ME-GI Gas-ready Ship
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ME-GI gas-ready ship

Introduction
Given the volatile nature of today’s fuel prices combined with the introduction of a more stringent emission regulation in emission control areas, it has never been more difficult to mitigate the economic risk associated with operating a vessel. Heavy fuel oil has unquestionably been the cheapest option for vessel operation, and although there have always been price fluctuations, it has been possible to compensate for these fluctuations during the lifetime of the vessel with relatively simple operational or technical measures.

The implementation of MARPOL Annex VI (14.8) from 1 January 2015 for operation on fuels containing less than 0.1% in ECAs has now forced many owners and operators to make their own investigations into economic feasibility of alternative fuels. This, in turn, has given rise to a renewed interest in alternative fuels, particularly natural gas, which has been reduced somewhat in cost due to increased global production and has become increasingly available in the form of LNG, mainly due to political and financial initiatives for increased funding of the construction of LNG bunker stations within ECAs.

However, the investment required to allow for bunkering of LNG on board and consequent use of natural gas for propulsion can be prohibitively expensive, and as the volatile fuel prices dictate, any business case can be broken down. Therefore, a compromise is emerging in the marine industry whereby the vessel can be considered “gas ready” without requiring full investment in LNG bunkering or gas operation, but still allowing the owner or operator the opportunity to upgrade the vessel to operate on gas by implementing all the relevant requirements for gas operation at the design stage.

Applications – Ship Types
With the exception of LNG tankers, the fundamental reasons for selecting gas operation on the vessel are essentially the same whether the vessel is gas ready or a fully prepared gas vessel. The key factor for differentiating the two lies in the availability of the LNG bunker. If the LNG bunker station on the vessel’s route is expected only after five years of the vessel entering service, it is likely to be more economically feasible to have the vessel “gas ready” rather than have the investment cost installed on board by lying idle in the period until the LNG bunker station is completed. In this case, the full conversion to gas operation could take place at the first major docking.

As many of the charters are for short-term variable routes, it makes it rather difficult to predict the availability of the fuel. Given that most of the LNG bunker stations are currently under construction, and not available within the next 5 years, it is easy to see the attractiveness of the gas-ready solution.

For LNG tankers, where the gas is already available on board, there are no conceivable benefits of a “gas-ready” vessel contra a full gas installation new-building; therefore, this is not described further in this article.
The ME-GI Engine

The ME-GI engine is capable of operating on conventional fuel oil or gas fuel, depending on the operator’s fuel preference. Thus providing an unprecedented degree of flexibility for the operator, accommodating the economic advantages of choice of fuel type, environmental benefits of gas fuel operation and accessibility of fuel oil.

The ME-GI engine has similar, if not improved, performance in gas operation compared to fuel oil operation. The fundamental design of the engine is unchanged when compared to ME engines, meaning that the application potential for the ME-GI engine applies to the entire ME engine programme. Further, as the GI concept is already class approved, all ME engines can be considered “gas ready”, as the GI is simply an add-on to the existing engine. In order to convert an ME engine to an ME-GI engine, both the mechanical and electrical components for gas operation need to be installed and the software enabled. The conversion of the engine itself can be performed by MAN Diesel & Turbo’s PrimeServ organisation during a docking period.

Typically for a standard conversion from ME-C to ME-C-GI, the mechanical components required for a six-cylinder engine would be as shown in Table 1:

In order to prepare the vessel design for the ME-GI engine, it is recommended that the vessel designers study the ME-GI documentation carefully, especially the ME-GI project guide, to ensure they have at least basic knowledge of the details of the ME-GI hardware and software. With respect to the practical aspects, it is important to obtain the outline drawings, pipe connection drawings and GI capacities requirements of the ME engine that is to be installed, so that the designers can consider all the design aspects into the engine room at this early stage.

