FEEDBACK ON THE OPERATION OF THE DUAL FUEL DIESEL ELECTRIC PROPULSION ON LNG CARRIERS: IMPACT OF GAS FUEL QUALITY ON PROPULSION EFFICIENCY

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ABSTRACT

GAZOECAN is the operator of the 3 first built Dual Fuel Diesel Electric LNGC’s: Provalys and GDF SUEZ Global Energy owned by GDF SUEZ, and Gaselys, owned by GDF SUEZ and NYK Line. Dual Fuel Engines of these vessels, delivered from the end of 2006 and to the beginning of 2007 will cumulate early 2013 more than 300 000 running hours. This presentation aims to present the feedback of GAZOCEAN in the operation and maintenance of the DFDE Propulsion including a description of the troubles shooting, the performances, and will focus on the maintenance: performance in Dry Dock of maintenance visits and the improvement of the maintenance plan.

1 INTRODUCTION

LNG is considered by a great number of operators of merchant ships as a solution to comply with the environment rules requirements limiting the air emission in certain trading areas and for some of them as a competitive fuel on an economical point of view.

Therefore, at the present days, not only LNG is used as fuel on board LNG Carriers but as well on a more and more important number of vessels as ferries, tankers, supply vessels, feeders, etc.

Based on their experience, GAZOCEAN and GDF SUEZ as first operator and owner of Dual Fuel Diesel Electric (DFDE) LNG carriers are wishing to share with the industry its feedback on the operation of this propulsion type, focusing on the impact of gas fuel quality on the efficiency of this Dual Fuel Engines.

This paper will firstly describe the DFDE propulsion type; secondly the characteristics of the LNG and the challenges of using it as fuel, which will be illustrated in the last part by GAZOCEAN’s feedback on the operation of the DFDE propulsion.

2 DESCRIPTION OF DUAL FUEL DIESEL ELECTRIC PROPULSION SYSTEM

2.1 The Thermodynamic Otto Cycle

Dual Fuel engines are based on the lean-burn Otto principle which is summarized below:

Two strokes and four strokes marine engines or generators are based on the Thermodynamic OTTO cycle, which consists into two isentropic (reversible adiabatic) phases interspersed between two constant-volume phases.

The diagram below illustrate the thermodynamic working fluid in the cycle which is subjected to an isentropic compression (phase 1–2); a constant-volume heat addition (phase 2–3); an isentropic expansion (phase 3–4); and a constant-volume heat rejection (cooling), phase 4–1.
2.2 Dual Fuel Engines

On gas mode, a lean premixed air-gas mixture is provided by the turbocharger and admitted in the combustion chamber of each cylinder at a low pressure (<5 bar) by a controlled gas admission valve; the mixture is ignited by a small amount of pilot Diesel Fuel (less than 1% of the fuel consumption at nominal load). Injection valve of the gas and pilot fuel can be combined or separate according the makers’ design.

In Diesel mode the fuel is injected at high pressure in the combustion chamber of each cylinder by the conventional injection pump just before the top dead centre. In diesel operation gas admission is deactivated, but the pilot fuel remains activated to ensure reliable pilot ignition when the engine is transferred to gas operation.

In gas mode, the combustion must be closely controlled to prevent knocking and misfiring.

The global air-fuel ratio is controlled by a wastegate valve, which lets some of the exhaust gases bypass the turbine of the turbocharger. This ensures that the global air-fuel ratio has the correct value independent of changing ambient conditions such as the ambient temperature.

The quantity and timing of the injected pilot fuel are adjusted individually together with the cylinder-specific and global air-fuel ratio to keep every cylinder at the correct operating point and within the operating window between the knock and misfire limits.
Therefore, in order to achieve the required accurate combustion control, the gas admission and ignition of cylinder charge is electronically controlled on the Dual Fuel engine. Each cylinder is equipped with:

- electronically controlled valves,
- one gas admission valve for the gas injection into air intake channel,
- one pilot injection valve for the ignition.

The control of injection is handled by the Engine Control System.

