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Dual-Fuel ME-GI Engine Operation on Large LNG Carriers (Q-Flex and Q-Max vessels)

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Abstract

Today, greenhouse gases and exhaust gas emissions are rightly high on the agenda for all ships owners, operators and charterers. With this in mind, a Charterer Certificate (Green Award Certificate) can be awarded to those demonstrating reduced emissions and fuel oil consumption and increased shipping efficiency. Therefore, a working group of maritime companies (Qatargas Operating Company Ltd. (QG), RasGas Company Ltd. (RG), ConocoPhillips and Rio Tinto) was established to develop a strategy to meet and demonstrate the targets required to achieve this Charterer Certificate. The group has identified the operation of Dual Fuel Main Engine Gas Injection (ME-GI) Engines as a way to help do so.

In consideration of the above, a total of 45 Q-Flex and Q-Max vessels chartered to Qatargas Operating Company Ltd. (QG) and RasGas Company Ltd. (RG) are being considered for conversion to Dual Fuel Gas Injection (ME-GI) Engine. Using Liquefied Natural Gas (LNG) vapour for the operation of Electronically Controlled High Pressure Gas Injection Engine for propulsion of ships, the conversion work will significantly reduce the emissions when compared with Marine Diesel Oil (MDO) and / or Heavy Fuel Oil (HFO) in terms of Carbon Dioxide (CO_2), Oxides of Nitrogen (NO_x), Sulphur Oxides (SO_x) and particulate matter (PM). Therefore, there are clear environmental benefits for using this fuel in the main engines along with a general reduction in particulate emissions.

Taking into consideration, the relative differences in fuel prices and the strong requirements for lowering engine emissions the interest for using the LNG gas as fuel in the QG and RG LNG carriers has increased. In addition the ME-GI engine has the flexibility to combust both QG and RG gas compositions. Using LNG as a fuel will not affect engine performance in terms of speed, thermal efficiency or power output, and will maintain the same rating as for the fuel oil burning engine.

LNG is destined to become the preferred energy source of the future in many areas of the world, and very few doubt this prediction. Hence, as there will most likely be an overcapacity in LNG production and tanker tonnage, this has generated additional interest in using LNG as a fuel source for ocean-bound vessels as it is expected to be cheaper than other types of fuel. This is especially true for vessels trading in Sulphur Emission Control Areas (SECA) as they are required to burn Low-Sulphur fuels when within 200 nautical miles of any port or terminal within such an area. As such, it is felt that the cost savings will be even greater if the LNG fuel price is compared against the price for other types of Low- Sulphur fuels.

This paper describes the operating philosophy and scope of works that will be required for the retrofit conversion of the Q-Flex and Q-Max vessels to ME-GI duel fuel two-stroke engines.

Background

During the last few years, the ME-GI engine has mainly been considered for LNG carriers. Therefore in 2007, the Shipping Department within Qatargas Commercial & Shipping Group initiated a study into retro-fitting of process machinery to deliver natural gas at high pressure. This equipment was to be installed on MAN 6S70-ME main engines to allow conversion to dual fuel burning. The study, which included both technical and financial information and those associated with costs, was completed in 2009 and looked at one specific vessel type.

HAZID and HAZOP workshops facilitated by one of the recognised vessel classification societies was held in 2011 as part of the "Approval in Principle" process required by Class; all QG and RG's respective shareholders (major gas and oil companies) participated in these workshops.

During May 2011, a ME-GI demonstration was successfully tested on 4 cylinder test engine (4T50ME-GI-X). Participants from the three classifications societies, shareholders and operators including a member from the Society of International Gas Tanker and Terminal Operators (SIGTTO) witnessed the successful demonstration, all transition modes from fuel oil to fuel gas and vice versa were extensively tested, and the changeover operation was very smooth and stable without any manual interference. An additional shutdown process for the fuel gas has also been tested, which did not affect the main engine speed and the engine continue to run on fuel oil. Also, during the demonstration the engine gas supply was shut in slowly to find the gas combustion instability point, which occurred at 7% ~ 8%, at which point the gas could not maintain combustion and the engine switched to 100% fuel oil. It is planned to carry-out a demonstration on full scale engine (S70ME-GI) with gas plant as fitted on QG and RG vessels.

A shore based slow speed 2-stroke dual fuel engine has been in operation in Chiba, Japan as a source of power generation. This engine has a fixed cam profile for gas injection. The engine runs at a constant speed / constant load, which is not an option for a marine engine.