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder cover*</td>
<td>6</td>
</tr>
<tr>
<td>Gas block (including adaptor block)*</td>
<td>6</td>
</tr>
<tr>
<td>Gas injectors*</td>
<td>12</td>
</tr>
<tr>
<td>Gas dummy injectors*</td>
<td>12</td>
</tr>
<tr>
<td>Control oil high pressure pipes*</td>
<td>6</td>
</tr>
<tr>
<td>Fuel oil high pressure pipes*</td>
<td>6</td>
</tr>
<tr>
<td>Exhaust valve high pressure pipes*</td>
<td>6</td>
</tr>
<tr>
<td>Gas chain pipes*</td>
<td>12</td>
</tr>
<tr>
<td>Gas helix pipes</td>
<td>2</td>
</tr>
<tr>
<td>Sealing oil pump unit</td>
<td>1</td>
</tr>
<tr>
<td>Various pipes &amp; cabling</td>
<td>1</td>
</tr>
<tr>
<td>GI Engine Control System &amp; Instrumentation</td>
<td>1</td>
</tr>
<tr>
<td>Starter cabinets*</td>
<td>2</td>
</tr>
<tr>
<td>Gas system wiring, incl. remote</td>
<td>1</td>
</tr>
<tr>
<td>Tools</td>
<td>1</td>
</tr>
<tr>
<td>PMI online</td>
<td>1</td>
</tr>
</tbody>
</table>

(note that the quantity of components with * are cylinder dependent)

Table: 1
Ship Design
The majority of the aspects required for a “gas-ready” vessel will be related to all the auxiliary equipment required for gas operation. This starts at the LNG bunker station and follows the whole process to the gas inlet on the main engine. Every detail in this chain must be considered when designing the vessel. Furthermore, at the 95th MSC, IMO has formally adopted the international code of safety for ships using gases or other low flashpoint fuels (IGF code). A careful study of these requirements is necessary in order to ensure that the gas-ready design will be in compliance. Some of the relevant sections from the IGF code are referenced in this description; however, it is ultimately the ship designer’s responsibility to ensure full compliance with the IGF code and any additional classification society requirements.

Classification Societies
Depending on the class of the vessel, the specific rules must be examined. There is typically a conceptual design approval, and then a detailed design approval where the vessel is granted a state of gas readiness of equivalent status denoting compliance of design and construction with their own design guidelines for gas fuelled vessels. Additionally, there are various notations, which indicate that there may already be gas equipment approved and installed on the vessel prior to entering service.

It should be noted that any vessel with an ME-C engine installed is ready for conversion to gas operation, thereby inherently “gas ready”. Examples of gas readiness notations from the classification society LR.

Gas Fuelled Readiness
Notation – Details
GR Assigned to ships other than LNG carriers, detailing the aspects of design and construction that are prepared for gas-fuel operation in accordance with the Lloyd’s Register Rules and Regulations.

The level of gas fuelled readiness is structured in a flexible manner through the following associated characters denoting:

A That approval in principle has been achieved for the basic design.
S Necessary structural reinforcement and materials have been installed.
T Gas storage tank is in place.
P The gas fuel piping arrangements are installed.
E Those engineering systems (main engine(s), auxiliary engines, boiler, etc.) being also gas fuelled.

The level of documentation required differs slightly depending on the class of the vessel; however, it is expected as a minimum to have a vessel GA, including a gas system plan, arrangements of LNG equipment, hazardous area classification of the vessel, design of LNG handling equipment, fuel gas supply and handling system arrangements, including piping, GVU’s, engine room, vent masts, gas management plan and concept safety assessment.
Hazardous Area Designation for ME-GI

Classification societies will typically require arrangement drawings indicating all the hazardous areas on the vessel. As a guideline for ME-GI type engines, the following illustration shows a typical installation and designation of hazardous areas.

