Dual Fuel Seminar, Athens

Market update, dual fuel engines & SOx 2020 sulphur cap

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23rd October 2019
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1. Marine market, merchant vessels
2. Dual fuel main engines & GenSets
3. 2020 Sulphur cap challenges & solutions
Stable World Trade Fundamentals

Global GDP will continue to grow

Source: IMF & Lloyd’s List Intelligence
Global trade will also continue to grow

Global seaborne trade will grow 33% within next 10 years

78% of all goods transported is seaborne
Regulation – a driving factor for engine development

- **SO\textsubscript{x}**
- **NO\textsubscript{x}**
- **GHG**

Our forecast indicates a slow recovery
Legislation will impact the pace of recovery
Dry bulk market is accelerating

Relatively small order book and high demand from China
Improving efficiency is key to winning

New engines for the bulker market

Reductions at 85% load for L1 engine
- G80ME-C10.5 - 2 g/kWh
- G70ME-C10.5 - 4 g/kWh
- G60ME-C10.5 - 2 g/kWh
- S65ME-C8.6  - 3.5 g/kWh
- S60ME-C10.5 - 3 g/kWh

Ensure optimum propeller diameter for low-speed vessels

G80ME-C10.5 layout diagram extended down to 58 rpm

S65ME-C8.6 layout diagram extended down to 75 rpm
Container market is growing, but at a slow pace

Increasing bunker cost and demand for decarbonisation are leading to faster renewal of fleet

Source: IHS Markit & MAN ES
Improving efficiency is key to winning

ULCVs and New Panamax designs
- G95ME-C10.5 ensures maximum efficiency
- 6.7% saving with G95ME-C10.5-EcoEGR and optimised propeller compared to S90ME-C9.2

New engines for booming feeder-segment
Reductions at 85% load for L1 engine:
- S70ME-C10.5 - 3 g/kWh
- G60ME-C10.5 - 3 g/kWh
- S50ME-C9.7 - 4 g/kWh

G60ME-C10.5 layout diagram extended up to 103 rpm to suit the higher speed of feeder vessels
Crude tankers short term market is stable

50% of new refineries are built in India and in non-OECD countries
Efficiency and lower capex is key to winning

Aframax
- G60ME-C10.5 - 3 g/kWh
- S60ME-C10.5 - 3 g/kWh

Suezmax
- G70ME-C10.5 - 4 g/kWh
- S70ME-C10.5 - 3 g/kWh
- S65ME-C8.6 - 3.5 g/kWh

VLCC
- G80ME-C10.5 - 2 g/kWh

Reductions are stated at 85% load for L1 engine
Product tankers are accelerating growth

IMO sulphur cap is increasing the demand for capacity

Number of ships

Source: IHS Markit & MAN ES

- Small
- Handysize
- Handymax
- Panamax
New engines tailored for specific designs

Continuous improvements

Reductions at 85% load for L1 engine
- S50ME-C9.7 - 4 g/kWh
- G50ME-C9.6 - 2 g/kWh
- S46ME-C8.6 - 2 g/kWh

Large rpm-range of engines for product tankers – suitable solution for every size and design speed

Low-rpm extension of layout diagram of S50ME-C9.7 to provide high-efficiency solutions for slower vessels
LNG carrier market is growing

LNG is seen as the major transition energy source
Several major projects are in the pipeline

Source: IHS Markit & MAN ES
>550,000

Duel Fuel operation hours from 107 engines in service
The Multifuel success
4 x World’s first duel fuel driven ships equipped with MAN B&W engines

- **World’s first LNG driven ocean going ship 2014**
  - **Owner:** TOTE
  - **Ship type:** Container ship
  - **Capacity:** 3,100 Teu
  - **Dual Fuel engine type:** 8L70ME-C8.2-GI

- **World’s first methanol driven ocean going ship 2016**
  - **Owner:** MOL
  - **Ship type:** Methanol carrier
  - **Capacity:** 50,000 dwt
  - **Dual fuel engine type:** 7S50ME-B9.3-LGIM

