Making Marine Applications Greener 10-11 October 2018

Two stroke methanol engines
Design and Manufacturing
Copenhagen, Denmark

- Design of Two-Stroke Engines
- Production of Spare Parts
- PrimeServ Academy
- R&D Center
- Diesel House

Employees (31.12.2016): 1,250
CSSC-MES Diesel Co. Celebration
Manufacturing 10 million MAN Diesel & Turbo designed BHP
License Network Developing and Concentrating where Ships are Built

- **China**
  - HHM: 1980
  - DMD: 1980
  - YMD: 1989
  - CMD: 2007
  - STX: 2007
  - JAD: 2007
  - ZJCM: 2008
  - ZHD: 2008
  - RPM: 2008
  - YungPu: 2008

- **Croatia**
  - Uljanik: 1954
  - Split: 1967

- **Korea**
  - Hyundai: 1976
  - Doosan: 1983
  - STX: 1984

- **Russia**
  - Bryansk: 1959

- **Vietnam**
  - Vinashin: 2004

- **Poland**
  - Cegielski: 1959

- **Japan**
  - Mitsui: 1926
    - Makita: 1981
    - Diesel United: 2008
  - Hitachi: 1951
    - Incl. IMEX
    - Kawasaki: 1923
      - Incl. Hanjin

- **Croatia**
  - Split: 1967

- **Korea**
  - Hyundai: 1976
  - Doosan: 1983
  - STX: 1984

- **Russia**
  - Bryansk: 1959

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  - Vinashin: 2004

- **Poland**
  - Cegielski: 1959

- **Japan**
  - Mitsui: 1926
    - Makita: 1981
    - Diesel United: 2008
  - Hitachi: 1951
    - Incl. IMEX
    - Kawasaki: 1923
      - Incl. Hanjin
# Total Reference List ME / MC 1982 - 2020

**MAN B&W Two-stroke Engines**

### ME-GI
- K98: 718
- K90: 549
- K80: 217
- L90: 26
- L80: 194
- L70: 356
- L60: 676
- L50: 356
- L42: 181
- L35: 1,219

### ME-LGIM
- S90: 489
- S80: 582
- S70: 2,205
- S65: 90
- S60: 4,784
- S50: 6,147
- S46: 870
- S42: 867
- S40: 126
- S35: 1,175
- S30: 6
- S26: 210

### ME-LGIE
- G95: 78
- G90: 8
- G80: 289
- G70: 447
- G60: 534
- G50: 422
- G45: 38

### ME-LGIP
- Dual fuel type
  - ME-GI: 121
  - ME-GIE: 8
  - ME-LGIM: 9

As of 2017.12.01

**Total:** 362 GW

**Total 23,859 Engines**
MAN Diesel & Turbo – Out of one hand:

MAN 2-stroke dual fuel main engine

- Turbocharger
- LNG tanks
- Fuel gas supply system
- Propulsion system
- Emission after treatment
- Auxiliary dual fuel GenSets

MAN PrimeServ
Fuel Types

- Residual ME / MC
- Distillates ME / MC
- ULSFO ME / MC
- Methane ME-GI
- Methanol ME-LGIM
- LPG ME-LGIP
- Ethane ME-GIE
- Biofuel (2nd+3rd gen.) ME / MC

MAN Diesel & Turbo supports all
SOx rules

- Methods for SOx compliance:
  - Operating on low sulfur fuel
  - Using SOx scrubbers
What Fuel will be used in 2020 and beyond?

**Compliant fuel**

MC/ME/-C engine
Single Fuel:
0.1%S fuel, 0.5%S fuel

ME-GI / ME-LGI engine
Dual Fuel:
LNG, Ethane, LPG, MeOH ........