LNG Bunker Station

Typically, the location and arrangement of the bunker station will need to be included in the ship design. Further, it may be required to specify in detail all the piping and equipment used in the bunker station. When designing the bunker station, one of the key factors is the filling capacity requirement. This needs to be matched with both the bunker barge or terminal and the amount of time the vessel has to bunker. Moreover, it is important to consider the allowable LNG tank pressures on board the vessel, and how this will affect the LNG bunkering process. It is certainly recommended to have an LNG bunkering procedure in place at this stage, so it is already factored in at the design stage. As an example, the bunker checklist found here (lngbunkering.org) can be followed, and the LNG bunker delivery note in the Annex of the IGF Code can be considered for implementation into the bunkering procedures.

Further the Society for Gas as a Marine Fuel (SGMF) has issued comprehensive safety guidelines for bunkering.

Fig. 2: Hazardous area designation scheme

Fig. 3: Courtesy of ESSF LNG subgroup recommendation for LNG bunker connections
The capacity of the bunkering station will also have an effect on the type of bunker connection to be used. The current recommendation is split into two different connector types based on the bunkering flow rate. The flow chart below illustrates the methodology for choosing the correct bunker connection.

**LNG tanks**

As the most expensive item in the LNG package, it is not expected that the LNG tanks will be installed in the new-building, but rather that the vessel construction is made ready for tank installation, including a plan for installation at a later stage. The LNG tank will have the biggest influence on the vessel design and will require some relatively detailed investigation as to the size, arrangement and location of the tank/s at this early stage. This is perhaps the most difficult factor to estimate for the “gas-ready” vessel, as it is unlikely that the route of the vessel in 5-10 years’ time is well known. If the vessel is primarily sailing outside ECAs, then the LNG tank size could be estimated based on a reduced sailing time in ECAs. For correct dimensioning of the LNG tank, see the recommendation in Fig. 4.

\[
\text{HFO (tonnes requirement) } \times \text{ LCV ratio } / 0.42 = \text{ LNG m}^3
\]

LCV ratio has 5% tolerance, and 5% tolerance on SFOC

5% heel and max. 91% filling

(double check with IGF 6.8 for actual bunkering temperature condition and impact on loading limit)

**Example:**

Calculated HFO capacity for ECA sailing per round trip is 250 tonnes = 250\*1.05 = 263 tonnes

\[
\text{LCV}_{\text{hfo}} = 40600 \text{ kJ/kg, LCV}_{\text{lng}} = 48500 \text{ kJ/kg,}
\]

\[
\text{LCV ratio} = 40.6/(48.5 \times .95) = 0.883
\]

\[
\text{LNG requirement} = 263 \times 0.883 / 0.42 = 552 \text{ m}^3
\]

Then add on 14% for heel and filling limit = 630 \text{ m}^3

**Fig. 4: LNG tank dimensioning**

A fundamental aspect of choosing an LNG tank is the expected holding time required. This will impact both the price and size of the LNG tank significantly depending on the requirements. In this respect, it is recommended to make a realistic evaluation of the holding time in order to avoid the introduction of potentially unnecessary expense into the LNG tank system. It is expected that for the “gas-ready” vessel, tank type C will be applied as this does not involve design integration into the actual vessel design form itself, and it can be pressurised to a certain extent, giving the longest holding times. Other tank types could be considered, but these may require significantly more expense at the retrofit stage, unless already constructed into the new building.
Once the tank capacity and type have been determined, the location and arrangement of the LNG tank/s can be analysed. In order to find the optimum solution, the following factors can be considered:

- Locations, foundations for LNG storage tanks
- Locations, deck houses for LNG equipment including foundation
- Routing of deck pipes, electrical cable pipes and pipe foundations
- Grating, platforms and ladders of LNG storage tanks
- Foundations for LNG pipe system
- Additional masses, effect on CoG, trim
- Fire management in tank room

If a long holding time is necessary, it can also be considered whether a boil off gas (BOG) compressor can be applied. There are various possibilities for system arrangements, but a low-pressure BOG compressor can be applied to supply the gensets or DF boiler or a higher pressure BOG compressor can be applied to deliver gas directly into the high-pressure gas piping supply to the main engine. The application of such a BOG compressor has the advantage that it will be more feasible for the crew to control the LNG tank pressure during sailing and waiting conditions, and for example prior to bunkering, the LNG tank pressure can be reduced somewhat in order to speed up the bunkering process.

