The MEGI engine

Giorgos Plevrakis
Head of Power Plant and Turbomachinery

MAN Diesel & Turbo Hellas
**The world's first ME-GI LNG Carrier**
Launching at DSME, Korea, May 2015

<table>
<thead>
<tr>
<th>Order details</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>No. of ships:</td>
<td>5 + 5 options</td>
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<tr>
<td>No. of engines:</td>
<td>10 + 10</td>
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<tr>
<td>Ship type:</td>
<td>LNG tankers</td>
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<tr>
<td>Capacity:</td>
<td>173,400 CBM</td>
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<tr>
<td>Engine type:</td>
<td>2 x 5G70ME-C9-GI</td>
</tr>
<tr>
<td>Builder:</td>
<td>Hyundai</td>
</tr>
<tr>
<td>Yard:</td>
<td>DSME</td>
</tr>
<tr>
<td>Owner:</td>
<td>Teekay</td>
</tr>
<tr>
<td>Fuel type:</td>
<td>HFO, MGO, NG</td>
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LNGC NB market share in Korea
2000 ~ 2015 July

S/T
2 Stroke
DFDE
X-Df
ME-GI

LNGC NB market share in Korea 2000 ~ 2015 July
## ME-GI
### Operation Hours on Dual Fuel

<table>
<thead>
<tr>
<th>Engine type</th>
<th>Owner</th>
<th>Engine builder</th>
<th>Operation hours on Dual Fuel</th>
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<tbody>
<tr>
<td>4T50ME-X-GI</td>
<td>DRC</td>
<td></td>
<td>473</td>
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<tr>
<td>8S70ME-C8.2-GI</td>
<td>HHI-EMD</td>
<td></td>
<td>268</td>
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<tr>
<td>6S70ME-C8.2-GI</td>
<td>MES</td>
<td></td>
<td>230</td>
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<tr>
<td>2S50ME-GI</td>
<td>KHI</td>
<td></td>
<td>100</td>
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<tr>
<td>8L70ME-C8.2-GI</td>
<td>TOTE 1</td>
<td>Doosan</td>
<td>141</td>
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<td>TOTE 2</td>
<td>Doosan</td>
<td>101</td>
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<td>5G70ME-C9.2-GI</td>
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<td>HHI-EMD</td>
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<td>5G70ME-C9.2-GI</td>
<td>TK 3</td>
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<td>5G70ME-C9.5-GI</td>
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<td>6S50ME-C8.2-GI</td>
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<td>HHI-EMD</td>
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<tr>
<td>6S50ME-C8.2-GI</td>
<td>NavGas 2</td>
<td>HHI-EMD</td>
<td>delivered</td>
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<tr>
<td>6S50ME-C8.2-GI</td>
<td>NavGas 3</td>
<td>HHI-EMD</td>
<td>ongoing test</td>
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<td>6S50ME-C8.2-GI</td>
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<td>Crowley</td>
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<td>delivered</td>
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<tr>
<td>8S50ME-C8.2-GI</td>
<td>Wallenius NYK</td>
<td>KHI</td>
<td>ongoing test</td>
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<tr>
<td>7G70ME-C9.5-GI</td>
<td>Elcano 1</td>
<td>MES</td>
<td>delivered</td>
</tr>
<tr>
<td>7G70ME-C9.5-GI</td>
<td>Knutsen 1</td>
<td>HHI-EMD</td>
<td>delivered</td>
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<tr>
<td><strong>Total running hours</strong></td>
<td></td>
<td></td>
<td><strong>1784</strong></td>
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Delivery of Dual Fuel engines has become a daily routine.

Note: The GI system has been in service for approx. 20,000 hours on the Chiba Power Plant in Japan. It was a 12K80MC-GI-S version.
Ethane Engine Sub-Con Order:

- Hartmann Reederei
- Sinopacific Shipyards
- 3 x 36K cbm. LEG Carrier
- TIER II
- 7G50ME-C9-GI-Ethane (MES)
- 400 bar injection pressure
- Alpha CPP with Kappel design
- Shaft Alternator System
- Delivery: 2015/16
The Worlds First ME-LGI Methanol Engine
Shop Test at Mitsui, Japan, June 2015