**High-Sulphur fuel**

MC/ME/-C engine
0-5%S fuels:
HFO/MDO + Scrubber

*COMBUSTION CHAMBER: WILL BE DESIGNED WITH A FULL CERMET RING PACK*

*COMBUSTION CHAMBER: ALREADY NOW DESIGNED WITH A FULL CERMET RING PACK*

*COMBUSTION CHAMBER: NO CHANGES AS COMPARED TO TODAY*
Influencing Factors on Fuel Choice

Fuel choice

- CAPEX and OPEX
- Legislation
- Logistics
- Flexibility (dual fuel)
- Sustainability of fuels
- Fuel price

- Distillates
- ULSFO
- LNG
- Ethane
- Methanol
- Heavy fuel
- Biofuel
- LPG
Indexed Fuel Prices

Index: January 2010 = 100

MGO (Rotterdam)
LNG (US)*
HFO (Rotterdam)
Methanol (US)*
Propane (US)*

* US Export prices

Source: Bunkerindex, EIA & Methanex

Data retrieved end May 2018, Dept. EELC
ME-GI engine
GI components
**ME-GI Concept**
Combustion Concept

- Direct injection of pilot oil and gas
  - Yellow = pilot oil
  - Blue = gas
- Conventional slide fuel valve
- Gas fuel valve
- Gas distribution channel
- Gas block
- Gas chain link double-walled pipes
Change-over from Diesel to Gas

Change-over from diesel to ethane

- GasChem Beluga experience rough weather in the Atlantic
- Perfect change over in rough weather condition
The dual fuel options

**ME-LGI**
Available for LPG and Methanol

**ME-GI**
Available for NG and Ethane
The new MAN B&W ME-LGI engine

Two-stroke market – Dual fuel contracting of total contracting

- Highest thermal efficiency
- Lowest unburned hydrocarbons
- Largest range of available fuel types
- Best controlled combustion under all dynamic and ambient conditions
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
Initially Installed Equipment

ME-GI
Available for NG and Ethane

ME-LGI
Available for LPG and Methanol
The Dual Fuel success
4 x World’s first duel fuel driven ships equipped with MAN B&W engines

World’s first methanol driven ocean going ship
Owner: MOL
Ship type: Methanol carrier
Capacity: 50,000 dwt
Dual fuel engine type: 7S50ME-B9.3-LGIM

World’s first LNG driven ocean going ship
Owner: TOTE
Ship type: Container ship
Capacity: 3,100 Teu
Dual Fuel engine type: 8L70ME-C8.2-GI

World’s first ethane driven ocean going ship
Owner: Hartmann Schifffahrt
Ship type: LEG Carrier
Capacity: 36,000 M³
Dual Fuel engine type: 7G50ME-GI

World’s first LPG driven ocean going ship
Owner: Exmar
Ship type: VLGC
Capacity: 80,000 M³
Dual Fuel engine type: 6G60ME-LGIP
The new MAN B&W ME-LGIP engine
Regulation – a driving factor for engine development

Today, focus is on SO$_x$ and NO$_x$:  
- NO$_x$ reduction is achieved with EGR and SCR  
- SO$_x$ reduction is achieved with MGO, LFSO, scrubber, LNG, methanol and LPG

In the future, we will see a growing focus on CO$_2$, methane slip and VOC:  
- 40% reduction of carbon intensity per transport work by 2030 and 70% by 2050 compared with 2008  
- 50% reduction of greenhouse gas emissions from ocean shipping by 2050 compared with 2008  
- Reduction of methane slip emissions $\rightarrow$ Diesel cycles  
- Reduction of VOC emissions $\rightarrow$ ME-LGIP

Our dual fuel engine technology is well suited to support such goals
**WHR System - Configuration:**

- **Dual pressure exhaust gas boiler**
- **Exhaust gas receiver**
- **Main Engine**: 27 – 80 MW<sub>mech</sub>
- **Sum Power Generation (ST/PT)**: 2 – 9 MW<sub>el</sub>
- **Steam Turbine**: 1,5 – 5,5 MW<sub>el</sub>
- **Power Turbine**: 0,5 – 3,5 MW<sub>el</sub>
- **Gearboxes 1 u. 2**
- **Turbocharger**
- **PT1 / PTO**