There may also be some design and PID requirements for the tanks, in which case some of the factors to consider are:

- Tank safety valves
- Max. pressure alarm, max. level alarm (95% and 98%), level measurement (radar or microwave type), temperature measurement, pressure measurement
- Spray line to reduce the pressure during loading
- Foundations for in-tank installation of pump
- Access to tank (manholes)

### Table 5: LNG tank types summary. Courtesy of TGE

<table>
<thead>
<tr>
<th>Tank type</th>
<th>Concept</th>
<th>Pressure</th>
<th>Partial Filling</th>
<th>Second Barrier Required</th>
<th>Dis-Advantages</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane</td>
<td>Integrated in hull</td>
<td>&lt;0.25 barg (max. 0.7)</td>
<td>No</td>
<td>Yes</td>
<td>Very sensitive against variations; Pressure holding necessary; Not gastight</td>
<td>Can be adapted to hull</td>
</tr>
<tr>
<td>Semi-membrane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Independent type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Prismatic with straight planes, adapted to hull shape</td>
<td>&lt; 0.7 barg</td>
<td>Yes</td>
<td>Yes</td>
<td>Pressure holding necessary; very voluminous vent system due to low pressure</td>
<td>Can be approx. adapted to hull shape</td>
</tr>
<tr>
<td>B</td>
<td>Prismatic with straight planes, adapted to hull shape</td>
<td>&lt; 0.7 barg</td>
<td>Yes</td>
<td>Partly</td>
<td>Pressure holding necessary; very voluminous vent system due to the low pressure</td>
<td>Can be approx. adapted to hull shape</td>
</tr>
<tr>
<td>Spherical (Moss)</td>
<td>&lt; 0.7 barg</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td>Pressure holding necessary</td>
<td>Very reliable system</td>
</tr>
<tr>
<td>C</td>
<td>Independent pressure vessels</td>
<td>&gt; 0.2 bar</td>
<td>Yes</td>
<td>No</td>
<td>Space requirements</td>
<td>- very solid design</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- flexible pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- easy installation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- no leakages occurred</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- no maintenance needed</td>
</tr>
</tbody>
</table>
Through consultation with the LNG tank or gas system supplier, it may be possible to estimate the pressure rise in the LNG tank based on gas quality, LNG tank size and design, and environmental conditions. This is a useful tool when considering how long the vessel will be stationary, and the necessary measures for BOG handling that will be required.

Further design requirements of the tanks can be found in IGF Chapter 6 and in the classification society rules.

**Fuel Gas Supply System**

The second most costly item is the FGS system; therefore, it is expected that this will also be installed at a later stage. The typical layout of the FGS system will be similar regardless of supplier, as the delivery conditions are already specified by MAN Diesel & Turbo. A list of potential suppliers is available on request.

![Fig. 6: LNG holding tank pressure vs duration. Courtesy of TGE](image)

**Fig. 6: LNG holding tank pressure vs duration. Courtesy of TGE**

![Fig. 7: Basic gas system diagram](image)

**Fig. 7: Basic gas system diagram**

**Gas condition at engine inlet:**
- Pressure: 250-300 barg (engine load dependent)
- Temperature: 45±10°C
The FGS is typically delivered on skid modules, which vary in size, mass and contents, depending on the FGS supplier. However, the principal components of the FGS system comprise of the HP pump, HP vaporiser and glycol water system, so 1-3 skids can be expected. Additional low-pressure gas supply equipment for DF gensets will typically be included in the FGS supplier scope of supply and can be somewhat integrated into the skids. The following example is given by Hyundai Heavy EMD for a 24 MW vessel and is typically delivered on one skid or two skids (9 m x 1.5 m x 1.25 m and 9 m x 3.5 m x 2 m), depending on vessel design requirements.

