PIONEERING SOX SCRUBBER SYSTEMS
LOWEST COST FOR MEETING MARPOL ANNEX VI REQUIREMENTS
**NO\textsubscript{x}**
Acid rains
Tier II (2011)
Tier III (2016)

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

**CO\textsubscript{2}**
Greenhouse gas
Under evaluation by IMO
SO$_x$ and NO$_x$ Emission Control Area.

- Entry into force August 2011
- 200 miles from coast.
- Fuel Sulphur Initially 1%, then 0.1 % from 2015, all ships.
- NO$_x$ Tier III (Tier I minus 80 %) 2016, new buildings.
Geographically defined SO\(_x\) Emission Control Areas

- Baltic Sea
- English Channel
- North Sea

© Wärtsilä. STRICTLY CONFIDENTIAL. This document is the property of Wärtsilä Corporation and shall not be copied or reproduced without the consent of the owner.
IMO & EU Sulphur Limits

Sulphur limit (%)

Fuel type
Not regulated = both HFO and distillate are permitted.

Exhaust gas cleaning
Permitted alternative under Regulation 4 to achieve any regulated limit.

Particulate Matter (PM)
No limit values.

World

-67%  -78%  -71%  -97%  -86%

ECA

EU in ports

### Alternatives to reducing SOx

<table>
<thead>
<tr>
<th>Option</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FUEL SWITCH</strong></td>
<td>Switch to low sulphur fuel in SECA.</td>
<td>High operating cost in SECA</td>
</tr>
<tr>
<td><strong>CHANGE TO MGO</strong></td>
<td>Run full time on Marine Gas Oil (MGO).</td>
<td>High operating cost, Future availability?</td>
</tr>
<tr>
<td><strong>CONVERT TO LNG</strong></td>
<td>Convert engines to run on gas (LNG).</td>
<td>Investment cost, LNG availability</td>
</tr>
<tr>
<td><strong>USE SCRUBBERS</strong></td>
<td>Install an exhaust gas cleaning system (scrubber).</td>
<td>ROI depends on fuel oil price difference between low S fuel oil and high S HFO</td>
</tr>
</tbody>
</table>

- **Flexible**
- **Convenient**
- **A solution which also reduces NOx and particulates**
- **Works with high S HFO**
- **Easy operation**
Fuel prices (Rotterdam)

Δ = 140–700$ / ton MGO–HFO

Fuel prices (Rotterdam)
Cost comparison for 25 years
Total engine power: 10 MW
Annual fuel consumption: 9800 ton/a
Annual average load: 69%
Interest rate for NPV calculations: 5.0%
Fuel price inflation rate: 4.8% (1980-2010 average)
Currency rate: 1.27 US$/€
NaOH 50%: 200€/ton

Fuel prices are prices in Rotterdam
Case 1: 31.08.2010
Case 2: August 2008
Case 3: May 2008

*System delivery cost (not including installation)
Seawater scrubbing system chemistry

Engine Exhaust Chemistry:
\[ S + O_2 \rightarrow SO_2 \quad (~95\%) \]
\[ SO_2 + \frac{1}{2}O_2 \rightarrow SO_3 \quad (~5\%) \]

Scrubber Chemistry:
\[ SO_2 + H_2O \rightarrow H_2SO_3 \quad \text{(Sulphurous Acid)} \]
\[ SO_3 + H_2O \rightarrow H_2SO_4 \quad \text{(Sulphuric Acid)} \]

Scrubber Reactions:
\[ CaCO_3 + H_2SO_3 \rightarrow CaSO_3 + H_2O + CO_2 \]
\[ 2CaSO_3 + O_2 \rightarrow 2CaSO_4 \quad \text{(Calsiumsulphate)} \]

Alkalinity (Bicarbonates \( HCO_3^- \) and carbonates \( CO_3^{2-} \))
– **neutralize** and help to buffer the pH rapidly
Example alkalinity in the Baltic Sea

- Open sea alkalinity
- Surface data (0... 15 m)
- Data from 2001-2005

Typical open sea alkalinity outside Baltic Sea is ca. 2200 – 2400 µmol/L
## SOx Scrubbers and Survey Schemes

