EXHAUST GAS SCRUBBING SYSTEMS
TECHNICAL AND ECONOMICAL ASPECTS

MARITIME STAKEHOLDER EVENT, BRUSSELS 1ST JUNE 2011

B-M KULLAS-NYMAN
WÄRTSILÄ
Environmental challenge

**NO\textsubscript{x}**
- Acid rains
- Tier II (2011)
- Tier III (2016)

**SO\textsubscript{x}**
- Acid rains
- 3.5% (2012)
- ECA 0.1% (2015)

**PM**
- Harming humans and animals
- Along with SO\textsubscript{x} reduction

**CO\textsubscript{2}**
- Greenhouse gas
- Under evaluation by IMO
Wärtsilä freshwater scrubber test unit (MT Suula)

**Type**
- Fresh water NaOH scrubber.

**Application**
- Auxiliary engine Wärtsilä 4L20.

**Purpose of testing**
- Performance mapping.
- Certification experience.
- Operational feedback.

**Status**
- First marine scrubber certificate
Wärtsilä freshwater scrubber test unit (MT Suula)

Exhaust gas in

Water spray

Water + NaOH

Water + Sulphates

Exhaust gas out

Packed bed spray scrubber
Freshwater scrubber layout

System main components
1. SOx Scrubber unit
2. Alkali feed module
3. Bleed-off treatment module
4. Effluent monitoring module
5. CEMS (Continuous Emissions Monitoring System)
6. Scrubbing water pump module
7. Sea water pump
8. Heat exchanger
9. Buffer tank
10. Alkali storage tank
11. Sludge tank

- Sludge ~ 0.1-0.4 kg/MWh
- Effluent ~ 0.1 m³/MWh
- Freshwater ~ 0.1 m³/MWh
- Bleed-off ~ 0.1 m³/MWh
- ~25 m³/MWh

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**Bleed-off treatment**

**Scrubbing water circulation**

**Process tank**

**Bleed-off**

A small amount of scrubbing water extracted to bleed-off unit to remove contaminants.

**Disposal**

(never sent overboard)

**Storage**

in a buffer tank to allow scrubber operation without bleed-off treatment unit (e.g. maintenance), or vice versa.

**Sludge**

*Disposal*

In port, never overboard

*Storage*

In ship’s “sludge” tank, possibly in the existing tank with separator and other sludge

**Effluent**

A cleaned bleed-off within and beyond IMO requirements

**Disposal**

Can be discharged overboard at open sea

**Storage**

Can be stored in a buffer tank

Permits cleaning of bleed-off anytime, also when scrubber is not operating
## Typical Wärtsilä scrubber performance and operation data

<table>
<thead>
<tr>
<th>Performance</th>
<th>SO$_x$ reduction</th>
<th>&gt; 97%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td></td>
<td>Up to 3.5% S content</td>
</tr>
<tr>
<td>Power consumption</td>
<td></td>
<td>0.5% of actual Power</td>
</tr>
<tr>
<td>NaOH price</td>
<td></td>
<td>50 – 250 $/m^3</td>
</tr>
<tr>
<td>Installation example</td>
<td></td>
<td>10 MW, 85% MCR</td>
</tr>
<tr>
<td>3.5% S, scrubbing to 0.1 % level</td>
<td></td>
<td>ISO conditions</td>
</tr>
<tr>
<td>NaOH consumption</td>
<td></td>
<td>Approx. 130 litres /h (~7% of SFOC)</td>
</tr>
<tr>
<td>Dimensions / Weight in operation</td>
<td></td>
<td>6m × Ø 3.4m / 10 tons</td>
</tr>
<tr>
<td>Fresh water consumption</td>
<td></td>
<td>Approx. 1 m$^3$/h</td>
</tr>
<tr>
<td>Effluent* sea discharge</td>
<td></td>
<td>Approx. &lt; 1 m$^3$/h</td>
</tr>
<tr>
<td>Sea water (cooling)</td>
<td></td>
<td>Approx. 100 m$^3$/h</td>
</tr>
</tbody>
</table>

* Cleaned bleed-off extracted from scrubbing water to remove contaminants
Theoretical 50% NaOH solution consumption

- 3.5% S cleaned to correspond to 0.1% S
- 2.7% S cleaned to correspond to 0.1% S
- 1.0% S cleaned to correspond to 0.1% S

Operating power (kW) vs. NaOH consumption (l/h)
Wärtsilä FWS options

Main stream scrubber
– One scrubber unit for each engine
– Not suitable for fuel oil fired boilers

Integrated scrubber
– One scrubber unit for several engines and/or oil fired boilers
– Suitable for fuel oil fired boilers
Wärtsilä Integrated Scrubber

Benefits
- Completely avoids increased exhaust gas back pressure
- Minimizes the amount of equipment

Main features
- One common unit with suction fans for all combustion units onboard
- Suction branches with shut-off valves from all exhaust gas and flue gas pipes
- Fan redundancy embedded
- Constant under-pressure prevents undue flow of gases
• Containerships VII, scrubber delivery in August 2011
• Main stream scrubber for Wärtsilä 7L64 main engine, 12600kW
• Vessel built 2002 (Sietas, Hamburg).
• Operating area Baltic Sea and North Sea
• Finnish flag, classification society GL
Containerships VII

A full commercial project

Turn-key delivery:
- Equipment
- Installation, piping, cabling
- Interfaces to existing systems
- Commissioning
- Performance guarantee
- Class approval
- Certification
- Documentation
- Customer training
Parameters affecting the scrubber economics

Equipment on board to cover
- Main engine(s)
- Auxiliary engine(s)
- Boiler(s)

Vessel operation and routes
- Operation profile and fuel oil consumption
- Number of hours in/out of SECA waters

Pricing of consumables
- HFO vs. MGO price
- NaOH price

Current configuration
- Existing fresh water capacity
- Ship design layout
- Tank arrangement
- Available space
- Elevation
Fuel prices, Rotterdam

• = 140… 700 $/ton

MGO - HFO

Updated 12 April 2011

Source: bunkerworld.com
Fuel and Scrubber Operating Costs

HFO 403 $/ton (Rotterdam 21.05.2010)
MGO 614 $/ton (Rotterdam 21.05.2010)
Scrubbing cost with 2.7% S in fuel:
6,2 $/MWh for caustic soda, pumping, maintenance, water)

HFO 588 $/ton (Rotterdam 05.2008)
MGO 1,290 $/ton (Rotterdam 05.2008)
Scrubbing cost with 2.7% S in fuel:
6,7 $/MWh for caustic soda, pumping, maintenance, water)
Scrubber operating cost saving and payback time

Large ship

Scrubber operation cost saving and payback time

Fuel price difference (MGO-HFO) [USD/t]

Operating cost savings [1000 €/year]

Payback time [years]

Summer 2008

Operating cost savings and payback time for large ship as a function of fuel price difference between MGO and HFO.
CONCLUSIONS
SO\textsubscript{x} scrubbing advantages

- SO\textsubscript{x}-scrubbing is the most economical way to comply with IMO regulation regarding SO\textsubscript{x} (Regulation 14)
- In SO\textsubscript{x} Emission Control Areas the cost saving is immediate. In 2015 the cost savings will be dramatic
- Wärtsilä freshwater scrubber solutions are fit for new buildings and retrofits, for any engine and boiler brands

The scrubber solution is ready