Again, depending on the FGS system supplier, the actual component delivery and operating philosophy may differ slightly. It is also necessary to communicate with the potential FGS supplier at the vessel design stage to obtain an understanding of the PID and operating philosophy of the supplier in order to incorporate their philosophies into the vessel alarm and monitoring system and to ensure that when the time comes, the vessel’s alarm and monitoring system is prepared for the FGS control system signals and will take action accordingly. This is a vital part of the approval process and should already be considered in the FMEA, HAZID and HAZOP of the gas handling and supply systems. The vessel designer must also check that the FGS control system will deliver the safety requirements as specified in Chapter 15 of the IGF Code.
Inert gas system

Some vessels may already have an inert gas system installed, in which case it is recommended to incorporate the additional volume required from the ME-GI, the gas piping and the FGS into the inert gas system at the time of newbuilding. The capacity is likely to be small if compared to the inert gas system for tank inerting, for example. Therefore, it will not significantly impact the cost of the newbuilding, and a connection to the inert gas system can easily be made at the newbuilding stage.

Purging of the main engine and piping to the main engine take place after every gas stop and before every gas start. The purpose of purging is to inert the gas pipes and to ensure that there is no possibility for a combustible mixture present in any gas piping or components at any point in time. The volume of inert gas required for the main engine is available from a CEAS report, and the MAN Diesel & Turbo recommendation to calculate the inert gas volume and further system requirements are available in the project guide or installation section of the design specification, which is available on MAN Diesel & Turbo’s extranet, Nexus:

http://nexus.md-extranet.local/projects/Teamwork/ME-GISpecification/Pages/default.aspx

For access, please submit the form found at the link below; write “ME-GIspec” in the “Applications/projects that you want access to” field:


Gas piping

It is strongly recommended to consider routing of all gas piping from LNG bunker stations to LNG tanks, from LNG tanks to FGS, and from FGS to main engine, and if relevant, gensets. Further material and safety requirements should also be considered in the PID. Whilst it may not be strictly necessary to complete a detailed design of the piping, including placement of fixed or flexible supports and a full stress analysis, it is recommended that these design requirements are considered at this stage, as it will also influence the routing of the piping and will save both time and money at the retrofit stage if these items are already designed into the piping.

Single-wall pipe system

All piping in non-enclosed spaces can be single-wall type, this will typically be all piping on deck, any deckhouses or rooms designed as hazardous areas. During planning of the routing, fixed and flexible supports should be considered, as well as any insulation requirements.

The shipyard must also consider allowable pressure drop in the single-wall or inner piping from the FGS to the M/E, as this will influence the piping diameter. A large pressure drop is not desirable, and MAN Diesel & Turbo’s recommendation is less than 5 bar in total. The single-wall and inner piping should then be dimensioned accordingly.

Double-wall pipe system

Once the gas pipes enter enclosed spaces, typically as they go below main deck, double-wall piping is required. Design of the double-wall piping is slightly more complex, as the designer must consider stress and vibrations for both the inner and outer pipe simultaneously and incorporate flexible or fixed support accordingly. The inner pipe can be supported by means of fixed or flexible supports according to MAN Diesel & Turbo’s guidelines, within the outer pipe. The outer pipe can also be supported by means of fixed or flexible supports onto the hull as per standard shipyard designs for any other type of piping.