- **World’s first ethane driven ocean going ship 2017**
  - **Owner:** Hartmann Schifffahrt
  - **Ship type:** LEG Carrier
  - **Capacity:** 36,000 M³
  - **Dual Fuel engine type:** 7G50ME-GIE

- **World’s first LPG driven ocean going ship 2020**
  - **Owner:** Exmar
  - **Ship type:** VLGC
  - **Capacity:** 80,000 M³
  - **Dual Fuel engine type:** 6G60ME-LGIP
MAN B&W ME-GA dual-fuel engine
Targeting LNG carriers

Why?

The high cost of high pressure BOG compressors for LNG carriers
ME-GA  Low pressure gas engine

Project background:
HP gas → High CAPEX for BOG compressor
MAN ES loosing LNGC market share.

Goal
Re-capture LNGC market with LP gas product focused on competitive system CAPEX and OPEX.

Project timeline
Delivery of commercial engines from end 2021.

ME-GI
The ME-GI remains the most efficient, lowest CO₂ and GHG emissions, most proven and by far best business case for merchant ships
LPG carrier market is also growing

Following a few years with difficult market conditions, things are now improving.
The LGIP technology is key to carbon-free shipping

The LGIP technology is future-proof:
- LPG burning engine
- methanol burning engine
- volatile organic compounds (VOC) on crude and shuttle tankers
- ammonia
- new Tier III solutions using water emulsified in fuel
Will the auxiliary market also change?

Auxiliary market will gradually change towards more holistically optimised systems.
MAN Dual Fuel GenSets
L28/32DF, L23/30DF and L35/44DF

Current power range
- L23/30DF  625 – 1,000 kW  ➔  900 rpm version with increased power output  ➔  625 – 1,200 kW
- L28/32DF  1,000 – 1,800 kW
- L35/44DF  3,060 – 5,300 kW

Reliable operation
- More robustness, lower energy consumption, lower emissions.

Full fuel flexibility
- Full IMO Tier III compliance with SCR in both gas and diesel operation
- Wider range of liquid fuels will be tested

Competitive CAPEX – simplified fuel injection system
- Cost down activities
2020 Sulphur Cap
At the doorstep......

0.50 % S Fuel

Challenges & Solutions
Which solution will dominate 2020 Sulphur cap?

IMO global sulphur cap of 0.5% on 1 January 2020

<table>
<thead>
<tr>
<th>Compliant fuel</th>
<th>High-sulphur fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MC/ME-C engine:</strong></td>
<td><strong>MC/ME-C engine:</strong></td>
</tr>
<tr>
<td>0-0.50% S fuel</td>
<td>0-3.50% S fuel + scrubber</td>
</tr>
<tr>
<td><strong>Dual fuel ME-GI/ME-LGI engine:</strong></td>
<td></td>
</tr>
<tr>
<td>LNG, ethane (LEG), MeOH, LPG and 0-0.50% S fuel</td>
<td></td>
</tr>
</tbody>
</table>
It is expected that the 0.50% S VLSFO types will be fully capable of being categorized within the existing ISO 8217 standard.
### Examples of 0.50% S VLSFO

Fuel diversity within an ISO Grade is expected to increase

<table>
<thead>
<tr>
<th>0.50%S VLSFO</th>
<th>Kin. Visc. at 50°C, cSt</th>
<th>Density at 15°C, kg/m³</th>
<th>Pour point, °C</th>
<th>Al+Si, ppm</th>
<th>MAN ES comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel 1</td>
<td>45</td>
<td>990</td>
<td>27</td>
<td>&lt; 15</td>
<td>Unusual viscosity (low) to density (high) relationship. Note: high pour point.</td>
</tr>
<tr>
<td>Fuel 2</td>
<td>360</td>
<td>969</td>
<td>&lt;24</td>
<td>55</td>
<td>Al+Si: above average. Pour point may be high.</td>
</tr>
<tr>
<td>Fuel 3</td>
<td>7.4</td>
<td>885</td>
<td>-24</td>
<td>28</td>
<td>Very low viscosity and density. High Al+Si</td>
</tr>
<tr>
<td>Fuel 4</td>
<td>215</td>
<td>942</td>
<td>30</td>
<td>45</td>
<td>Al+Si: above average. Note: high pour point.</td>
</tr>
<tr>
<td>Fuel 5</td>
<td>60</td>
<td>985</td>
<td>&lt; -3</td>
<td>33</td>
<td>Al+Si: above average. Unusual viscosity (low) to density (high) relationship.</td>
</tr>
</tbody>
</table>
Challenges 0.50% S VLSF