Aims

ME-GI engine has a number of benefits in terms of environment, operation, low fuel oil consumption and reduced time or stoppage for fuel oil bunkering. In addition, the safety system for main engine gas injection and fuel gas supply system (FGSS) will be designed to "Fail to Safe Condition". All failures detected during the gas fuel running including failures of the control system itself will result in a gas fuel stop / shut-down and change over to fuel oil operation. The changeover from fuel gas to fuel oil and vice versa will be seamless, and will not result in any power loss or change in the engine load (rpm) on the main engines.

I. Environment and Emissions

As mentioned at the beginning of this presentation, the high-pressure gas injection system on the ME-GI Engine has the advantage of significantly reducing the emissions (SO_x, NO_x, CO_2 and PM) compared with HFO. As a consequence, LNG gas fuelling will give a much cleaner exhaust as the sulphur content will much lower. The emission of particulates will also be reduced considerably, as will that of NO_x, thus meeting international Maritime Organization (IMO) emission standards ie.Tier I, II and III standards. Hence, ME-GI Engines should provide greater flexibility to comply with current and future environmental legislation.

The following table shows main engine emissions with and without the Gas Injection System (reference is the test engine).

Estimated emissions 6S70ME-C		Estimated emissions 6S70ME-GI	
Load 100%	g/kWh	Load 100%	g/kWh
CO^2	577	CO^2	446
O^2 (%)	1359	O^2 (%)	1340
CO	0.64	CO	0.79
NO_x	11.58	NO_x	10.12
HC	0.19	HC	0.39
SO_x	10.96	SO_x	0.88
PM (mg/m^3)	0.54	PM (mg/m^3)	0.34

Table 1 - Emissions Control ME-GI Engines

II. Operational Flexibility

One of the advantages of the ME-GI engine is its fuel flexibility, from which LNG carriers can certainly benefit. A two-stroke, high pressure gas injection engine is able to burn different fuels with no decrease in thermal efficiency, load and speed (rpm) of the engine. ME-GI engine can be operated in three operating modes:

a. Fuel oil only mode - operating the engine in this mode can only be done on fuel oil.

b. Fuel gas mode - operating the engine in this mode will be with fuel gas and a minimum amount of fuel oil (pilot oil - 5%). Both heavy fuel oil and marine diesel oil can be used as pilot oil. In case the engine load is below 30% then the engine will run on fuel oil only mode due to the instability of gas and pilot oil combustion.

c. Mixed Mode or “specified gas mode” - the engine should be started manually by an operator on the gas main operating panel in the control room. In this mode the control system will allow any ratio between fuel oil and fuel gas.

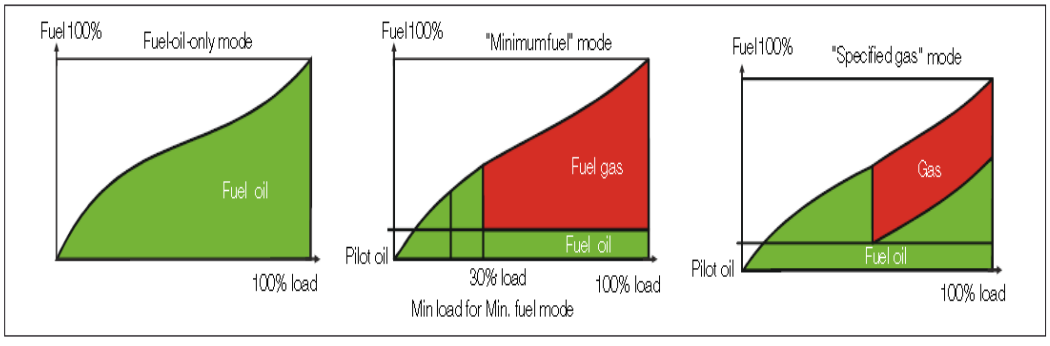

Figure 1 - Main Engine Operating Modes

III. Optimising Bunker Requirements

ME-GI Engines will reduce fuel oil bunkering requirements. As the overall bunker consumption for the vessels would reduce with ME-GI engines and the main engines would only infrequently be operated on a fuel oil mode. Thus significantly reducing stoppage time required for bunkering, lowering overall voyage time and enabling more efficient usage of vessels.

IV. Optimal Solution

ME-GI engines provide flexibility to owners and charterer's, allowing them to find an optimal solution and strategy for fuel operation providing flexibility in reacting to price changes in the market (LNG price versus fuel oil price).