*Image: MAN Energy Solutions*
New fuels - emissions

<table>
<thead>
<tr>
<th></th>
<th>NOₓ</th>
<th>SOₓ</th>
<th>PM</th>
<th>CO₂</th>
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<tbody>
<tr>
<td>LNG</td>
<td>20-30%</td>
<td>90-99%</td>
<td>90%</td>
<td>24%</td>
</tr>
<tr>
<td>LPG</td>
<td>10-15%</td>
<td>90-100%</td>
<td>90%</td>
<td>13-18%</td>
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<tr>
<td>Methanol</td>
<td>30-50%</td>
<td>90-97%</td>
<td>90%</td>
<td>5%</td>
</tr>
<tr>
<td>Ethane</td>
<td>30-50%</td>
<td>90-97%</td>
<td>90%</td>
<td>15%</td>
</tr>
</tbody>
</table>

- Compared with Tier II engines on HFO
- Based on estimates
Tier III can be met with EGR or SCR

**Note**: For methanol, Tier III can be met by blending with water
IMO Tier III regulation from 2016 in ECA areas

Two-stroke diesel engines

- **Tier I**
  - \( n < 130 \text{ rpm} \rightarrow 17.0 \text{ g/kWh} \)
  - \( 130 \leq n < 2000 \text{ rpm} \rightarrow 45 \times n^{0.2} \text{ g/kWh} \)
  - \( n \geq 2000 \text{ rpm} \rightarrow 9.8 \text{ g/kWh} \)

- **Tier II (Global)**
  - \( n < 130 \text{ rpm} \rightarrow 14.4 \text{ g/kWh} \)
  - \( 130 \leq n < 2000 \text{ rpm} \rightarrow 44 \times n^{0.23} \text{ g/kWh} \)
  - \( n \geq 2000 \text{ rpm} \rightarrow 7.7 \text{ g/kWh} \)

- **Tier III (NOx Emission Control Areas)**
  - 80% reduction of Tier I
Tier III NO\textsubscript{x} Control Technologies
MAN B&W two-stroke engines

Low-sulphur fuel design: Max. 0.10%S

High-sulphur fuel design: Max. 3.5%S

EGR
On-Engine

SCR
High-Pressure

SCR
Low-Pressure

EGR
On-Engine

SCR
High-Pressure

SCR
Low-Pressure
Technologies for emissions reduction
Technical countermeasures – Two stroke

Countermeasures for

<table>
<thead>
<tr>
<th>NO\textsubscript{x}</th>
<th>SO\textsubscript{x}</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGR</td>
<td>MGO, low sulphur HFO</td>
</tr>
<tr>
<td>SCR</td>
<td>Wet Scrubber</td>
</tr>
<tr>
<td>Tier-III Methanol + Water</td>
<td>Methanol, LNG, LPG</td>
</tr>
</tbody>
</table>
Final Tier-III Layout

Emissions
MeOH fuel supply system

System arrangement – blending water and methanol
ME-GI
ME-GI Supply Systems - Solutions implemented

300-bar gas supply system

Open air

Engine room

Cryostar
LNG Pump System

DSME
Burckhardt Compression

Hamworth
LNG Tank & Pump System

TGE

Kobelco
High Pressure Gas Compressor

MHI
LNG Tank & Pump System

HHI
LNG Tank & Pump System

LNG tank

GVT

Inert gas purge system

Hydraulic oil

Sealing oil

Double-pipe ventilation

FS

HP

VP
Conclusions from tier III test
Lowering the emissions with the use of Methanol & Water

- Tier-III, methanol + water, can easily reach Tier-III NOx emission levels.

