The 2-stroke ME-LGIM

The dual fuel engine designed for operation on Methanol

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CSSC-MES Diesel Co. Celebration
Manufacturing 10 million MAN Diesel & Turbo designed BHP
## Dual fuel engine reference list

Orders including options

<table>
<thead>
<tr>
<th>No. of engines</th>
<th>Type</th>
<th>Type</th>
<th>Mk.</th>
<th>Gensets</th>
<th>Fuel</th>
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<tbody>
<tr>
<td>5</td>
<td>S</td>
<td>90</td>
<td>ME-C-GI</td>
<td>10.5</td>
<td>Methane</td>
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<td>G</td>
<td>90</td>
<td>ME-C-GI</td>
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<td>128</td>
<td>G</td>
<td>70</td>
<td>ME-C-GI</td>
<td>9.5 , 9.2</td>
<td>Methane</td>
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<td>5</td>
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<td>Methane</td>
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<td>S</td>
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<td>8.2, 7</td>
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<td>6</td>
<td>S</td>
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<td>ME-C-GI</td>
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<td>Methane</td>
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<tr>
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<td>G</td>
<td>50</td>
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<tr>
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<td>G</td>
<td>45</td>
<td>ME-C-GI</td>
<td>9.5</td>
<td>Methane</td>
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<tr>
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<td>G</td>
<td>50</td>
<td>ME-B-LGIM</td>
<td>9.5</td>
<td>Methanol</td>
</tr>
<tr>
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<td>S</td>
<td>50</td>
<td>ME-B-LGIM</td>
<td>9.3</td>
<td>Methanol</td>
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<tr>
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<td>G</td>
<td>60</td>
<td>ME-C-GIE</td>
<td>9.5</td>
<td>Ethane</td>
</tr>
<tr>
<td>3</td>
<td>G</td>
<td>50</td>
<td>ME-C-GIE</td>
<td>9.5</td>
<td>Ethane</td>
</tr>
</tbody>
</table>

### Total dual fuel engines including options

177 engines

### Total power main engine

3.19 GW

### Total dual fuel 2-Stroke in service

28 engines
Korea and Japan Welcome the First Methanol-Fueled, Ocean-Going Vessels

Starting on April 18, Waterfront Shipping Company Ltd. (WFS), Marinvest/Skagerack Invest (Marinvest), Westfal-Larsen Management (WL), and Mitsui O.S.K. Lines, Ltd. (MOL) attended a series of traditional ship-naming ceremonies and took delivery of the first Korean- and Japanese-built, methanol-fueled ocean tankers – the ‘Lindanger’, ‘Mari Jone’ and ‘Taranaki Sun’.

All 7 Methanol-fuelled vessels entered service in 2016

Today more than 7500 operations hours on methanol
ME-GI and ME-LGI Gas Technologies
ME-LGI Methanol - Development Milestones

LGI demonstration event at MDT 4T50ME-X
Test at MDT 4T50ME-X
Test at MES 4S50ME-T9
Test at MES 7S50ME-B9.3
Celebration at MES
Test at HHI 7G50ME-B9.3
TAT at MES 4S50ME-T9
Sea trial MNS Taranaki Sun
Sea trial HMD Lindanger
Sea trial HMD Mari Jone
Sea trial HMD Leikanger
Sea trial M752

2015 2016 2017
The ME-GI is derived from the industry’s standard MC and ME engine.

- **Diesel cycle** high fuel efficiency ~50% versus much lower for other engine types.
- High fuel flexibility
- High **reliability** – same as fuel engines.
- **No derating** because of **knocking** danger.
- **Negligible fuel slip.**
- A robust gas combustion – unchanged load response – unaffected by ambient condition
ME-LGI Combustion Principle

- The ME-LGI engine is a dual fuel engine
- Diesel combustion process →
- High efficiency

Main injection

Pilot injection
Dual Fuel Operation Keep the Power

Fuel-oil-only mode

Fuel

100% load

Maximum-gas-amount mode

Fuel

Gas

100% load

Automatic switch-over between gas and pilot oil or fuel injection at 10% load

% Gas

% Pilot

5%
ME-LGI-S System Overview

- Air supply 7 bar
- Fuel valve train
- Liquid fuel gas
- Liquid fuel gas service tank
- Vent
- Outside engine hall
- Inside engine hall
- Cooling oil system
- Purge return system
- Supply pressure and temperature according to specification
- Liquid fuel gas tank
- Standard piping
- Double-walled piping, ventilated
- Double-walled piping

Liquid Fuel Gas Supply System
ME-GI and ME-LGI Gas Technologies

ME-LGI G50 and S50 Methanol Engines: Service Experience

**Service status:**
- 4 vessels from HHI in service
- 1 out of 3 vessel from MES in service
- Approx. 7500 service hours
- First start up of MeOH operation was carried out by the crew alone

**Challenges:**
- Plunger in good condition after shop-test
- Cut-off shaft in good condition after shop-test
- Atomiser in good condition after shop-test
- Broken springs in fuel diesel fuel valves
- Unstable HC sensors fixed
- Several SW bugs have disturbed operation
To reach Tier-III NOx emissions:

- Tested at Mitsui test engine with compromised performance setup
- Two separate technologies:
  - EGR
  - Water mixing in methanol

EGR

- The same EGR system and settings were used for diesel (DI) and methanol (LGI)
- Duration: 4 days September 2016

Methanol + water

- Water was mixed into the methanol in order to cool the flame, which should reduce the thermal NOx production
- Duration: 2 days September 2016

<table>
<thead>
<tr>
<th>Engine</th>
<th>4S50ME-T-9.5-LGI</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCR rating</td>
<td>7120kW @ 117 rpm</td>
</tr>
<tr>
<td>MIP</td>
<td>21 bar</td>
</tr>
<tr>
<td>Bore</td>
<td>0.5 m</td>
</tr>
<tr>
<td>Stroke</td>
<td>2.214 m</td>
</tr>
<tr>
<td>Cylinders</td>
<td>4</td>
</tr>
<tr>
<td>$V_{\text{comp}}$</td>
<td>20 liter /cyl.</td>
</tr>
<tr>
<td>Fuels</td>
<td>Diesel and methanol</td>
</tr>
</tbody>
</table>
ME-GI and ME-LGI Gas Technologies
ME-LGI: Performance Results: EGR - SFOC and NOx

<table>
<thead>
<tr>
<th>Tests</th>
<th>#</th>
<th>NOx ISO</th>
<th>ΔSFOC ISO (relative to LGI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DI</td>
<td>T60</td>
<td>14,0</td>
<td>+10,8</td>
</tr>
<tr>
<td>DI+EGR</td>
<td>T63”</td>
<td>6,2</td>
<td>+14,1</td>
</tr>
<tr>
<td>LGI</td>
<td>T62</td>
<td>7,8</td>
<td>0</td>
</tr>
<tr>
<td>LGI+EGR</td>
<td>T63’</td>
<td>2,7</td>
<td>+1,8</td>
</tr>
</tbody>
</table>

Tests and performance results for EGR - SFOC and NOx.
NOx decreases almost linearly with water content.

- NOx emissions are close to 2 g/kWh at 50 and 75% load.
- NOx emissions at 25% load is at the “not to exceed limit” for Tier-III, but can be lowered further.
- 100% load with high water content not possible due to system limitations.
The 3rd option tier III: Water in Methanol is under investigation.

Tier III can be met with a mixture of 40% water and 60% methanol
Long term effect on liner and piston ring wear needs to be investigated
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