Fuels of 2020 and beyond

Dorthe Jacobsen
R&D Fuels & Lubes
Member of WG ISO 8217 & CIMAC Fuels
02 October 2018
Agenda

1 SOx Regulation
2 0.50%S fuel
   – Ship implementation plan
      – Up to 2020
      – 2020 ->
   – Coming Service Letter
   – ISO 8217 and ISO/PAS 23263
   – Fuel testing
3 High-S fuel and scrubbers
4 Lubrication strategy
1 SOx Regulation
Sulphur Emission Controlled Areas

Global Limit:
Now: Max. 3.50% S
2020: Max. 0.50% S

SECA: Max. 0.10% S

1st of January 2019: Max. 0.50% S in Chinese waters for all ships
Sulphur Emission Controlled Areas

**Global Limit:**
- Now: Max. 3.50% S
- 2020: Max. 0.50% S

**SECA:** max. 0.10% S

1st of January 2019: Max. 0.50% S in Chinese waters for all ships

All ships
What Fuel will be used in 2020 and beyond?

**Compliant fuel**
- **MC/ME/-C engine**
  - Single Fuel: 0.10%S fuel, 0.50%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

**Dual Fuel**
LNG, Ethane, LPG, MeOH
Use of High-Sulphur fuel after 2020

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

MC/ME/-C engine
0-0.5%S fuels:
HFO/MDO + No Scrubber

No fuel >0.5%S used or carried for use on board a ship
Sulphur Content in Pilot Fuel
0.1% SECA and 0.5% S fuel 2020

0.10% SECA
In order to be compliant, the Sulphur content of the fuel should be max 0.10%.

ME-GI engines:
1. LNG + <0.10% S ULSFO (RM or DM)
2. <0.10% ULSFO (RM or DM)

ME-LGI engines:
1. Methanol + <0.10% S ULSFO (RM or DM)
2. <0.10% ULSFO (RM or DM)

0.50% S in 2020
In order to be compliant, the Sulphur content of the fuel should be max 0.50%.

ME-GI engines:
1. LNG + <0.50% S ULSFO (RM or DM)
2. <0.50% VLSFO (RM or DM)

ME-LGI engines:
1. Methanol + <0.50% S VLSFO (RM or DM)
2. <0.50% VLSFO (RM or DM)

As long as there is no approved equivalent means in accordance to IMO Regulation 4.1, the above operation modes are the possibilities to be compliant.

References:
IMO, Revised MARPOL ANNEX VI. Sulphur oxides (SOx) – Regulation 14,
IMO, Revised MARPOL ANNEX VI. Equivalents - Regulation 4
# Engine configuration

## CEAS

<table>
<thead>
<tr>
<th>Tier</th>
<th>Tier technology</th>
<th>Sulphur content</th>
<th>Scrubber option</th>
<th>Backpressure range</th>
<th>Sulphur content range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier II</td>
<td>HS</td>
<td>Standard</td>
<td>Not installed</td>
<td>BP = 30</td>
<td>T2: 5%; 3 [0-3.5]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>Not installed</td>
<td>Not installed</td>
<td>BP = 90</td>
<td>T2: 5%; 0.5 [0-0.5]</td>
</tr>
<tr>
<td>Tier II</td>
<td>HS</td>
<td>Standard</td>
<td>Not installed</td>
<td>BP = 90</td>
<td>T2: 5%; 3 [0-3.5]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>Not installed</td>
<td>Not installed</td>
<td>T2 BP: 90</td>
<td>T2: 5%; 3 [0-3.5]</td>
</tr>
<tr>
<td>Tier II</td>
<td>EGR</td>
<td>HS</td>
<td>Not installed</td>
<td>T2 BP: 90</td>
<td>T3: 5%; 0.1 [0.1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>Not installed</td>
<td>Not installed</td>
<td>T2 BP: 90</td>
<td>T3: 5%; 0.1 [0.1]</td>
</tr>
<tr>
<td>Tier II</td>
<td>HPSCR</td>
<td>HS</td>
<td>Not installed</td>
<td>T2 BP: 90</td>
<td>T3: 5%; 0.1 [0.1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>Not installed</td>
<td>Not installed</td>
<td>T2 BP: 90</td>
<td>T3: 5%; 0.1 [0.1]</td>
</tr>
<tr>
<td>Tier II</td>
<td>LPSCR</td>
<td>LS</td>
<td>T2 mode</td>
<td>T2 BP: 90</td>
<td>T3: 5%; 0.1 [0.1]</td>
</tr>
</tbody>
</table>

*Note: BP stands for Back Pressure.*
CEAS – Fuel Selection
MAN Diesel & Turbo – Two-stroke

This is the high %S option. Few changes in combustion chamber design. Note max 3.5% S.