**Figure 3 – Lean Burn Combustion**

**Figure 4 – Engine Control System - Source Wärtsilä**

### 3 GAS FUEL SUPPLY CHAIN

#### 3.1 Description of the Gas Fuel Supply Chain

The diagram below summarized the gas supply chain of the Dual Fuel Diesel Engines, based on the design of the LNG carriers operated by GAZOCEAN.
Cargo Tanks are designed to ensure a theoretical natural Boil Off of 0.15% of the tank capacity per day. (According to the containment system, this value could be decreased to 0.10%).

Natural Boil Off Gas (NBOG) is sent to the Dual Fuel Engines through a multi-stage process:

- NBOG is cooled by a LNG spray pipe (to -105°C, corresponding to the design inlet temperature of the Low Duty compressors); indeed, the NBOG temperature can be as high as -70°C during ballast voyage.
- A mist separator removes any liquid droplets that would cause serious damage to the compressors and removes the heavy components of the NBOG for the engines (risk of knocking);
- Low Duty compressors (LDC) bring NBOG to approximately 5.3 barg to allow the gas to be injected into the engines injection ramp;
- If needed, a gas heater using demineralised seawater brings NBOG to a temperature of about 20°C to guarantee good combustion by the engines.
- If needed, a gas cooler brings NBOG to a temperature lower than 30°C.

Excess of Boil Off is burnt into the Gas Combustion Units (GCU), which as well are used to regulate the pressure into the cargo tanks.

- In normal mode: burnt gas is compressed by the LD compressor;
- In “free-flow” mode: burnt gas flows directly from the tanks to the GCU. This mode is used when the LD compressors are turned off;
- When they are not needed, the GCUs can be put into “stand-by” mode, with only a pilot flame kept on (consumption about 10 kg/h).

When the demand is higher than the NBOG rate, additional fuel gas or “Forced BOG” (FBOG) is produced. The production of FBOG is done as follows:

- LNG is pumped from the cargo tanks to the Forcing Vaporizer and pressurized to 8 barg by the fuel gas pump;
- LNG is vaporized in the Forcing Vaporizer (FV) using the ship's steam supply;
- The resulting FBOG is led through a mist separator and a buffer tank to the gas heater where it mixes with the NBOG coming out the LD compressor.
3.2 Regulation of the Gas Fuel Supply Chain

In practice, two parameters must be regulated:

- The pressure within the tanks must be kept within acceptable range (50-190 mbarg) and adjusted by the crew depending on the operational situation (loading, laden voyage, etc...).
- The pressure delivered to the engines must be equal to 4.5 barg.

Those parameters are regulated as follows:

- The tank pressure is regulated by the flow rate of the LD compressor, which is adjusted by opening and closing the Variable Diffuser Valve (VDV) at its outlet.
- The pressure delivered to the engines is regulated by the gas demand of the GCU when the GCU is on, and by the FBOG production when the Forcing Vaporizer is in service.

In parallel, there are two parameters over which the crew has very little leverage:

- The BOG rate depends on the sea and air temperatures, the level of rolling and pitching, and the quality of the LNG;
- The gas demand of the engines depends on the operating speed of the ship, which is imposed by the charterer.

4 CHARACTERISTICS OF LNG, BOIL-OFF GAS AND GAS FUEL

4.1 Composition

4.1.1 LNG
Liquefied Natural Gas (LNG) is a mixture of different hydrocarbons; transported at -163°C at atmospheric pressure.

Its actual composition is depending of its source and liquefaction process, but main components will always be methane with small percentage of heavier hydrocarbons (ethane, butane, propane, pentane, and hexane) as well as nitrogen.

Characteristics of these components are presented in Annex 1

4.1.2 Boil-Off Gas
When LNG is boiling naturally, heavy hydrocarbons, which boiling point is higher than methane one are no more included in the associated Boil off Gas composition, as illustrated in the fig 6 below.

Figure 6 - LNG and Boil-Off Gas composition
However, a small percentage of Nitrogen included in the composition of LNG is significantly increased in the composition of the associated boil-off.

### 4.1.3 Gas Fuel
Gas Fuel is the Natural Boil-Off or Force Boil-off sent to the Dual Fuel Engines.

If LNG is pumped and vaporized to produce Forced Boil-Off Gas, the heavy hydrocarbons may be still part of the composition and will need to removed prior to be send at the engines.

The variation of Boil-off gas composition, and therefore Gas Fuel composition modify the performance of Dual Fuel engines, leading to increase emissions and decrease engine efficiency.

