First LNG Bunkering Vessel to Supply the LNG Bunkering Market from Zeebrugge

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1) General

In January 2015, new regulations decided by the International Maritime Organization (IMO) in 2008 for the shipping industry regarding air emissions became fully applicable: sulfur oxide emissions released by ships’ exhaust gas which was already limited to 1% since July 2010 now has to be lower than 0.1% since January 2015 in Northern European waters (North Sea, Baltic Sea and English Channel), and along the United-States and Canadian coasts. In July 2016, MARPOL Tier III requirement on NOx emissions to be reduced by 80% will enter into force in North American and US Caribbean ECA zones.

More regions are considering implementing similar Emission Control Areas, but eventually a cap on the sulfur emissions of ships will be implemented worldwide in 2025 at the latest1.

1 Depending on the result of a final availability review

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To comply with these requirements, only few solutions are available and using Liquefied Natural Gas (LNG as marine fuel is one of the options cumulating the most advantages on a long-term basis, in terms of air pollutant emissions and greenhouse gas reduction).

LNG bunkering is not a new concept as it has been developed in Norway for many years, but it has been brought to a different level by the teams of ENGIE together with its partners Nippon Yusen Kaisha (NYK) and Mitsubishi Corporation when announcing the order of the first LNG Bunkering Vessel on June 30th 2014.

The main challenge for the development of LNG bunkering being the availability and the distribution of LNG, in a way comparable to existing fuel oil bunkering infrastructures, an innovative and entrepreneurial view was required to overcome the famous chicken and egg situation.

It was consequently decided by ENGIE to partner with reliable and strong companies to develop this first project, and order the first LNG Bunkering Vessel of this dimension.

After having explained why and how this partnership has been structured, the paper will describe the first LNG Bunkering Vessel ordered to the Korean shipyard Hanjin Heavy Industries & Construction, classed by Bureau Veritas, and how the vessel differs from a small and standard LNG carrier.

When the LNG Bunkering Vessel will be delivered in the second half of 2016, it will be possible for ship operators in Northern European waters, and especially the ones calling the port of Zeebrugge and other ports in its vicinity, to rely on a credible solution of LNG as bunker fuel to both reduce their pollutants and greenhouse gas emissions and to limit the cost impact of this new regulation.

In parallel with the development of the ship specification, the required authorizations to perform the LNG bunkering operations in the port of Zeebrugge have been granted by the Zeebrugge Port Authorities following a risk and safety analysis.

Finally and in parallel with the order of the LNG Bunkering Vessel, a medium term contract has been signed with the ship owner United European Car Carriers to supply LNG in the port of Zeebrugge to its two new dual fuel car carrier ships that will operate in the North Sea and the Baltic Sea from the
second half of 2016; the paper will also cover the technical and commercial challenges of this new business activity for the LNG industry.

LNG as bunker fuel market is estimated to reach 30 million tons per year by 2025-2030 worldwide, representing almost 10% of today's LNG global production; the volumes at stake are consequently considerable and justify the involvement of ENGIE, NYK and Mitsubishi Corporation in the development of this new industry. The order of this LNG Bunkering Vessel is then a first step that will bring economical and environmental benefits to the shipping community.

2) LNG as fuel market

As one of the leading Class societies in LNG as cargo and LNG as fuel market, Bureau Veritas sees a wide interest and a large diversity in the use of LNG as fuel. The scope of LNG as fuel ships extends from ferries (RoRo and passengers ferries, either new constructions or retrofits) to dredgers, tugs, tankers of different sizes and products, container feeders, etc. If some years ago the market was limited to vessels confined in ECA or SECA areas, new projects have been signed recently in Spain for passenger ferries operating in Mediterranean sea and large Passengers cruise ships. A new era for LNG as fuel has started.

3) Bunkering Vessel description

2.1) Main dimensions

- LOA = 107.6 m
- Breadth = 18.4 m
- Draft design = 4.7 m

2.2) LNG bunker fuel capability

There are two Type C cargo tanks for a total tank volume of 5000 m³ at 98% filling ratio under atmospheric pressure.