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<tr>
<th>Order details</th>
<th>2 + 1 options</th>
<th>2 + 1</th>
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<td>No. of ships:</td>
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<tr>
<td>No. of engines:</td>
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<td></td>
</tr>
<tr>
<td>Ship type:</td>
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<td>Capacity:</td>
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<tr>
<td>Engine type:</td>
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<tr>
<td>Builder:</td>
<td>Mitsui</td>
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<tr>
<td>Yard:</td>
<td>MNS</td>
<td></td>
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<tr>
<td>Engine delivery year:</td>
<td>2015</td>
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</tr>
<tr>
<td>Fuel type:</td>
<td>HFO, MGO, Methanol</td>
<td></td>
</tr>
</tbody>
</table>
Gas valve leakage system

LNG tank
Inert gas system
Gas control block
Gas channel pressure sensor

Gas control block
Gas channel pressure sensor

Hydraulic oil
Sealing oil
Engine room
Open air

Gas valve leakage system

Gas control block
Gas channel pressure sensor
ME-ECS & PMI-Online connected
Closed loop PMI-Autotuning

Engine Monitoring System
PMI DAU
PMI sensor data

MAN LAN
EMS - MOP

PMI + CoCoS

MOP

ACU1
ACU2
ACU3

EICUB
EICUA

ECU A
ECU B
CCU 1
CCU 2
CCU n

SACU
SPCU
SPSU

SCSU

ECU A

ACU1
ACU2
ACU3

MOP

SCSU

ECU B
Dual Fuel engine design
ME-GI / ME-LGI
ME-GI
Combustion Concept

1. From actual footage (colorized)
   - Yellow = pilot oil
   - Blue = gas fuel

2. Conventional slide fuel valve
3. Gas fuel valve
4. Gas distribution channel (yellow)
5. Gas distributor block
6. Gas chain link double-walled pipes
ME-GI Design
Chain Link Double Walled Gas Supply Pipes
ME-GI Gas control block
ME-GI gas injection sealing
Sealing Solutions for GI-valve in Cylinder Cover

Naming of tested sealing solutions:
- “Bare” covers
- Chrome plating in cover
  - Hartchrom
  - Jonghap
- Hardened bushing
Interlocked Gas Injection Sequence

Gas Injector

Window Valve

Gas Channel

Gas Control Block
Interlocked Gas Injection Sequence
Before gas injection

- Closed gas injector
- Closed window valve

Diagram with symbols for gas injection control system.
Interlocked Gas Injection Sequence
Window opens

Closed gas injector

Open window valve
Interlocked Gas Injection Sequence
Gas injection

Open gas injector

Open window valve
Interlocked gas injection sequence
Gas injection ends

Closed gas injector

Open window valve
ME-GI
Gas Injection Control

Interlocked gas injection sequence
Window closes – cycle finished

Closed gas injector

Closed window valve
GI valve and Window-valve leakage detection methods, principle
ME-GI Combustion Principle

- The ME-GI engine is a dual fuel engine
- Diesel combustion process
- High efficiency
From Gas Tank to Combustion Chamber

Pressure [bar]

Methane Pressure-Enthalpy Diagram
S = Specific Entropy, kJ/kg*K
T = Temperature, °C

Corresponding to 2.5-3.0% of engine shaft power

- Cryogenic system for ME-GI
- Cryogenic system for DF Otto
- Compressor system for ME-GI
- Compressor system for DF Otto
**ME-GI Gas Fuel Mode**
Port to port in dual fuel mode

**Fuel oil only mode**
- Operation profile as conventional engine

**Dual fuel operation mode**
- No fuel slip
- No knocking problems
- Insensitive to gas fuel
- Unchanged load response

**News:**
Reduced pilot oil amount 5% → 3%
Reduced load on gas → 10% load
The World’s First ME-GI Retrofit Project
Service Delivery Test November 2015

Gas Valve Train (GVT)
Fuel Gas Supply System (FGSS)

Conversion of 2 x 7S70ME-C to ME-GI engine x 2

Submerged LNG feed pumps in cargo tank 4 + 5

Q-Max
- 266,000 m³ LNG
- Length: 345 m
- Breadth: 54 m
- Depth: 27 m
# Engine Retrofit