### 4.2 Methane Number

The Methane Number (MN) is a dimensionless factor which determines the detonating power of gas used as fuel.

Hydrogen has MN of 0 and Methane has MN of 100. Mixed gases, as Natural Gas, MN’s value is included between 0 and 100. Methane Number of no-detonating gases (as N2, CO2) is higher than 100.

The MN of a fuel gas is the main factor to determine risks of knocking and misfiring.

However the impact of MN on knocking effect highly depends on the engine architecture (direct injection, indirect injection) and its technology (gas engine or dual-fuel engine, etc.); for the moment it is difficult to be conclusive on this topic.

Indeed, some Engines manufacturers claim that when the MN is under 80, the concentration of heavy components (Butane, Pentanes etc..) is high; premature auto-ignition of these components causes vibrations and shocks (knocking).

Conversely, when the MN is higher than 110, the concentration of non explosive components (N2, CO2) is high and leads to misfiring.

It has to be emphasized that other parameters could impact the comportment of engines like quick evolution of the composition for instance.

Therefore real impact of these parameters, including MN, should be studied deeply.

In addition to the impact of MN, some work should be conducted to determine the MN calculation method of a gas. In fact several calculation methods exist but none of them has been unanimously accepted.

![Figure 7 - Representation of Methane Number](image-url)
4.3 LNG Ageing

Composition of LNG and its associated Boil-Off is changing permanently and depends on voyage conditions. Therefore, one of the main challenges for using LNG as fuel is the permanent knowledge of LNG characteristics.

This evolution of the LNG composition, temperature, density, GHV\(^1\) and Wobbe Index\(^2\) during the voyage is known as LNG ageing.

To follow this evolution, two ways are possible:

- Make LNG samples in tanks during all the trip
- Use ageing prediction software to follow and predict the evolution of LNG characteristics

The second is easiest and it’s applied by GDF SUEZ thanks homemade software developed by CRIGEN named CARGO.

5 ROLL OVER

Detailed description of Roll Over was subject of Paper presented by GDF SUEZ CRIGEN at LNG 16 (PS6-6 - On Assessing Rollover under Offshore Conditions, Y. ZELLOUF, J. MARIOTTI).

A brief summary of this phenomenon is described for the purpose of this present paper.

The rollover phenomenon is the overturning of two LNG stratified layers of different qualities stored in the same tank.

This event occurs when the two LNG layers densities equalizes mainly further to the LNG expansion in the lower layer due to heat ingress. The rollover event is then accompanied by a high peak of Boil-Off Gas (BOG) due to the sudden release of the energy accumulated in the lower layer through the incubation time.

The incompletely mix of two different LNG in a storage tank due to density difference leads to a creation of a stratification. Stratification is then created when:

- Filling lean (light) LNG from the top of the tank onto a rich (heavy) LNG heel,
- Filling rich LNG from bottom of the tank into a lean LNG heel.

The stratification is characterized by two bunk homogeneous layers (upper: heavy and lower: light) of constant but different density separated by a mixed zone, called interface or buffer zone, having a density gradient, as illustrated in fig 8 below.

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\(^1\) Gross Heating Value : The amount of heat produced by the complete combustion

\(^2\) Wobbe Index: A measure of the amount of heat released by a gas burner with a constant orifice, equal to the gross calorific value of the gas in British thermal units per cubic foot at standard temperature and pressure divided by the square root of the specific gravity of the gas.
Figure 8 - Characterization of the LNG stratification

The interface controls the heat and mass transfers between the two homogenous layers and determines the occurrence of rollover in terms of date of occurrence and the peak of Boil-Off Gas. More the interface is thick; more the rollover onset is delayed producing a higher BOG peak rate due to greater accumulation of heat in the lower layer.

In offshore conditions, the theoretical Boil-Off Rate given by cargo containment systems designer, usually given for a specific sea state (up to Beaufort 5 for 48h) take mainly into account the heat ingress through the tank walls while the potential liquid motion effect on the Boil-Off Gas production is not considered.

Thus, as the heat ingress is the main driving force of the rollover event by low sea state conditions, LNG stratification would be expected to evolve to rollover phenomenon accompanied with a high Boil-Off Gas production.