<table>
<thead>
<tr>
<th>Freshwater closed loop</th>
<th>Seawater open loop</th>
<th>Hybrid (seawater closed loop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not dependent on seawater alkalinity</td>
<td>Dependent on seawater alkalinity (issue for limited areas such as lakes, few ports close to estuaries, Northern and Eastern part of Baltic Sea; limitation: 1000 umol / L)</td>
<td>Possibility to operate independently from seawater alkalinity for a limited period (limitation: 1000 umol / L)</td>
</tr>
<tr>
<td>Zero effluent discharge for some time</td>
<td>No possibility for zero discharge</td>
<td>Zero effluent discharge for limited period</td>
</tr>
<tr>
<td>Needs caustic soda as a reagent</td>
<td>No need of NaOH (and logistics)</td>
<td>Needs caustic soda for intended closed loop operations</td>
</tr>
<tr>
<td>Low power demand (0.5-1.0 % additional engine power demand)</td>
<td>Slightly higher power demand (2.0 % additional engine power demand)</td>
<td>Slightly higher power demand (2.0 % additional engine power demand)</td>
</tr>
<tr>
<td>Slightly more complex system</td>
<td>Simple system</td>
<td>Slightly more complex system</td>
</tr>
<tr>
<td>Needs FW (possibility to use AWP treated water)</td>
<td>No need for additional FW</td>
<td>No need for additional FW</td>
</tr>
<tr>
<td>No issues related to sea chests</td>
<td>Sea chest capacity (retrofits)</td>
<td>Sea chest capacity (retrofits)</td>
</tr>
<tr>
<td>More tank requirements (alkali, buffer tank, holding tank, sludge tank)</td>
<td>Lower tank space demand (residence tank, sludge tank)</td>
<td>More tank requirements (alkali, 2x residence tanks, holding tank, sludge tank)</td>
</tr>
</tbody>
</table>
### SOx Scrubbers and Survey Schemes

<table>
<thead>
<tr>
<th></th>
<th>Type of scrubber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh water</td>
</tr>
<tr>
<td>Alkaline reactant</td>
<td>NaOH</td>
</tr>
<tr>
<td>Operating modes</td>
<td>Closed loop</td>
</tr>
<tr>
<td>Zero discharge mode</td>
<td>Periodical</td>
</tr>
<tr>
<td>Scrubbing water flow, m3/MWh</td>
<td>24</td>
</tr>
<tr>
<td>Fresh water consumption, m3/MWh</td>
<td>0.1…0.2</td>
</tr>
<tr>
<td>Water piping, m3 (large cruise ship)</td>
<td>18</td>
</tr>
<tr>
<td>Pumping power, % of engine power*</td>
<td>0.5</td>
</tr>
<tr>
<td>Suitable certification scheme**</td>
<td>Scheme A or B</td>
</tr>
</tbody>
</table>

* In case of Integrated Scrubber additionally fan power, load dependent, 0.1 – 0.5 %  
** Refers to IMO Resolution MEPC.184(59)
Scrubber approval alternatives according to IMO

**SCHEME A** – Exhaust gas cleaning (EGC) **system approval**, survey and certification using **parameter and emission checks**
- Compliance demonstrated by emission tests
- Possible to obtain for serially manufactured units and for a certain production range

**SCHEME B** – Exhaust gas cleaning (EGC), survey and certification using **continuous monitoring of SO_x emissions**
- Compliance demonstrated in service by continuous exhaust gas monitoring
Wärtsilä Scrubber Portfolio

• **Sea water scrubber (SWS) – open loop system**
  • Uses seawater i.e. no freshwater needs
  • Slightly higher power demand than FWS
  • Does not need caustic soda
  • **Applications:** main alternative for ocean-going ships

• **Fresh water scrubber (FWS) – closed loop system**
  • Not dependent on seawater alkalinity
  • Zero effluent discharge an option
  • Low power demand
  • Needs caustic soda as a reagent
  • **Applications:** seas with extremely low alkalinity and for operators looking for zero discharge

• **Hybrid scrubbers – both open loop and closed loop operations**
  • Flexible system
  • More complex system
  • **Applications:** ships requiring full flexibility of operations (e.g. sailing both in low alkalinity areas as well in open oceans)
Wärtsilä Hybrid scrubber

