Relief and depressuring lines for Tank Room & LNG/NG system, Ventilation air supply/discharge for Tank Room and Double barrier piping, Instrument air supply, Nitrogen supply, Control and monitoring system of valves and instruments (pressure transmitter, gas detector etc.)

5.0 Engine Room equipment: As a consequence of carrying LNG, several equipments can be deleted when compared to a typical diesel engine installation. The engine room arrangement is as shown in figure -----.

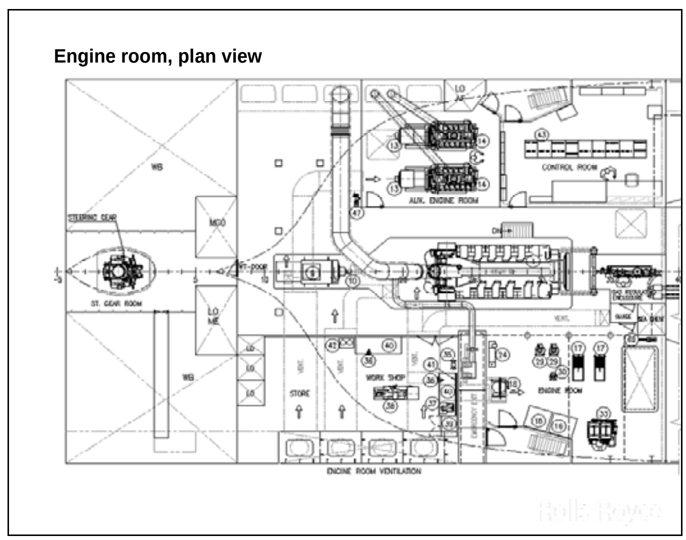


Figure 19

The list of equipments that can be deleted are:

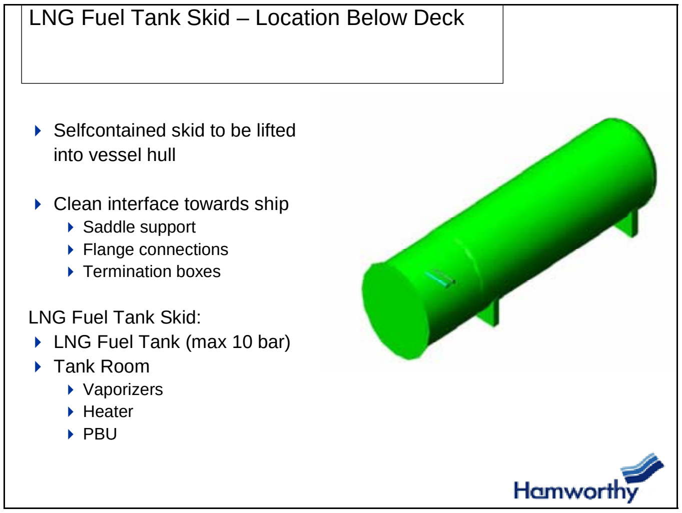
a) Boilers
b) Heavy Fuel oil purifiers
c) Heating coil in Heavy fuel oil tanks
d) HFO booster units
e) Steam tracing of fuel oil pipes
f) Pumps based on deletion of boilers and heavy fuel oil purifiers

6.0 Tank arrangement: As a consequence of carrying LNG, few tanks can be deleted from the engine room when compared to a typical diesel engine installation: They comprise the following:

a) HFO storage
b) HFO settling and service tanks
c) Boiler hot well
d) Sludge tanks for heavy fuel oil separators.

7.0 Installation and Maintenance:

7.1 The complete gas tank comes as a skid as shown in the figure 20 below.



Similarly bunkering skid is supplied as a complete installation for easy of fitment on board.

7.2 The reduced equipment would allow for reduced maintenance schedules for owners and eliminate dealing with heavy oil and steam, required for conventional diesel engine propelled vessel.

In addition a gas engine provides for a cleaner engine, with reduced wear, reduced lube oil consumption and longer change intervals.

7.3 Both the yard and the owners must however prepare itself for safe operations to be carried out on board and at site. Suitable hazard study in the location, for good practice compliance is required to be carried.

Conclusions:

While there is an additional investment to be made by owners towards gas equipments, there are significant advantages, owners may expect, especially by complying to present & future emission norms and eliminating heavy fuel oil bunkers.

The configurations in which the equipment is available, helps owners in mitigating risks involved with a gas installation. Associated gain in terms of reduced maintenance should also be looked at while considering a LNG fuelled version.

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