2.3) Propulsion / Manoeuvrability

- Service speed ~ 13 knots
- Dual fuel engines (LNG + MGO)
- Propulsion system allowing maximum maneuverability: twin shafts and 2 bow thrusters

2.4) Bunkering system

- Max bunkering rate 600 m³/h

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- Redundancy of LNG pumps
- Manifolds at mid ship and fore part
- Cranes + flexible hoses

4) **LNG as fuel regulation**

Regarding the LNG as fuel regulation for merchant vessels, many initiatives have been raised recently on LNG as fuel. First of all, the IGF code has been adopted recently. It will enter into force on January 1st 2017. We will have the benefit of a binding regulation that will avoid discrepancy in designs of LNG as fuel ships.

In addition to the prescriptive requirements of the code, a Risk Analysis on the design of such vessels is compulsory and is aimed to cover the additional risks added by the use of LNG as fuel compare to classic fuel oil.

The LNG bunkering vessels are also now benefitting of a specific notation from BV associated with a Rule Note BV NR620. This is the case for the Bunkering Vessel developed by ENGIE, NYK and Mitsubishi Corporation. The BV NR620 covers the ship design (already compliant with IGC Code) and the bunkering transfer installation onboard.

The LNG transfer equipment shall also comply with ISO standards such as 1474-2. Flexible hoses and ERC valves shall fulfill requirements from the Class.

Other standards are under development at ISO level, at the ESSF and USCG working groups. This the case in particular of new standards under preparation concerning LNG bunkering such as

- Equipment and procedures for LNG when used as fuel for marine, road and rail activities
- Safety and security on LNG installations
- Resistance to cryogenic spillage
- LNG specific equipment
- Offshore installations for LNG production or regasification

In addition LNG data and equipments, such as the one related to LNG quality and quantity and their measurements will be concerned by specific ISO standards under development.

5) **Comparison of risks associated with LNG as fuel versus Fuel Oil**

<table>
<thead>
<tr>
<th>Hazards</th>
<th>LNG</th>
<th>Fuel oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryogenic Burns</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Liquid contact with skin will cause burns and can result in fatality. Inhalation of gas can cause burns to the lungs and lead to fatal injury.</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Low Temperature Embrittlement</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Equipment/structures can fail on contact with liquid.</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Rapid Phase Transition (RPT)</td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td>Released onto the sea a near instantaneous ‘explosive’ transition from liquid to gas can occur. This can result in structural damage to the hull.</td>
<td>✓</td>
<td>x</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th></th>
<th></th>
<th>✓</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gas Expansion</strong></td>
<td>A liquid pool rapidly boils, and as the gas warms and expands it requires a volume 600 times that of the liquid. This can result in equipment damage.</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td><strong>Asphyxiation</strong></td>
<td>In a confined space, displacement and mixing of the gas in the air will reduce oxygen content and can cause asphyxiation.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Pool Fire</strong></td>
<td>Gas/vapour above the pool can ignite resulting in a pool fire. The intensity of the radiation can cause fatal injury and fail structure and critical equipment.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Flash Fire</strong></td>
<td>Gas/vapour can disperse away from the pool and ignite resulting in a flash fire. The short-duration and intense radiation can instigate secondary fires, and cause fatal injuries to those within the fire and to critical equipment. Most probably the fire will burn back to the pool and result in a pool fire.</td>
<td>✓</td>
<td>X&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Explosion</strong></td>
<td>Gas/vapour can disperse and collect in confined areas and ignite resulting in an explosion. The explosion can cause fatal injuries, instigate secondary fires, and fail structure and critical equipment. Most probably the explosion will burn back to the pool/gas source and result in a pool fire or jet fire.</td>
<td>✓</td>
<td>X&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Rollover</strong></td>
<td>Stored liquid can stratify, that is different layers can have different densities and temperatures. This can cause the layers to ‘rollover’ resulting in significant gas/vapour generation that must be contained. If released, this can result in flash fire or explosion.</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td><strong>Boil-off Gas (BoG)</strong></td>
<td>LNG continually boils and must be re-liquefied or burnt-off. A release of BoG can ignite and result in a jet fire (given sufficient release pressure), flash fire or explosion.</td>
<td>✓</td>
<td>X</td>
</tr>
</tbody>
</table>

6) **Technical requirements for bunkering systems**

The LNG / vapour transfer system should be designed and the bunkering procedure carried out so as to avoid the release of LNG or natural gas. The transfer system shall be designed such that any leakage from the system cannot cause danger to personnel, the receiving ship, the bunkering facility or the environment. Where any spillage of LNG can occur provisions shall be taken to contain the leakage and protect personnel and equipment from cryogenic hazards. The consequences of other fuel related hazards (such as flammability) shall be limited to a minimum through the arrangement of the transfer system and the corresponding equipment.