## From ME to ME-GI engine

<table>
<thead>
<tr>
<th>Changed or modified item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder covers</td>
</tr>
<tr>
<td>Engine hydraulic system</td>
</tr>
<tr>
<td>Exhaust valves</td>
</tr>
<tr>
<td>Fuel oil high pressure pipes</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Additonal item</th>
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</thead>
<tbody>
<tr>
<td>Gas Control Block complete</td>
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<tr>
<td>Gas injector valves</td>
</tr>
<tr>
<td>Sealing oil unit</td>
</tr>
<tr>
<td>Control- and sealing oil pipes</td>
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<tr>
<td>Atomizers for fuel injector valves</td>
</tr>
<tr>
<td>Gas pipe arrangement on engines</td>
</tr>
<tr>
<td>Control and safety system (GI-ECS)</td>
</tr>
</tbody>
</table>

![Diagram of engine retrofit](image)

- Gas injection valve
- Cylinder cover
- Control oil pipes
- Sealing oil pipes
- Gas control block
- Double-walled gas pipe

**Engine Retrofit Diagram:**

- Gas injection valve
- Cylinder cover
- Control oil pipes
- Sealing oil pipes
- Gas control block
- Double-walled gas pipe
Function Test

Ident No.: 0743879-2

Tightness Test of Gas Cylinder Cover with Gas Components, sub-assembly

Scope and Field of Application
This Production Recommendation describe the guidelines for tightness check of the assembled gas cylinder cover with mounted gas block, window valve, gas injection valve mounted in the cylinder cover.

The verification test of no leakage can be performed during sub-assembling.

Development of pre-function test procedures for main gas components before installation on engine.
The Nakilat MEGI Conversion Project
From Heavy Fuel Oil to LNG

Vessel: Rasheeda
FGSS: TGE - Germany
Yard: NKOM - Qatar

MDT site team

Engine work
Cylinder pressures & Scavenge air pressure from gas trial

- Pmax
- Pcomp
- Pscav

Engine load [% of Specified Maximum Continuous Rating]

- Gas + min. pilot
- Diesel
- Specified Dual Fuel, 50% gas
Gas Shut Down – Rasheeda CoCoS data

- Fuel Gas supply pressure
- GTIV (Gas train) pressure
- Fuel Gas inlet pressure
- Change over from dual fuel to fuel mode
- Fuel load (black)
- Gas load (blue)
- Fuel Gas pressure set point (red)
Gas Shut Down – Rasheeda
Data from unit #1

- Raw Engine speed
  (Speed drop 7 RPM, recovered after few seconds)

- Cylinder pressure

- Fuel oil injection

Gas shut down – Fuel recovery within one revolution
Worlds First ME-GI engined Vessel
Launching at NASSCO, April 2015
Gas trial successfully completed October 2015
ME-GI & LGI of MAN Diesel & Turbo
Uncompromisingly Diesel

- No methane slip
- No gas-quality issues
- No multiple de-ratings
- No heavy weather issues
- A fully proven concept backed up by FATs and more than 120 orders
New Concepts coming, TCEV + FBIV

Top Controlled Exhaust Valve (TECV)

FBIV + TCEV tested on Mitsui test engine 4S50ME-T9 2014
Lower weight (cost?) and fuel consumption suggested
Why do LNG carriers need either a SCR or an EGR to meet tier III?

Operating dual fuel engines on gas requires that gas is available, but this is not always the case for LNG carriers.

- When the charter requires to empty the LNG tanks.
  - When the ship runs out of gas.
  - When oil are cheaper than gas.

**EGR/SCR gives full fuel flexibility in Tier III areas, and avoid the need for tugboats.**

Lately we have learned that full redundancy in fuel choice is needed.
New FGSS Makers
SHI
New compressor makers
MES

High Pressure Gas Compressor
1st combined test with ME-GI

⇒ 1st combined test is scheduled in **July 2015** at MES Tamano works

with 8S70ME-C8.2-GI (26,160kW) by using of actual fuel gas
New compressor makers
Kobelco
New compressor makers
GE – (former Camaron compressors)

COMPACT DESIGN - 2

Having a wider compressor room is difficult due to given gas dome location and main pipe routing near the compressor room. So compact design is preferred.

Securing visibility around the manifolds from the bridge is very important for safe operation during cargo loading/unloading operation.
All data provided in this document is non-binding. This data serves informational purposes only and is especially not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.