- The measure SFOC increases 3-6g/kWh compared to the LGI-54 reference when adding water. The fuel penalty might be reduced further by lowering the pilot oil amount. Pilot oil expect to be reduced to 1%.

- Tier-III did not show increased liner wear. Inspection showed no significant alterations after the Tier-III tests.

- Component temperatures were lowered or unchanged when adding water.

- CO and HC emissions did not change indicating that the combustion process is not worsened.

- Longer time service test will however be mandatory before first engine delivery of a Methanol tier III engine.
Port inspection

- Scavenge port inspections before and after the Tier-III tests showed no visible changes.
- The number of running hours might however have been too few to detect small, but significant, changes.
Orders including options and engines in service

<table>
<thead>
<tr>
<th>No. of engines</th>
<th>Engine type</th>
<th>Mk.</th>
<th>Gensets</th>
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</thead>
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<tr>
<td>5</td>
<td>S 90</td>
<td>10.5</td>
<td>ME-C-GI</td>
</tr>
<tr>
<td>12</td>
<td>G 90</td>
<td>9.5, 10.5</td>
<td>ME-C-GI</td>
</tr>
<tr>
<td>4</td>
<td>S 80</td>
<td>9.5</td>
<td>ME-C-GI</td>
</tr>
<tr>
<td>6</td>
<td>S 70</td>
<td>7, 8.2, 10.5</td>
<td>ME-C-GI</td>
</tr>
<tr>
<td>148</td>
<td>G 70</td>
<td>9.2, 9.5, 10.5</td>
<td>ME-C-GI</td>
</tr>
<tr>
<td>5</td>
<td>L 70</td>
<td>8.2</td>
<td>ME-C-GI</td>
</tr>
<tr>
<td>2</td>
<td>S 60</td>
<td>10.5</td>
<td>ME-C-GI</td>
</tr>
<tr>
<td>8</td>
<td>S 50</td>
<td>8.2, 9.5</td>
<td>ME-C-GI</td>
</tr>
<tr>
<td>5</td>
<td>G 50</td>
<td>9.5</td>
<td>ME-C-GI</td>
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<td>4</td>
<td>G 45</td>
<td>9.5</td>
<td>ME-C-GI</td>
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<td>11</td>
<td>G 50</td>
<td>9.3, 9.5, 10.5</td>
<td>ME-B/ME-C –LGIM</td>
</tr>
<tr>
<td>3</td>
<td>S 50</td>
<td>9.3</td>
<td>ME-B-LGIM</td>
</tr>
<tr>
<td>18</td>
<td>G 60</td>
<td>9.5</td>
<td>ME-C-GIE</td>
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<td>3</td>
<td>G 50</td>
<td>9.5</td>
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</tr>
<tr>
<td>10</td>
<td>G 60</td>
<td>10.5</td>
<td>ME-C-LGIP</td>
</tr>
</tbody>
</table>

Total dual fuel engines including options: 244 engines
Total power main engine: 4.9 GW
Total dual fuel 2-Stroke in service: 55 engines

Methane
Methanol
Ethane
LPG
Car Battery

Approx. 300000 kJ

Ca. 1.5 M
ECA operation on "Battery"

- **Assumptions**
  - 40 Hours operation at 50 % MCR power
  - Storage units:
    - One 18.6 kWh battery

<table>
<thead>
<tr>
<th></th>
<th>Battery</th>
<th>22 feet containers</th>
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</thead>
<tbody>
<tr>
<td>Large container: 800.000 kWh</td>
<td>43000</td>
<td>150</td>
</tr>
<tr>
<td>VLCC/VLOC: 500.000 kWh</td>
<td>27000</td>
<td>100</td>
</tr>
<tr>
<td>Suezmax: 300.000 kWh</td>
<td>16000</td>
<td>50</td>
</tr>
<tr>
<td>MR tanker: 140.000 kWh</td>
<td>7500</td>
<td>25</td>
</tr>
</tbody>
</table>
Thank you!
Do you have any questions?