The environmental aspect should be carefully addressed: release of natural gas to the atmosphere during normal operations should be avoided, specific means should be provided to purge the lines efficiently without release of natural gas with all purged gasses either retained by the receiving ship or returned to the bunkering facility.

Accidental leakage from the LNG / vapour transfer systems including the connections with the receiving ship bunkering manifold and with the bunkering facility should be detected by appropriate means.
Hoses should comply with the requirements of IGC/IGF Codes and EN 1474-2; EN 12434 and BS 4089 standards. An enhanced type approval against a recognised industry standard for offshore flexible hoses should also be considered.

Transfer hose manufacturer's instructions, regarding testing and number of temperature and pressure operating cycles before removal from service, should be strictly followed.

Depending on which party owns the bunkering hose, a document should be included in the LNG Bunker management plan and a copy kept on board the LNG bunkering vessel.

- Hose identification number
- Type approval certificate
- Date of initial entry into service
- Initial test certificate and all subsequent test reports and certificates

The cryogenic hose should be subjected to hydrostatic testing once a year, if any defects appears during this inspection, the hose should be replaced. In addition the manufacturer of these hoses may lay down requirements relating to service life, inspection and maintenance. The manufacturer's instructions should be followed.

Pressure relief devices should be provided so that the hose or loading arm is not over-pressurised in the event that liquid is trapped between its isolating valves.

7) LNG Bunkering regulation

The LNG transfer operation is normally controlled by the Port Authority, through bunkering check list and Bunkering guidelines.

Recently, IACS has published its own LNG bunkering guidelines and this document has been made available to the industry. Specifically the Risk Analysis covering the LNG bunkering operation is described for a better understanding and for homogenization of the Risk Analysis existing methodologies.

8) Description of a typical LNG bunkering operation
9) **Risk analysis for LNG bunkering operation**

A bunkering operations risk assessment should be undertaken in accordance with ISO/TS 18683. This technical specification is specific to the supply of LNG as fuel to ships and refers to recognised standards that provide detailed guidance on the use and application of risk assessment. The objectives of the bunkering operations risk assessment are to:

- Demonstrate that risks to people and to environment has been eliminated when possible, and if not, mitigated as necessary, and
- Provide insight and information to help set the required safety zone and security zone around the bunkering operation.

In order to meet these objectives, as a minimum, the bunkering operations risk assessment should cover the following operations:

- Preparations before and on ship’s arrival, approach and mooring
- Preparation, testing and connection of equipment
- LNG transfer and boil-off gas (BOG) management
- Completion of bunker transfer and disconnection of equipment

Whether only a Quantitative Risk Assessment (QRA) is required or both a Qualitative Risk Assessment (QRA) and QRA are required, as a minimum the risk assessment should detail:

a. How the bunkering operation could potentially cause harm. That is, systematic identification of potential accidents/incidents that could result in fatality or damage to the environment;

b. The potential severity of harm. That is, the worst case consequences of the accidents/incidents identified in ‘a’, in terms of single and multiple fatalities and environmental damage caused;

c. The likelihood of harm. That is, the probability or frequency with which the worst case consequences might occur;

d. A measure of risk, where risk is a combination of ‘b’ and ‘c’; and

e. How the functional requirements are met.

In addition, the risk assessment should help identify the scenarios to be used to determine the safety zone; and as a minimum, consider SIMOPS within the safety zone.

A typical approach to QRA and QRA is described in ISO/TS 18683. These approaches or similarly established approaches should be used provided they cover a-e above.

The acceptance criteria should be agreed with the Administration.

Regardless of the approach used it should be applied by a team of suitably qualified and experienced individuals with collective knowledge of, and expertise in: risk assessment application; engineering design; emergency response, and bunkering operations.

10) **Safety and security zones**

A safety zone and a security zone should be established around the bunkering operation in accordance with ISO/TS 18683. These zones are in addition to the established practice of setting
hazardous area classification zones that will be required around areas with potential for explosive atmospheres such as the bunkering connections. Both the safety and security zones should be enforced and monitored at all times during bunkering, at all other times these zones are not enforced.

The purpose of the safety zone is to set an area within which only essential personnel are allowed and potential ignition sources are controlled. Essential personnel are those required to monitor and control the bunkering operation. Similarly, the purpose of the security zone is to set an area within which ship/port traffic is monitored and controlled.

