INDEX

- TREND
- SO\textsubscript{x} SCRUBBER TYPE
- ASPECTS TO CONSIDER
- TEST
- LESSON AND LEARN
SOx scrubbers have been installed for 213 vessels.
88 vessels were delivered. 125 vessels are under construction.
The SOx scrubber is applied for about 80% vessel for conventional fuel vessel.
2. SOx SCRUBBER TYPE

- OPEN LOOP vs. HYBRID TYPE

<table>
<thead>
<tr>
<th>Type</th>
<th>Open loop</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>Open only</td>
<td>Open + Closed loop</td>
</tr>
<tr>
<td>Water treatment system</td>
<td>X</td>
<td>O</td>
</tr>
</tbody>
</table>

- BYPASS vs. INLINE TYPE

<table>
<thead>
<tr>
<th>Type</th>
<th>Bypass</th>
<th>Inline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bypass line</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>Packing</td>
<td>O</td>
<td>X</td>
</tr>
<tr>
<td>Elec. power consumption</td>
<td>-</td>
<td>Higher</td>
</tr>
<tr>
<td>Exh. gas pipe arrangement</td>
<td>Complicated</td>
<td>-</td>
</tr>
<tr>
<td>Installation</td>
<td>Larger footprint</td>
<td>- Higher space</td>
</tr>
</tbody>
</table>
3. ASPECTS TO CONSIDER

- **SOx SCRUBBER OPERATION LIMITATION**
  - Discharge inhibited area (very limited at the moment)
    - Sulphur compliant fuel operation
    - Closed loop mode operation
      (Hybrid type scrubber to be installed)
  - Low alkalinity area of S.W.
    - Design S.W. alkalinity
      : Normally 2,200 or 2,300 µmol/litre
    - Performance is reduced in the lower S.W. alkalinity area than design value (it depends on maker’s standard).
  - Strict pH control area
    - US-VGP area: pH at discharge ≥ 6 (IMO rule: pH at 4m discharge ≥ 6.5)
    - Additional provision (NaOH dosing system, Additional S.W. pump) to be required for open loop scrubber or hybrid type scrubber to be considered.
3. ASPECTS TO CONSIDER

- **INSTALLATION SPACE**

<table>
<thead>
<tr>
<th></th>
<th>Dimension</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLCC</td>
<td>4.2m(W) x 7.5m(L) x 11.5m(H)</td>
<td>26 ton</td>
</tr>
<tr>
<td>15K CNTR</td>
<td>5.4m(W) x 10.5m(L) x 13.1m(H)</td>
<td>45 ton</td>
</tr>
</tbody>
</table>

→ Anchor, anchor chain, windlass capacity may be increased due to enlarged funnel size.

- **ADDITIONAL ELECTRIC CONSUMPTION**

<table>
<thead>
<tr>
<th></th>
<th>Elec. consumption at sea going condition(Open loop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLCC</td>
<td>280 kW</td>
</tr>
<tr>
<td>15K CNTR</td>
<td>670 kW</td>
</tr>
</tbody>
</table>

→ Generator capacity to be increased or two(2) generators to be operated at sea going condition.
3. ASPECTS TO CONSIDER

- **ADDITIONAL FUEL OIL CONSUMPTION**

<table>
<thead>
<tr>
<th></th>
<th>50%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main engine</td>
<td>-</td>
<td>+0.1 g/kWh</td>
<td>+0.45 g/kWh</td>
</tr>
<tr>
<td>Generator engine</td>
<td>+3 g/kWh</td>
<td>+2 g/kWh</td>
<td>+1 g/kWh</td>
</tr>
</tbody>
</table>

- **CORROSION (due to sulphuric acid)**
  - Overboard pipe: GRP (GRE or GRVE)
  - Exh. gas pipe inside: Special painting or 254 SMO / Duplex stainless steel
  - Ship side discharge piece: Special painting or GRP lining.
  - Overboard discharge surrounding: Special painting
  - Valve inside: Duplex stainless steel

- **ENGINE MODIFICATION**
  - T/C matching to be checked due to the increase of exh. gas line backpressure.
  - EIAPP certificate (NOx technical file) to be updated in case T/C matching is required.

- **NaOH BUNKERING (in case of hybrid type)**
  - NaOH (Caustic soda, neutralizer) bunkering onshore may be limited according to onshore bunkering facility. Offshore bunkering using barge or etc. to be considered.
4. TEST

**TEST METHOD**

- Scheme A: demonstrated by parameter check, daily spot check is recommended. (No CEMS required in principle)
- Scheme B (Almost all vessel): demonstrated by continuous exhaust gas monitoring on board

**TEST PROCEDURE**

- Shop test: Not available
- Onboard test (Function test only)
  - Installation inspection
  - Pre-commissioning check (Function test)
- Sea trial (Performance test)
5. LESSON & LEARN

- Performance fail
  - Insufficient packing quantity
  - Insufficient water flow
  - Improper water spray nozzle arrangement and number
  - In case of boiler application, the sufficient water flow to be considered due to low air/fuel ratio.
  - No specific EGCS design criteria / only required value

  Trial & error method for performance verification during sea trial only

→ Big burden for both ship owner and ship builder

The method to be established to verify the performance before sea trial.
5. LESSON & LEARN

- Safety
  - Engine failure due to water flooding in SOx scrubber

- Engineering capability
  - Insufficient engineering man power
  - Insufficient experience (in marine industry)
  - Unreliable CFD performance analysis

- Equipment delivery delay
  - Insufficient manufacturing capacity
  - Insufficient engineering capacity

- Poor quality control
  - Welding defect
  - Malfunction of equipment (e.g. gas analyzer)

Proven design model to be considered.
THANK YOU
Q & A