This is the low %S option. Significant impact on combustion chamber design.
Influencing Factors on Fuel Choice

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

Fuel choices:
- Distillates
- Heavy fuel
- ULSFO
- LNG
- Ethane
- Methanol
- Biofuel
- LNG
- Biofuel
- Heavy fuel
Fuel Price Development

Fuel Price

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

* US Export prices

Source: Bunkerindex, EIA & Methanex

Data retrieved end Aug 2018, Dept. EELC
Outlook: Future Marine Fuels
MAN Diesel & Turbo – Two-stroke

• No one knows for certain the actual balance of fuel use in 2020.
• Many surveys have been conducted.
• Every party has their own and different view.
• LNG is likely to remain small.

In communication on Sulphur-content of the fuel, we use the CIMAC definition:
• High-Sulphur fuel: HSFO
• Fuel max. 1.0% S: LSFO
• Fuel max. 0.5% S: VLSFO
• Fuel max. 0.1% S: ULSFO

For definition of types of fuel, we normally use the ISO 8217 definition:
• RM = Residual Marine (heavy fuel)
• DM = Distillate Marine
Knowingly, that the ULSFO’s sometimes are DM and sometimes are RM….
Where does the Fuel come from & What will it be?

- The fuels come from the refineries and many blend plants and many suppliers.
- Many kind of different streams will be used.
- The fuels in 2020 will most probably be blended so they comply with ISO 8217.

Examples of 0.50% S fuels
- Blends of residuals
- Hydro-treated residuals
- Heavy fractions from hydro-crackers
- Lighter hydro-treated fractions
2 0.50% S fuel

- Ship implementation plan
  - Up to 2020
  - 2020 ->
- Coming Service Letter
- ISO 8217 and ISO/PAS 23263
- Fuel testing
Ship implementation plan

Up to 2020
1. Change of high-S HFO to 0.50%S fuel
2. Prepare ship systems
   a. Tanks
      a. Storage -> settling -> service tanks
      b. Cleaning of tanks? Diluting
         i. Sludge in tanks -> ?
   b. Fuel system
   c. Engine high-pressure fuel pump: 2-20 cSt
      i. SL2014-593
3. Compliant fuel: High-S -> 0.50%S
4. Compatibility between fuels

2020 ->
1. New Service Letter
New Service Letter on 0.50% S fuels
Coming October 2018

Content

1. Stability of the fuel
   a. The fuel must be stable at delivery, and in typical ship fuel systems and in the high-pressure fuel injection equipment.

2. Compatibility between different fuel batches
   a. Different fuel batches may not be compatible
      ➢ Don’t mix different fuel batches

3. Fuel characteristics may vary between fuel batches within the same grade: Pay attention and act upon results
   a. Viscosity of the fuel
      ➢ Pay attention to the fuel temperature
   b. Density of the fuel
      ➢ Use the correct gravity disc in classic separators
   c. Cold flow properties of the fuel
      ➢ Heat the fuel sufficiently above pour point and possible wax formation point

4. Cylinder lube oil
   a. Use lube as according to fuel S – refer to relevant SL’s

5. Piston rings
   a. All piston rings should have cermet coating – see SL2018-659

6. Jacket cooling water
   a. Cooling water temperature can be reduced to 80 C.
Viscosity distribution of RMG380 with S% ≥ 1.1

Data from Lloyds Register FOBAS

Viscosity, cSt at 50°C

- 320.1 – 380:
  - 72% of the samples
- 180.1 – 320:
  - 16% of the samples
- 180 or lower:
  - 1.2% of the samples

Over specified limit

- 380.1 – 400:
  - 9% of the samples
- 400.1 – 877:
  - 1.1% of the samples

Evaluation and interpretation of the data are made by MAN ES
Expected viscosity distribution of future 0.50% S fuels

Viscosity distribution. Fuels supplied as RMG380 with S % ≥ 1.1 in 2017 & Dec 2016
Courtesy Lloyd's Register FOBAS

- Expected future 0.50% S fuels
- Data from 2017 (FOBAS)

Viscosity limit for RMG380, ISO 8217

Sample size: more than 20000
* = note the interval

Viscosity cSt at 50°C
Expected viscosity distribution of future 0.50% S fuels

2020 Challenge:

− When the viscosity distribution is more evenly divided within the same ISO 8217 grade (e.g. RMG380), two different fuel batches from the same grade may have different viscosity.
  