6 OPERATIONAL FEED-BACK OF GDF SUEZ AND GAZOCEAN ON THE IMPACT OF THE GAS FUEL QUALITY ON DUAL FUEL ENGINES

6.1 General


GDF SUEZ Global Energy and Provalys are owned by GDF SUEZ, GASELY by NYK Armateur, a Joint-Venture between GDF SUEZ and NYK Line. These three vessels have been built by Chantiers de l'Atlantique (today STX Europe) and are operated by GAZOCEAN, a shipmanagement company which shareholders are GDF SUEZ (80%) and NYK Line (20%)

Main Characteristics of these vessels are enclosed in annex 2

6.2 Operational Feed Back on Dual Fuel Engines

Dual Fuel engines fitted on board DFDE LNG carriers operated by GAZOCEAN run more than 90% of the time in gas mode, but minimum engines load to reach the maximum efficiency of the engines in gas mode is 60%.

Observation during operation confirmed the design predictions:

— In laden conditions, about 4.2 tons per hour of Boil off Gas is available (100 tons/day); such amount of gas allows the vessel to sail at 18-19 knots (depending on the sea state) without any use of
forced boil-off. When the speed of the ship is below this range, the extra gas is burnt into Gas Combustion Units (GCU).

— In ballast conditions, the Boil off Gas is reduced and forced boil off is necessary to accommodate with the service speed.

![Figure 9 - Observation of LNG Carrier Dual Fuel Engines Consumption in loaded conditions](image)

6.3 Impact of Gas Characteristics on the Dual Fuel Operation – engines derating

Influence of the quality of gas is confirmed in operation; troubles with gas quality (high nitrogen content & superheated LNG) have been observed leading to a derating of the Dual Fuel engines and therefore a speed limitation.

Paragraph 2 fig 3 shows the operating window between the knock and misfire limits.

6.3.1 Knocking

Knocking problems have been experienced due to the Gas Quality and High Temperature, illustrated by two examples:

First Example: on ballast voyage, in the case experienced, the forced boil off content had been about 30% of total gas consumption.

Engines tripped many times from Gas to Diesel Oil. When content of forced boil off had been reduced, from 30% to about 8%, knocking phenomenon has decreased significantly.

The heavy carbon removal tank fitted on board was not sufficient to face this higher flow of forced boil-off.

In order to run in best way, the gas quality must be considered during uploading and transfer to have even load and stable temperatures during transfer.

It’s has been observed as well that the impact of gas quality is depending on engines running hours and ambient temperature conditions.

Electronic control of the combustion,(refer to in § 2) is very sensitive. Depending on the different loads and various conditions, engine needs time to “learn” and adjust themselves. In particular in duration offsets of the gas valves of each engine due to total running hours. A too big offset step during switch-over and transfer, will make the cylinder drop out or start knocking.
Second example: a couple of times, High exhaust gas temperature was observed and exhaust gas valves burnt leading to the replacement of cylinder covers.

Dual Fuel Engines Maker, Wärstilä is considering that this failure of the exhaust valve may be due to dust deposit, originated from lubrication oil

But it was as well observed that the engines having higher exhaust gas temperatures made them more sensitive regarding knocking. Therefore gas quality could be one of the root causes of these damages.

6.3.2 Misfiring
After loading the percentage of nitrogen could reach 30% in the Boil-Off Gas composition; therefore to avoid misfiring, gas admission valve of the engines should remain open longer to allow the admission of the required quantity of methane.

7 MONITORING AND ANALYSIS OF THE CHARACTERISTICS OF LNG, BOIL-OFF GAS AND GAS FUEL

To improve the knowledge of the Dual Fuel engines and their performance according the evolution composition of the Gas Fuel, GDF SUEZ decided to fit on board of one LNG carrier of its fleet, GDF SUEZ Global Energy, an analytical unit was installed on the deck.

7.1 Analytical unit
This project was led by GDF-Suez’s Research and Innovation Division, with the participation of GAZOCEAN. BUREAU VERITAS as Classification Society gave its approval on this installation.

The installation took place in September 2009 during ship’s dry-dock in September 2009.

For the purpose of this present paper, we summarized the main characteristics of the analytical unit, which detailed description as well presentation of its installation on board was subject of a Paper presented by GDF SUEZ CRIGEN at LNG 16 (ref paper PS6-3 Improving Propulsion On A Diesel Electric LNG Carrier By Bog Quality Management: Setting of An Analytical Unit on Board for a better control).