V. Mean Time between Maintenance

Mean time between maintenance should be increased by using cleaner burning fuel, whereby the ships downtime will be reduced for planned maintenance.

Methods

The following is a brief description of the Fuel Gas Supply System (FGSS) and scope of works required for converting two-stroke engines into dual-fuel ME-GI Engines:

I. Fuel Gas Supply System

a. The LNG FGSS will extract LNG from the vessel cargo tank or Reliquefaction condensate return and deliver it to vessels main engines in the form of high pressure vapour (at 300 Bar), temperature (at 45 deg C ±10 deg C). The pressure characteristics of the vapour are such that they meet the requirements of vessels propulsion demand in all vessel operating scenarios. The LNG is to be extracted from cargo tanks using dedicated submerged supply pumps.

b. The LNG supply pump will maintain a working level in the following units:

   (i) High Pressure Pump (HPP) suction drum, suitably located to provide positive pressure to dedicated HP pumps.

   (ii) A suitably located HPP Suction Tank complete with Booster supply pumps, utilized to maintain a positive pressure on High Pressure (HP) pumps under all operating parameters.

c. The output from the HP pumps will supply High pressure LNG to a forced vaporizer from which the HP vapour will be supplied to the main engines. The forced vaporizer heat requirement are to be met by the use of an intermediate heating loop that transfers heat from the primary source to the LNG loop.

d. A dampening drum will be installed on the HP feed to main engines; this shall be sized to ensure that any pulsations that appear in the feed vapour are suitably reduced to levels within the main engine vendor's specification.

e. The LNG FGSS is seen as being totally independent of vessels Reliquefaction plant operations and tank spraying operation

f. The condensate return from Reliquefaction operations to be considered as an alternate LNG supply to the HP suction drum/tank, while still maintaining acceptable level with HP suction vessel, the overriding primary use of

Reliquefaction for cargo tank pressure control is to be maintained, regardless of any propulsion demands.

g. The High-Pressure Gas from the FGSS will be routed to ME-GI engines via double wall pipe; gas supply pipe (line) will be designed with ventilated double-wall piping and HC sensors for safety shutdown. Furthermore the piping will be designed to prevent gas outflow to the machinery space in the event of rupture of the inner pipe.

II. General Engine Systems Description for LNG Operation

a. Adding the gas injection system to the existing main engines on Q-Flex and Q-Max vessels does not eliminate the many new features developed for the ME system. The same system can also be offered for the ME-GI.

b. The cylinder heads (cover) will be replaced with new units, which have the following additions:

   (1) Gas control block - it incorporates an accumulator provided with a window / shut-down valve, two purge valves and Electronic Gas Injection (ELGI) valves.

   (2) Gas injectors.

   (3) High-pressure Gas supply pipe - this pipe will be a flexible so that it separates each cylinder unit from the rest in terms of gas dynamics avoiding any extra stress in the ME-GI engines that might be caused by the differences in the thermal expansion of the gas pipe system and ME-GI engines structure.

   (4) Control oil supply for actuation of gas injection vales and controlling amount of the injected gas.

   (5) Sealing oil supply to separate from the control oil and gas.

c. The gas is supplied to an accumulator via a non-return valve placed on the connection piece. From the accumulator, the gas passes through a bore in the gas control block to the window/shutdown valve and then the gas is led to the GI valves via bores in the gas control block and the cylinder cover.