  − Fuels with different viscosity must be heated to different temperatures to reach the same viscosity.
  
  − The fuel system will experience temperature change more often - when switching between batches.
  
  − If temperature and viscosity is not controlled correct:
    
    − A lower viscosity fuel may be heated too high, making the viscosity too low, which may lead to seizures in the engine fuel pump.
    
    − A higher viscosity fuel may not be heated sufficient, making the viscosity too high, which may lead to insufficient atomisation of the fuel and possible bad combustion.

− Solution:

  − Make sure the viscorater is working - and set to max. 2 cSt/min.
Ultra low sulphur fuel
Change-over procedure HFO-DO

- Viscosity: 2-20 cSt
- Fuel temperature gradient: Max. 2 C/min.

Set visc. to 18 cSt

- Reduce load to 25-40%
- Stop steam tracing

Stop preheater

Start cooler

Running hours

Fuel viscosity, cSt

Heavy Fuel (HFO)
Diesel (DO)

Ultra low sulphur fuel
Change-over procedure HFO-DO

- Viscosity: 2-20 cSt
- Fuel temperature gradient: Max. 2 C/min.

Set visc. to 18 cSt

- Reduce load to 25-40%
- Stop steam tracing

Stop preheater

Start cooler

Running hours

Fuel viscosity, cSt

Heavy Fuel (HFO)
Diesel (DO)
Ultra low sulphur
Change-over procedure

- Viscosity: 2-20 cSt
- Fuel temperature gradient: Max. 2 C/min.
- Load: 25-40 % MCR

Fuel viscosity, cSt

Running hours

- Start heater
- Start steam tracing
- Decrease cooling
- Stop cooling

Heavy Fuel (HFO)
Diesel (DO)
Case 1: RMG 380:
- Batch 1: Viscosity: 380 cSt
- Batch 2: Viscosity: 180 cSt
Case 1: RMG 380:
- Batch 1: Viscosity: 380 cSt
- Batch 2: Viscosity: 180 cSt
Case 1: RMG 380:
- Batch 1: Viscosity: 180 cSt
- Batch 2: Viscosity: 380 cSt
Case 1: RMG 380:
- Batch 1: Viscosity: 80 cSt
- Batch 2: Viscosity: 380 cSt
Case 1: RMG 380:
- Batch 1: Viscosity: 380 cSt
- Batch 2: Viscosity: 80 cSt
Case 1: RMG 380:
- Batch 1: Viscosity: 380 cSt
- Batch 2: Viscosity: 2 cSt

Too low viscosity:
- Fuel pump seizures
- Engine start?

**Fuel system**
- Batch 1
- Batch 2
- Change over to new batch
- No temperature change

**Engine**
- Batch 1
- Batch 2
- Change over to new batch
- Too low viscosity:
  - Fuel pump seizures
  - Engine start?
Density distribution of RMG380 with S% ≥ 1.1

Density kg/m³
- 975.1 - 991
  86% of the samples
- 975 or lower
  12% of the samples
Over specified limit
- 991.1 - 1010
  2.5% of the samples
- 1010.1 or higher
  0.01% of the samples

Evaluation and interpretation of the data are made by MAN ES.
Expected density distribution of future 0.50% S fuels

Density distribution. Fuels supplied as RMG380 with S % ≥ 1.1 in 2017 & Dec 2016
Courtesy Lloyd's Register FOBAS

Expected future 0.50% S fuels
Data from 2017 (FOBAS)

Density limit for RMG380, ISO 8217

Sample size: more than 20000
* = note the interval
Expected density distribution of future 0.50% S fuels

Density distribution. Fuels supplied as RMG380 with S % ≥ 1.1 in 2017 & Dec 2016
Courtesy Lloyd’s Register FOBAS

- Expected future 0.50% S fuels
- Data from 2017 (FOBAS)

Sample size: more than 20000
* = note the interval

Density kg/m³

Data from 2017 (FOBAS)
Expected density distribution of future 0.50% S fuels

2020 Challenge:

− When the density changes from e.g. high to lower, the gravity disc must be changed in older separators - when switching between batches. If gravity disc doesn’t fit with the fuel in use, the fuel will either not be cleaned from water, or the fuel will be let to the drain?