HMI Control Cabinet

Scrubber unit

De-aeration vessel

Seawater pumps

NaOH tank

Water Monitoring

Water monitoring

Water refill 0.14 m³/MWh

Residence tank

Bleed of 0.14 m³/MWh

Sludge tank 2 l/MWh

Existing ballastwater/cooling water line

Monitoring for SO2/CO2

Cleaned exhaust gas

Exhaust gas

Open loop

Closed loop

De-aeration vessel

Residence tank

Holding Tank

0.138 m³/MWh

30 m³/MWh

32 °C

32 m³/MWh

Water monitoring
Wärtsilä Closed loop scrubber

Closed loop with NaOH

- Exhaust gas fan module
- Emission monitoring
- Scrubber unit (4.4m x 9.2m)
- By-pass valves
- Scrubbing water pump module
- Bleed-off treatment units
- Effluent monitoring
- Sludge tank
- Holding tank (optional)
- Alkali feed module
- Alkali (NaOH) tank, 14 days autonomy
- Sea water heat exchanger
- Sea water pump
- Freshwater in
Wärtsilä Integrated Scrubber

Main features
• For diesel engines and oil-fired boilers
• One common scrubber unit with suction fan for all combustion units onboard
• Suction branches with by-pass valves from all exhaust gas and flue gas pipes
• Constant under-pressure at scrubber inlet prevents undue flow of gases

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

Ideal for
• Single engine cargo ships with HFO gensets
• Multi engine ships
• Tankers with large boilers

1. Diesel engine
2. Oil-fired boiler
3. SCR
4. Exhaust gas boiler
5. Silencer
6. By-pass valve
7. Exhaust gas manifold
8. Scrubber unit
9. Exhaust gas fan
Containerships VII SOx measurements

- Fuel sulphur content 1.84%.
The collected sludge:
Non-hazardous by legislation
To be disposed of ashore
Can be disposed with the vessels waste oils/sludge

Estimated amount closed loop: 2 l/MWh
Estimated amount from Engine Manufacturers open loop: 0,1 g/kWh

The amount depends on silt content in water and engine running profile

Sludge is collected in standard 1m³ plastic container
Wärtsilä’s unparalleled reference list

Hybrid – Wilhelmsen

- Vessel: MV Tamesis
- Size of SWS: 1 x 25 MW, 1 x 6 MW
- Installation type: Retrofit
- Delivery: November 2012
- Performance:
  - 97% SOx Removal
  - 85% Particulate Removal
  - 3.5% fuel sulphur content
An installation in cooperation with Port of Long Beach and APL

- **Vessel**: APL England
- **Size of SWS**: 1 x 8 MW with 3 inlets
  Each inlet for a 2.94 MW engine
- **Installation type**: Retrofit
- **Delivery**: January 2011
- **Performance**:
  - 97% SOx Removal
  - 85% Particulate Removal
  - 3.5% fuel sulphur content
Wärtsilä’s unparalleled reference list

Ignazio Messina & C

• Vessel: DSME Hull 4465/66/67/68

• Size of SWS: 4 x 2 MW auxiliary
  1 x 1 MW boiler

• Installation type: New building

• Delivery:
  January 2011           January 2012
  July 2011             June 2012

• Performance:
  – 98% SOx Removal
  – 60-80% Particulate Removal
  – Up to 4.5% fuel sulphur content
  – Prepared for main engine scrubbi
• 1 MW Exhaust Gas Cleaning installation

• Tests run continuously

• Training for ships crew on Inert Gas Systems

• Future training on Exhaust Gas Cleaning Systems

• Demonstration for potential customers
For existing ships, the retrofit of a scrubber requires tailor-making. Some aspects to be considered for retrofits are:

- Space; design of exhaust gas funnel
- Ship stability
- Space available for tanks, pumps and water treatment unit(s)
- Power demand for the scrubber system
- Sea chest, capacity of supplying water to the scrubber system
- Fresh water capacity (closed loop and hybrid scrubber only)
technology choice to suit the ship type and operational profile

turnkey supply capability

¬ trusted partnership
¬ survey and equipment selection
¬ engineering and project management
¬ procurement and equipment delivery
¬ installation, commissioning and certification
¬ through life technical, spares and service support

credible supplier to the marine and offshore sector

proven global support capability
Conclusions
Global demand for distillates is likely to increase → Price of MGO is expected to increase while price of HFO will stay the same or even decrease

Scrubbers demonstrated to work in marine environment

Scrubbers allow for same bunkering and same engine operation as before

European SECA now ratified, more SECAs can be expected

Wärtsilä has the largest portfolio of marine scrubber solutions

Wärtsilä scrubber solutions are fit for new buildings and retrofits, for any engine and boiler brands
Thank You!

morten.letnes@wartsila.com