The parameters required in this survey are the gas composition and calorific values.

Gas composition can be obtained using chromatography. Calorific values can be calculated using gas composition and ISO6976 standard.

The determination of methane number is realized using a correlative equation made by the GDF SUEZ CRIGEN.

![Figure 10- Description of the Analytical Unit and Gas Analyzer fitted on bard GDF SUEZ Global Energy](image)
There are technical constraints due to the installation of a chromatograph onboard an LNG carrier. The equipment selected must respect constraints such as:

- Safety rules applied on LNG carriers: ATEX equipment in gas areas
- Equipment protection for use in saline atmosphere
- Merchant marine’s approved equipments: mechanically protected and flame retardant.
- Resistance to vibrations and rolling
- Small congestion
- Easy mode of operation

The composition of the gas supplied to the engines is therefore be analyzed continuously, but as well the LNG composition during loading and unloading operations.

The module which integrates the chromatograph was set on the upper deck, close to the “cargo roof”.

The monitoring system was installed in the Cargo Control Room.

The analytical unit is started up by the cargo officer and the results recorded all along both laden and ballast voyages.

The methane number (MN) is a good indicator to characterize changing composition of gas and knock occurrence. The measured gas characteristics are the concentrations in hydrocarbons from methane to pentane and nitrogen (fig ).

![Figure 11 - typical evolution of Gas Fuel composition during ballast and loaded voyage](image)

8 Operation and Maintenance

Additionally to the gas analysis, monitoring of the Dual Fuel Engines parameters is essential to understand the phenomenon’s encountered and adapt the setting and the maintenance accordingly.
8.1 Dynamic Based Maintenance

In 2010, was settled the Wärtsilä Dynamic Maintenance Plan adapted thanks to GAZOCEAN operational feedback.

Compared to a conventional Maintenance Plan, the maintenance is performed depending of the actual need based on the analysis by Wärtsilä of the Engine control system (WECS) data, parameters and quality of lubricating oil and marine diesel oil fuel used as pilot, recorded by the crew, and the results of the annual, or every 4,000 running hours, (whichever occurs last) inspection. Scope of this inspection included as well resetting of control system parameters based according operational observations.

A periodic “Condition Based Operation and Maintenance” report is issued summarizing main parameters of the engines operation.

Figures below, extracted from a recent report of GDF SUEZ Global Energy illustrate the running hours and main gas injection duration in the engines, which is directly linked to the gas quality.

![Figure 12 –CBM report Running Hours by Fuel of Dual Fuel Engines of GDF SUEZ Global Energy Dec 2012/Jan 2013](image1)

![Figure 13 –Main Gas Injection Duration per Engines of GDF SUEZ Global Energy 2012](image2)

Regular meetings between Engine Maker and Operator are hold and where maintenance periods are adapted according engines performances.

With Dynamic Maintenance intervals of the visits are increase, as well as coordination of the major visits between crew and Engine Maker Service improved.
8.2 Dual Fuel Engines Operation Optimization

Record of gas fuel composition, results of calculation of Methane Number performed thanks to the gas analytical unit, may be correlated to engine settings parameters and information consolidated in the CBM reports.

If engines derating are noted, investigations will be facilitated and setting could therefore be optimized

9 CONCLUSION

LNG, and its associated Boil-Off used as Fuel Gas for the propulsion systems is a complex product.

According the source of production, liquefaction process LNG composition is different. According the type of ship operation, sea state and environmental conditions, quantity and quality of boil-off generated are different. In certain specific conditions phenomenon as Roll Over may occur generating peak of boil-off gas.

GDF SUEZ and GAZOCEAN, as first owner and operator of Dual Fuel Engines on board LNG carriers, have the opportunity to measure the impact of the gas quality, and the difficulties to optimize the engines’ efficiency due to the complexity of the product and of the gas supply chain.

Monitoring systems as the Gas Analytic unit and an the improved Maintenance Program as the Dynamic Maintenance Plan have been settled to improve the knowledge of the behavior of the propulsion according the quality of the Gas Fuel and optimize the operation.

But moreover than the monitoring equipment or procedures implemented, the most important criteria is knowledge of gas supply chain design, equipment and regulation operation, learnt since the last six years by GAZOCEAN’s crew members.