Properties of the 0.50% S VLSFO family

- Cat fines
- Viscosity
- Density
- Pour point
- Compatibility

Compatible fuel blend
Incompatible fuel blend
Challenges 0.50% S VLSF

What to consider – for the ship?

Properties of the 0.50% S VLSFO family

- Cat fines
- Viscosity
- Density
- Pour point
- Compatibility

Low

Compatibility of mixed fuels

Fuel change-over

Temperature

Viscosity

Clean the fuel

Fuel tank system considerations
What to consider - Main Engine

- Cylinder condition
  - piston rings
  - lubrication

- High-pressure fuel pumps
  - Viscosity variations

- Liner cooling
  - Reduced heating needs due to less corrosion
Solutions

0.50% S fuel operation 2020

MAN Energy Solutions
Future in the making

Important service letters and papers on MAN B&W two-stroke engines

Do you have questions about 0.50% sulphur (S) operation? Or do you consider retrofitting a scrubber? MAN Energy Solutions has issued information and recommendations relevant to 0.50% S operation and how to prepare for IMO’s global 0.50% sulphur limit. Check on the link below and chew it well!

Main 2019 information on 0.50% S fuel operation

This service letter and paper listed below provide information and guidance on 0.50% S fuel operation and how to prepare for the change from operation on high-sulphur fuel to 0.50% S fuel. Attention is drawn to specific fuels properties that change in fuel and how 0.50% S fuels affect the equipment on-board. Expectations for the new types of fuels are given, and information on fuel testing, blending, and fuels that are not fit for purpose is also included.

- [MAN-2019-675] - Operation on fuels with max. 0.50% S
- Paper: [MAN-2019-679] - Operation on fuels with max. 0.50% S
- [MAN-2019-680] - Operation on fuels with max. 0.50% S

Cylinder lubrication

The cylinder lubrication recommendation has undergone extensive revision. The three most important factors are, 1. cleanliness of the piston ring pack, 2. feed ratio and 3. race monitoring of the cylinder condition and appropriate action.

- [MAN-2019-671] - Cylinder lubrication guidelines for 0 to 0.50% sulphur fuels
- [MAN-2019-672] - Cylinder lubrication guidelines for engines with sulphur content of 0.10% (or lower)

Fuel cleaning

Fuel cleaning and removing salt (MGO) are and will still be very important.

- [MAN-2019-671] - Fuel tank cleaning
- [MAN-2019-679] - Cleaning of heavy fuel oil and maximum 0.50% S fuels - How to remove oil fines
- [MAN-2019-690] - Impact on engine wear and how to reduce wear

Scrubbers

MAN PrimeServ offers a SO scrubber retrofit package with recommendations on the Kurner/Bergman engine parts.

- [MAN-2019-995] - SO scrubber retrofit on two-stroke engines in service

Link to Service Letters (Su)

- https://www.man-es.com/tea-two-stroke/service-letters

Link to Technical Papers:

- https://www.man-es.com/tea-two-stroke/technical-papers
What to consider - Vessel
Prepare, Act and Implement

Regulations and Ship updates

• Be informed about the regulations, e.g. sulphur limitations, HS HFO carriage ban.

• 0.50% S compliance options: 0.50%S VLSFO, SOx scrubber, LNG, liquefied ethane, methanol, LPG.