− Solution:

  − Be aware of the density of the fuels: in-use and next batch
  − If necessary change the gravity disc
# Typical fuel type characteristics

**Schematic:** High: ••••• Low: •

<table>
<thead>
<tr>
<th>Properties</th>
<th>General fuel data</th>
<th>HSHFO</th>
<th>VLSFO (0.50%S)</th>
<th>ULSFO-DM (MGO)</th>
<th>ULSFO-RM</th>
<th>Paraffinic type</th>
<th>Aromatic type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur, %</td>
<td>0-3.5 %</td>
<td>Up to:</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Density, kg/m³ at 15°C</td>
<td>800-1010</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Viscosity, cSt at 50°C</td>
<td>2-700</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Pour point, C</td>
<td>-15+-40</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>Up to:</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Cat fines: Al+Si, ppm</td>
<td>0-60-80 (+++</td>
<td>•</td>
<td>Up to: ••••</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>Up to: ••••</td>
</tr>
<tr>
<td>Combustibility</td>
<td>n.a.</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Stability</td>
<td>n.a.</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Mixability (compatibility)</td>
<td>n.a.</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>
Fuel type characteristics

Density @ 15 C
kg/m3

Highly parafinic + high Pour point

HFO aromatic type

Don’t mix

Distillate (DMA) + low Pour point

Kin. Viscosity @ 50 C, cSt
# 0.24 – 0.50% S Fuel data 2017

<table>
<thead>
<tr>
<th>Bunkering Country</th>
<th>Residual grades, 0.24-0.50% S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>China</td>
</tr>
<tr>
<td>Number of samples</td>
<td>14</td>
</tr>
<tr>
<td>Density (kg/m³)</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>977</td>
</tr>
<tr>
<td>Max.</td>
<td>991</td>
</tr>
<tr>
<td>Min.</td>
<td>963</td>
</tr>
<tr>
<td>Viscosity (cSt) at 50°C</td>
<td></td>
</tr>
<tr>
<td>Average (median)</td>
<td>145 (154)</td>
</tr>
<tr>
<td>Max.</td>
<td>179</td>
</tr>
<tr>
<td>Min.</td>
<td>92</td>
</tr>
<tr>
<td>Net specific energy (MJ/kg)</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>41,2</td>
</tr>
<tr>
<td>Max.</td>
<td>41,4</td>
</tr>
<tr>
<td>Min.</td>
<td>40,9</td>
</tr>
<tr>
<td>Pour Point (°C)</td>
<td>Median</td>
</tr>
<tr>
<td></td>
<td>19,5</td>
</tr>
<tr>
<td></td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Less than 6</td>
</tr>
<tr>
<td></td>
<td>Comments</td>
</tr>
</tbody>
</table>
2020: MDT Fuel and lube test plan

In order to prepare for the new types of 0.50%S fuels, test engine, service tests and lab tests will be carried out.

This will be done in collaboration with lube oil suppliers, fuel oil suppliers, ISO 8217 WG, CIMAC WG Fuels, ship owners and other relevant partners.

Potential challenges:

• Fuel:
  a. Technical:
     i. Stability in the fuel
     ii. Compatibility between fuels
     iii. Ignition –> knocking
     iv. Burn out –> deposits
  b. Commercial:
     i. ISO 8217 -> ISO/PAS or CIMAC

• Lube:
  a. Deposit
  b. Corrosion – how much?
  c. Smearing

Feedback from market?
Testing new 0.50%S fuel – for 2020

Testing new types of fuel, we recommend to do lab analysis as follows:

1. ISO 8217-2017: All parameters

2. Cold flow properties: important for both residual and distillate grades:
   a. Pour point (ISO 3016)
   b. Cloud point (ISO 3015)
   c. Cold filter plugging point (45 µm filter, 60 sec., ASTM D6371 or see ISO 8217-2017)