Thanks to this experience, the Dual Fuel Engines propulsion is used at their optimum for the benefit of owners and charterer.
## ANNEX 1
CHARACTERISTICS OF LNG COMPONENTS AND SAMPLE OF COMPOSITION OF TYPICAL LNG

<table>
<thead>
<tr>
<th>Gas</th>
<th>Formula</th>
<th>Boiling Point at Atmospheric Pressure in °C</th>
<th>Liquid Density Kg/m3 at Boiling point (Water 1)</th>
<th>Specific Gravity (Air 1)</th>
<th>GHV at 15°C (KJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>-195.8°C</td>
<td>1.2037</td>
<td>0.967</td>
<td>-</td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>-161.5°C</td>
<td>0.427</td>
<td>0.55</td>
<td>55,5</td>
</tr>
<tr>
<td>Ethane</td>
<td>C₂H₆</td>
<td>-88.6°C</td>
<td>0.540</td>
<td>1.03</td>
<td>51,87</td>
</tr>
<tr>
<td>Propane</td>
<td>C₃H₈</td>
<td>-42.3°C</td>
<td>0.583</td>
<td>1.55</td>
<td>50,36</td>
</tr>
<tr>
<td>Butane</td>
<td>C₄H₁₀</td>
<td>-0.5°C</td>
<td>0.582</td>
<td>2.08</td>
<td>49,52</td>
</tr>
<tr>
<td>Pentane</td>
<td>C₅H₁₂</td>
<td>36.1°C</td>
<td>0.626</td>
<td>2.55</td>
<td>49,00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gas</th>
<th>Arzew (Algeria)</th>
<th>Bony (Nigeria)</th>
<th>Point Fortin (Trinidad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>0,35</td>
<td>0,07</td>
<td>0,008</td>
</tr>
<tr>
<td>Methane</td>
<td>88</td>
<td>90,4</td>
<td>96,2</td>
</tr>
<tr>
<td>Ethane</td>
<td>7,95</td>
<td>5,2</td>
<td>3,26</td>
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<tr>
<td>Propane</td>
<td>2,37</td>
<td>2,8</td>
<td>0,42</td>
</tr>
<tr>
<td>Butane</td>
<td>1,05</td>
<td>1,5</td>
<td>0,07</td>
</tr>
<tr>
<td>Pentane</td>
<td>0,02</td>
<td>0,002</td>
<td>0,01</td>
</tr>
<tr>
<td>Density</td>
<td>466</td>
<td>453</td>
<td>433</td>
</tr>
</tbody>
</table>
### ANNEX 2
**SHIPS' TECHNICAL MAIN CHARACTERISTICS OF DUAL FUEL DIESEL ELECTRIC LNG CARRIERS**
**GDF SUEZ GLOBAL ENERGY, PROVALYS AND GASELYS.**

<table>
<thead>
<tr>
<th></th>
<th>GDF SUEZ Global Energy</th>
<th>Provalys/Gaselys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>220 m</td>
<td>290 m</td>
</tr>
<tr>
<td>Breath</td>
<td>35 m</td>
<td>43.5 m</td>
</tr>
<tr>
<td>Depth @ main deck</td>
<td>22.00 m</td>
<td>26.25 m</td>
</tr>
<tr>
<td>Design draught</td>
<td>9.70 m</td>
<td>11.60 m</td>
</tr>
<tr>
<td>Air draught in ballast draught conditions</td>
<td>39 m</td>
<td>40.20 m</td>
</tr>
<tr>
<td>Deadweight</td>
<td>34,800 t</td>
<td>74,300 t</td>
</tr>
</tbody>
</table>

| Cargo containment   | GTT – C S 1            |
| LNG capacity @ 100% | 74,500 m³ in 4 tanks   |
|                     | 154,500 m³ in 4 tanks  |

| Main engines sets   | WARTSILA 4 * 6L50DF    | WARTSILA 3*12V50DF + 1*6L50DF |
| Electric propulsion system | CONVERTEAM 2 x 9,500 kW | ABB 2*14,000 kW |
| Bow thruster        | 2,000 kW               | 2,200 kW          |

| Service Speed       | 17.5 knots             | 19.0 knots        |