• Make a Ship Implementation plan for each of the vessel and execute it.
  1. Now and until 2020
  2. Operation after 2020
**Fuel systems - New Buildings**

Increased fuel flexibility can be achieved by installing separate fuel lines. Making it easier to handle different types of fuels.

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**Flexible fuel system**

- **Storage tank**
- **Settling tank**
- **Service tank**

For each fuel type (1-4), separate fuel lines and cleaning systems are used.

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**Simple fuel system**

- **Storage tank**

For fuel types A-C, a single fuel line and cleaning system are used.

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Increased attention to fuel system handling is necessary when changing fuels.
Fuel systems - Existing vessels

Plan for potential tank segregation during dry docking
- Decide on fuel type(s) to be used in future
- Establish the degree of tank segregation to be considered according to vessels needs and practical considerations.

Example provided by www.naval-dme.com
Fuel System diagram
Update the systems to handle 0.5% S VLSF fuels

- Viscometer should be installed and working
- Fuel pump drain overflow tank
- Cooler(s) and Heaters should be installed & working
Ammonia as fuel
NH3 as potential green fuel of the future

- Can be produced 100% from renewable energy sources
- Clean combustion without CO2 or carbon emissions
- Easy to store (liquid -33 deg C or 20 deg C at 9 bar) compared to LNG (-163 deg C) or hydrogen (-253 deg C)
- Industrial experience with ammonia (180 mill ton production per year). Used as refrigerant onboard ships
## Alternative fuels

### Properties

<table>
<thead>
<tr>
<th>Energy storage type</th>
<th>Specific Energy MJ/kg</th>
<th>Energy Density MJ/L</th>
<th>Required Tank Volume m³</th>
<th>Supply pressure bar</th>
<th>Injection pressure bar</th>
<th>Emission Reduction Compared To HFO Tier II</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFO</td>
<td>40,5</td>
<td>35</td>
<td>1000</td>
<td>7-8</td>
<td>950</td>
<td>SOₓ: 90-99% NOₓ: 20-30% CO₂: 24% PM: 90%</td>
</tr>
<tr>
<td>Liquefied natural gas (LNG - 162 °C)</td>
<td>50</td>
<td>22</td>
<td>1590</td>
<td>300 METHANE</td>
<td>300 METHANE</td>
<td>90-97% 30-50% 15% 90%</td>
</tr>
<tr>
<td>LPG (including Propane / Butane)</td>
<td>42</td>
<td>26</td>
<td>1346</td>
<td>50</td>
<td>600-700</td>
<td>90-100% 10-15% 13-18% 90%</td>
</tr>
<tr>
<td>Methanol</td>
<td>19.9</td>
<td>15</td>
<td>2333</td>
<td>10</td>
<td>500</td>
<td>90-97% 30-50% 5% 90%</td>
</tr>
<tr>
<td>Ethanol</td>
<td>26</td>
<td>21</td>
<td>1750</td>
<td>10</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Ammonia (liquid -33 °C)</td>
<td>18,6</td>
<td>12,7</td>
<td>2755</td>
<td>70</td>
<td>600-700</td>
<td>100% Compliant with regulation &gt;95% &gt;90%</td>
</tr>
<tr>
<td>Hydrogen (liquid -253 °C)</td>
<td>120</td>
<td>8.5</td>
<td>4117</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine battery market leader, Corvus, battery rack</td>
<td>0,29</td>
<td>0,33</td>
<td>106,060</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tesla model 3 battery Cell 2170*</td>
<td>0,8</td>
<td>2,5</td>
<td>14000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **1:** Given a 1000 m³ tank for HFO. Additional space for insulation is not calculated for in above diagram. All pressure values given a high pressure Diesel injection principle.
- **2:** Values for Tesla battery doesn’t contain energy/mass obtained for cooling/safety/classification.
DNV forecast on maritime energy transition

Projected fuel mix

**DNV GL Main indicators**

- LNG and Ammonia will make up a large amount of future fuels
- LSFO and MGO will in the next 15 years remain the most popular fuel by demand
Thank you for the attention!