3. Stability within the fuel and compatibility to other fuels should also be investigated. E.g. TSE/TSP/TSA (ISO 10307-1/2)

4. ECN analysis (IP 541/06)
   This analysis will give indication on combustion properties

5. Boiling curve (ASTM D1160)
   This analysis will give indication on composition of the fuel

Service testing new 0.50%S fuel – for 2020

Service testing new types of fuel, we recommend to do as follows:

1. Take samples of fuel on board and send for analysis
   a. 0.50% S fuel
   b. High-S fuel
   c. <0.10%S fuel: Distillate or other fuel type

2. Do spot testing on board (ASTM D4740)
   a. 0.50%S fuel alone
   b. High-S fuel alone
   c. 0.50%S fuel vs high-S fuel: 50-50 (and 80-20 and 20-80)
   d. 0.50%S fuel vs distillate: 50-50 (and 80-20 and 20-80)

3. Cylinder lube drain oil from operation on:
   a. 0.50%S fuel
   b. High-S fuel

4. Scavenge port inspection
   a. Before start of test
   b. After test

5. Inspect – Observe - take note on the fuel system during the 0.50%S testing
   a. Separators
   b. Filters
   c. Drains
   d. Tanks
   e. Fuel pumps
   f. More?

6. Make performance evaluation. Operation on:
   a. High-S fuel
   b. <0.10%S fuel
   c. 0.50% S fuel

- Don’t mix
- Viscosity
- Density
- Empty tanks
We can learn from the 0.10% SECA ULSFO < 0.10% Sulphur

There are a range of different types fuels. These are not distillate types, rather new blends or types.

**General characteristics are:**
- Higher viscosity than distillate
- Some contain cat fines (Al+Si)
- Some have high pour points
- Compatibility with other fuels may also be an issue.
2020 -> Solutions
Fuel tanks

Pre 2020: Few big fuel tanks

Post 2020: Multiple smaller fuel tanks
Summary

Future fuels

1. Max. 0.1% S fuels
   a. Distillate
   b. ULSFO-RM -> 0.50% S fuel?
2. Max. 0.5% S fuels
   a. Very diverse properties
   b. Challenges similar to ULSFO-RM
      -> Try to use an ULSFO-RM to gain experience
3. High-S fuels
   a. Up to 4.5-5% S
4. Alternative fuels
   a. LNG
   b. Methanol, LPG, Ethane, biofuel,…
5. Cat fines (Al+Si) are and will be in the fuels and they have to be removed.
Cat fines - paper
Impact on engine wear and how to reduce the wear

Link to paper:
What Fuel will be used in 2020 and beyond?

<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>Single Fuel:</td>
<td>0-5%S fuels:</td>
</tr>
<tr>
<td>0.1%S fuel, 0.5%S fuel</td>
<td>HFO/MDO + Scrubber</td>
</tr>
<tr>
<td><strong>ME-GI / ME-LGI engine</strong></td>
<td></td>
</tr>
<tr>
<td>Dual Fuel:</td>
<td><strong>ME-GI / ME-LGI engine</strong></td>
</tr>
<tr>
<td>LNG, Ethane, LPG, MeOH</td>
<td><strong>ME-GI / ME-LGI engine</strong></td>
</tr>
<tr>
<td>...........</td>
<td>Dual Fuel:</td>
</tr>
</tbody>
</table>

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

*High-Sulphur fuel:*
- MC/ME/-C engine
  - 0-5%S fuels: HFO/MDO + Scrubber
Fuel 2020 - Commercial

Commercial standards for purchase of marine fuel:

- **ISO 8217-2017:** Specification of marine fuels
- **New to come:** ISO/PAS 23263:
  Considerations for fuel suppliers and users regarding marine fuel quality considering the implementation of max. 0.50%S in 2020.
  - In public: Mid-2019
ISO/PAS 23263 content:

- Considerations for fuel suppliers and users regarding marine fuel quality considering the implementation of max. 0.50%S in 2020.
- ISO 8217 covers all fuels
- Not expected to include new limits or grades.
- Properties that will be considered in more detail in view of safety aspects, such as:
  - Viscosity
  - Cold flow
  - Stability
  - Compatibility
2 High-S fuel and scrubbers
Bunker Fuel Price

$/MT

Bunker Fuel Price

$/MT

MGO (Rotterdam)