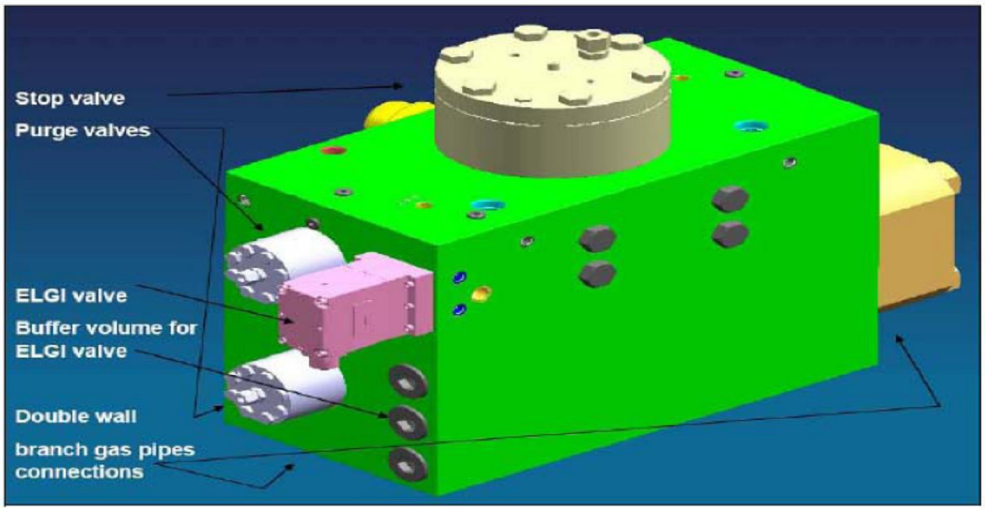

Figure 2 - Gas Control Block

Results

As mentioned above, the ME-GI engine has been approved in principle by the classification societies (ABS, DNV and LR) that the Large LNG carriers are classed for retro-fitting the FGSS and ME-GI engine on LNG vessels. Furthermore, a technical qualifications study will be conducted for the ME-GI engines and FGSS by September 2011, which is the target period for agreement on Technical Qualification Management System (TQMS) and type approval on ME-GI proposal for QG/RG and shareholders. The Final Investment Decision (FID) is planned to be obtained by December 2012.

ME-GI engine demonstration was held in May 2011 and verified that the dual burning engine will meet future IMO regulation in terms of emissions and efficient M/E control system.

Conclusion

ME-GI Engines have the potential to provide significant economies of scale and other advantages for QG and RG chartered vessels, including improved emission levels and reduced fuel oil costs for charterers. Moreover, with dual-fuel capabilities, the charterers will have the flexibility to select fuel oil, fuel gas or a combination of both for main engines operation. The selection of the energy resource on the main engines will be driven by a number of factors, which are listed below:

- The price of LNG versus fuel oil and bunkering time.
- Agreed delivered LNG cargo to the receiving party (commitment with various receivers on long-term LNG supply).

The reduction in emissions is a future regulation of IMO and listed with high priority in the agenda, whereby all ships owners and operators are required to use low-sulphur fuels within 200 nautical miles from the coast (ECA). There are other technologies currently are available in the market that could be installed on chartered vessels for emissions reduction such as scrubber and exhaust gas recirculation. However, ME-GI has an economic advantage in comparison with these other technologies as the initial capital cost of installing ME-GI engines onboard QG and RG vessels can be paid back after a certain period of time based on delta in the price between LNG and MGO / MDO.

QG and RG will conduct a technical qualification study and dynamic simulation into retro-fitting two-stroke engines for dual fuel operating mode. The primary focus in this study will be to evaluate the safety, efficiency, risk, reliability, quality and control system of ME-GI conversion and FGSS.

All the modifications and installed equipment will comply with current and draft International Gas Code (IGC) requirements, Safety Of Life At Sea (SOLAS) and flag state (Marshall Island) requirements for fire safety and detection systems, Classifications Societies requirements and other standards.

Topics:

- Either Energy efficiency (Committee and number WOC5-5C) or;
- Gas Emission – greenhouse gas (GHG) reduction efforts (Committee and number PGCA-6D).

ABBREVIATIONS

ABS	American Bureau of Shipping
CO_2	Carbon Dioxide
DSME	Daewoo Shipbuilding & Marine Engineering
ELGI	Electronic Gas Injection
ECA	Emissions Control Areas
FG	Fuel Gas
FID	Final Investment Decision
FGSS	Fuel Gas Supply System
GI	Gas Injection
GCU	Gas Combustion Unit
HAZID	Hazard Identification Studies
HAZOP	Hazard and Operability Studies
HC	Hydrocarbon
HFO	Heavy Fuel Oil
HP	High Pressure
HPP	High Pressure Pump
HHI	Hyundai Heavy Industries
IGC Code	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IMO	International Maritime Organization
LNG	Liquefied Natural Gas
MCR	Maximum Continuous Rating
MDO	Marine Diesel Oil
ME	Main Engine
ME-C	Main Engine - camshaft
MEGI	Main Engine Gas Injection
N_2	Nitrogen
NO_x	Oxides of Nitrogen
PM	Particle matters
QG	Qatargas Operating Company Limited
RG	RasGas Company Limited
SO_x	Sulphur Oxides
SIGTTO	Society of International Gas Tanker and Terminal Operators
SOLAS	Safety Of Life At Sea
SHI	Samsung Heavy Industries
TQMS	Technical Qualification Management System
VFD	Variable Frequency Drive