![Double-wall piping in production](image)

The double-wall connection to and from the main engine is supplied with the gas pipes on the main engine as part of the GI component delivery. However, there may be some reduction pieces required to connect the gas supply piping to the M/E connection, depending on the dimensions of the gas supply piping chosen by the designer. This is decided by the desired pressure drop in the inner piping from which the outer pipe dimension can also be chosen according to MAN Diesel & Turbo’s recommendations.
Ventilation and leakage monitoring

The annular space between the inner and outer pipe is ventilated. In case of any gas leakage, the ventilation air will contain gas, which will be detected by the leakage monitoring system, leading to a gas shutdown. Therefore, the ventilation outlet must be installed in an otherwise non-hazardous zone. The installation of a ventilation inlet creates a zone 1 area within 1.5 m of the inlet, and the ventilation outlet a zone 1 area within 3 m of the outlet. Additionally, a hazardous zone 2 will be applied further 1.5 m from the zone 1 area.

To prevent possible condensation in the ventilation air, which could lead to corrosion, and failure of the high-pressure inner pipe, there are two options:
1. Installation of a drying system based on start air.
2. Installation of an air dryer at the air intake.

It is MAN Diesel & Turbo’s recommendation to consider design option 1 at the newbuilding stage and already install the necessary pipework from the start air receiver to the ventilation inlet. This will save considerable time and money at the retrofit stage.

Gas Valve Train

The gas valve train (GVT) is MAN Diesel & Turbo’s designation for the high-pressure gas valve unit, familiar to low-pressure gas systems. MAN Diesel & Turbo has worked closely with sub-suppliers to develop a novel solution, which is both compact, easy to maintain and flexible with regard to the vessel design requirements. Space must be allocated on board for the GVT (1300mm x 970mm x 1500mm), which can be installed in either hazardous or non-hazardous areas (without creating a hazardous area), depending on GVT type. The electrical and pneumatic connections should also be considered.

For the control and monitoring requirements specified in Chapter 15, Table 1 of the IGF code, MAN Diesel & Turbo has incorporated these requirements into the GVT, so the component can be supplied from MAN Diesel & Turbo, and combined with the main engine, thereby automatically fulfilling these requirements.

Fig. 10: Assembled gas valve train
**Gas Valve Units**
If applying DF gensets, the installation of the GVUs must also be considered. For the low-pressure gas supply piping from the FGS to the gensets, it is recommended to check the MAN Diesel & Turbo recommendation specified in the “Safety Concept” documentation for the specific gensets considered, as the requirements are slightly different when compared to the ME-GI type engine.

In addition to the gas valve units, there are additional valve installations recommended by MAN Diesel & Turbo for the system arrangement. This is extremely important for locating gas leakages in the high-pressure gas piping and components, as this can be time consuming during the commissioning stage. Therefore, it is recommended to include the MAN Diesel & Turbo arrangement into the PID already at the design stage.

**Vent Mast**
Typically, the requirements for the vent mast can be found in the IGF codes 6.7.2.7, 6.7.2.8 and 12.5.2. The vent location must be at least 10 m from any air inlet or exhaust outlet, 6 m above any walkways or working areas and B/3 or 6 m (whichever is greatest) above the weather deck. Further, there is a 3-metre hazardous zone 1 around the vent mast outlet, and a 1.5-metre hazardous zone 2 beyond the zone 1 area. As MAN Diesel & Turbo’s recommendation is to have a separate HP vent mast for ME-GI application, it is recommended to plan the location of at least two vent masts (1x HP and 1xLP) already at the new-building stage.

For the high-pressure gas purge line from the ME-GI engine, a silencer is also required upstream of the vent mast to reduce the noise during gas blow-off and the subsequent decompression of the gas. Gas detectors can be mounted in or just after the silencer, which gives feedback to the GI ECS to detect when the gas purge is complete. For this reason, it is not recommended to join the piping after the silencer with any other pipes leading to the vent mast, as this could lead to back flow of gases to the gas detectors, which could give false positives to the GI ECS for gas detection.

**Retrofit**
MAN Diesel & Turbo’s PrimeServ organisation can be contracted to perform such a retrofit whether it is just a main engine upgrade to gas or for a turnkey contractor. Please contact your nearest PrimeServ representative for more information.

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Fig. 11: HP gas silencer from ME-GI