HFO (Rotterdam)

DIFF: MGO - HFO

Guestimate

0.5%S fuel

Data retrieved end Aug 2018, Dept. EELC

Source: Bunkerindex
Bunker Fuel Price

$/MT

Bunker Fuel Price

$/MT

MGO (Rotterdam)

HFO (Rotterdam)

DIFF: MGO - HFO

Guestimate

0.5%S fuel

Data retrieved end Aug 2018, Dept. EELC

Source: Bunkerindex
### Scrubber – business case

#### 7, 25 and 60 MW engines

**Fuel cost**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Cost/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSHFO (&gt;0.5%)</td>
<td>470</td>
</tr>
<tr>
<td>LSFO (0.5%)</td>
<td>660</td>
</tr>
<tr>
<td>ULSFO (0.1%)</td>
<td>700</td>
</tr>
</tbody>
</table>

Calculated by ECA Engineering

- **7 MW.**
  - Total cost comparison
  
- **25 MW.**
  - Total cost comparison
  
- **60 MW.**
  - Total cost comparison

- **2.3 years**
- **1.3 years**
- **0.9 years**
New Service Letter

SOx scrubber retrofit on two stroke engines in service

MAN PrimeServ supply:

- Evaluation
- T/C rematching parts
- Re-certification work for the engine modifications and approval with relevant classification societies.

Service Letter SL072-05/06

SOx scrubber retrofit on two-stroke engines in service

MAN Energy Solutions

Confidential

02.10.2018 Dorthe Jacobsen – Future fuels – ©2018 02.10.2018 50
Number of vessels and bunker consumption as a function of installed power

Source: Lindstad and Eskeland 2016
Sulphur Distribution for Residual Fuel
MEPC 62-69

Average Sulphur content: 2.65% m/m

Average Sulphur content: 2.58% m/m
3 Lubrication strategy
Lube Oils

Key properties for cylinder lube oil:
- Lubricate, decrease friction
- Neutralize sufficiently
- Provide a gas-seal between rings and liner
- Keep parts clean:
  - Avoid coke formation (thermal stability of the base oil)
  - Remove coke, additives, impurities and wear particles from liner and piston ring area

SAE = Viscosity scale.
- SAE50: 18.5 - 21.9 cSt @ 100°C
- SAE30: 9.3 - 12.5 cSt @ 100°C

BN = Base Number, neutralization ability
Cylinder Condition – Cylinder Oil
Sulphur content in fuel - challenges

Lubrication strategy:
- For low-Sulphur fuel:
  Use low-BN cylinder oil
- For high-Sulphur fuel:
  Use high-BN cylinder oil

Risk: Bore polish & deposit build-up

“Bore polish” from topland deposits rubbing against the liner surface.

Risk: Cold corrosion

Piston topland deposits

Increasing Fuel Sulphur Content

0 %
What is ahead
Different choice, different solutions

SOx scrubber?
Fuel: 0.1 to 4+ %S
Cyl oil: BN25 & BN140

Cylinder condition focus:
• Cold corrosion!
• Ring wear
• Liner wear

2020 Fuel?
Fuel: 0.1 to 0.5 %S
Cyl oil: BN25 & BN40

Cylinder condition focus:
• Detergency
• Minimise liner polish
• Liner scuffing
Cylinder oil, development
Pre and post 2020

Ships burning 0.50% S fuel:
15 to 40 BN oil

Ships burning High-Sulphur fuel:
100 to 140+ BN oil and ACOM
Cylinder oil
Cylinder oil system

Typical setup of storage and service tanks on-board a ship
Cylinder oil – for 2020: 0.50% S fuel
Cylinder oil system

Typical setup of storage and service tanks on-board a ship
Cold Corrosion
Selection of feed rate of cylinder lube oil

Feed rate (FR) may be reduced by the ratio between the BN in the oils.

\[ E.g. \quad FR_{70BN} = 1.4 \frac{g}{kWh} \]
\[ FR_{100BN} = \frac{70}{100} \times 1.4 \frac{g}{kWh} = 1.0 \frac{g}{kWh} \]
\[ FR_{140BN} = \frac{70}{140} \times 1.4 \frac{g}{kWh} = 0.7 \frac{g}{kWh} \]
Disclaimer

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.
Thank you very much!