Together, the safety and security zones help further minimise the low likelihood of a fuel release and its possible ignition, and help protect individuals and property via physical separation.

11) LNG Bunkering Management Plan

A LNG bunker management plan should be established in order for the involved parties to agree technically and commercially on methodology, flow rate, temperature, pressure of the delivery of LNG and receiving tank. This plan gathers together all the information, certificates, procedures, and checklist(s) necessary for an effective and safe LNG Bunkering operation.

The LNG Bunker Management Plan should be included in the ISM of the RSO.
12) **Quality and quantity testing challenges**

LNG bunkering also differs from oil bunkering in that LNG is an evaporating liquid and the energy content in a same volume can differ depending on the LNG origin. A major challenge is to be able to measure the quality and the LNG transferred from a ship to another one.

LNG as marine fuel has then to be sold in terms of energy delivered. This means that both the quantity and the quality of the product transferred from the bunkering vessel to the LNG fuelled vessel has to be determinate.

In the LNG bulk industry, methods have been already developed for unloading an LNG tanker into an LNG terminal. These methods, known to be robust, redundant and easy to implement, can generate confidence from both sellers and buyers. For these reasons, ENGIE, NYC and Mitsubishi Corporation decided to apply them in the same way for the LNG bunkering.

The method consists in three steps:

**Step #1: determine the net volume transferred (m³)**

- Gauging the level of LNG in the tanks of the bunkering vessel before and after bunkering operation with a radar and /or float level gauge
- Correcting for movement of the ship using trim and list tables
- Measuring LNG and vapor temperature and pressure before and after the transfer

**Step #2: determine the gross heating value (kWh/kg)**

- In parallel, a gas chromatograph on board the bunkering vessel connected to a small vaporizer provides the composition of LNG delivered
- The LNG gross heating value (GHV) is directly derived from the composition

**Step #3: density (kg/m³)**

LNG density is calculated based on the composition of the LNG at the LNG temperature (around −160 °C), according to the revised Klosek MacKinley calculation method published in the NBS (National Bureau of Standards) Technical Note in December 1980.
Then, the quantity of energy sent to the client vessel through the LNG loading hose is by definition, the result of the multiplication of the volume, the gross heating value and the density.

The bunker delivery notice can be handled to the captain of the client vessel a few minutes after the disconnection of the hoses and in case of dispute, sealed cylinders containing gas samples are kept by both the bunkering vessel and the client vessel.

Particular case of the Methane Number

It appears that manufacturers of gas engines use the so-called methane number (MN) for specification of gas quality requirements. MN characterizes the tendency of gas spark ignition engine and the knock resistance.

There is not yet a standardized method for determining it, but for the sake of simplicity, this article reckons three different methods for calculating the methane number.

The three methods for MN calculation are well correlated with LNG density as shown in the below table.

![Graph showing relation between methane number and LNG density.](image)

In the future, the question will arise whether MN or, density, an universal and measurable physical quantity, is the most relevant criteria for LNG bunker specifications?

13) LNG Bunkering Vessel BV Notation

The Bureau Veritas Rule Note NR620 address specific requirements for LNG bunkering ships. The specific notation “LNG bunkering ship” includes technical and functional requirements for the LNG transfer system. There are also operational optional suffixes such as:

- RE: LNG bunkering ship with ability to take LNG from a gas fuelled ship if necessary.
- IG-Supply: LNG bunkering ship with ability to provide Inert Gas.
- Initial CD: LNG bunkering ship with ability to provide Initial CD for a gas fuel ship.
14) **Conclusion**

IMO and EU stringer regulations on emissions and price opportunities have established the necessary environment that creates a unique opportunity for triggering the LNG demand within the shipping sector.

The question is not anymore to know if LNG could be a solution but rather how much of the market will be replaced by LNG and further how to best introduce LNG as the preferred fuel.

The main concern in this development will certainly be safety during LNG bunkering operation. LNG as cargo has reached for 50 years an exemplary safety record that has to be maintained in order to protect the whole LNG industry. As always, the stakes are higher than the sole business potential for bunker LNG itself.

In order to be able to develop a sustainable market there are many challenges to overcome but there has not been identified any showstopper. It is essential that all stakeholders from regulators to ship owners to suppliers work together in order to provide a solid and commonly agreed framework that allows LNG to take its share of this new demand to the interest of all involved parties.