Why emission monitoring in the marine industry?

Main drivers:
• Meeting regulations: NOx and SOx reduction
• Energy optimization; CO₂ reduction

Resolution 177(58) NOx Technical Code is specifying the technical requirements for compliance with the emission limit values.
Regulations for preventing vessels from polluting the air

IMO is the United Nations agency responsible for the safety and security of shipping and preventing ships from polluting the environment.

IMO  International Maritime Organization
MARPOL  Marine Pollution
(International Convention for the Prevention of Pollution from Ships)
MEPC  Marine Environment Protection Committee
Regulations for the prevention of air pollution from ships

Specification of the technical requirements with emission limit values and procedures for the testing and certification of marine diesel engines

There are 3 important topics in relation to emission monitoring:

• Setting limits on the emissions of nitrogen oxides (NOx) from new ship engines
• Setting limits on the sulfur content of marine fuel oils
• Defining “Emission Control Areas” (ECA)
Topic 1 - NOx emission standard
Current legal situation with pollutant NOx

Global reduction of NOx emissions according to a “tiered approach”.

- **Tier I**: Up to Dec. 2010
- **Tier II**: After 1st Jan. 2011
- **Tier III**: After 1st Jan. 2016 when the ship is operating in an ECA

IMO postponed Tier III NOx emission limits for ship engines which should come into force in the year 2016 due to Russian veto in May 2013.
Topic 1 - NOx abatement technologies with an online measurement example

- Water injection
- Lower combustion temperature
- Exhaust gas recirculation
- Selective catalytic reduction, SCR

NH$_3$ slip measurement enables:
- cost-saving and rapid setting of urea injection
- diagnosis of catalyst deactivation
- On-line monitoring of all results instantly

In situ continuous gas analyzers LDS 6:
- cross-duct NH$_3$ measurement
- diode laser in the near infrared region
- adjusted range: 0-50 ppm
NH₃ slip measurement -
Transmitter mounted on a exhaust duct of a ship

- Window protection from soot by purging with air using fans (no probe or filter blockages by generated ammonium sulfate)
- Varying gas temperatures can be compensated for
- Laser beam can be easy aligned, low installation costs
- High long-term stability as it is built-in, maintenance-free
- Extremely rugged design
- Real-time measurements
- Reference gas cell
Starting in 2015, all vessels entering an ECA (Emission Controlled Area) have to use a fuel with less than 0.1% sulfur - or need to have an exhaust gas cleaning systems (scrubber) that scrub the flow of exhaust gas prior to being discharged to the atmosphere. Emission monitoring is required when employing such an arrangement.

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel regulation out of ECA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005-2011</td>
<td>4.5% S m/m</td>
</tr>
<tr>
<td>2012-2020</td>
<td>3.5% S m/m Jan. 2012</td>
</tr>
<tr>
<td>2020-2025</td>
<td>0.5% S m/m Jan. 2020</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel regulation in ECA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005-2010</td>
<td>1.5% S m/m up to Jun 2010</td>
</tr>
<tr>
<td>2010-2015</td>
<td>1.0% S m/m Jul. 2010</td>
</tr>
<tr>
<td>2015-2020</td>
<td>0.1% S m/m Jan. 2015</td>
</tr>
</tbody>
</table>
Topic 2 – SOx regulation
The possibilities for ship owners to meet the legal restrictions regarding SOx pollution limits

OPTION 1
‘Dual-fuel’
Heavy oil (high sulfur) + Diesel-oil (low sulfur)
No exhaust emission monitoring required

OPTION 2
‘Dual-fuel’
Heavy oil (high sulfur) + LNG (no sulfur)
No exhaust emission monitoring required

OPTION 3
‘Scrubber technology’
Heavy oil (high sulfur) + EGCS for SOx removal

EGCS – exhaust gas cleaning system

Requirements for emission monitoring
How does exhaust gas scrubbing work....

CEMS application:

SO$_2$ range: 0 - 100/750 ppm
CO$_2$ range: 0 - 10 Vol-%

Wet scrubber principle:

As a result from the chemical absorption process sulphur oxides from the exhaust gas are neutralized to sulphates in the scrubbing water.
Compliance demonstration by use of the SO$_2$ (ppm)/CO$_2$ (Vol-%) ratio method. This method is independent of the engine load, moisture content and does not require flue gas flow monitoring.

<table>
<thead>
<tr>
<th>Fuel Oil Sulphur Content (% m/m)</th>
<th>Emission Ratio SO$_2$ (vpm) / CO$_2$ (Vol-%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,5</td>
<td>195,0</td>
</tr>
<tr>
<td>3,5</td>
<td>151,7</td>
</tr>
<tr>
<td>1,5</td>
<td>65,0</td>
</tr>
<tr>
<td>1,0</td>
<td>43,3</td>
</tr>
<tr>
<td>0,5</td>
<td>21,7</td>
</tr>
<tr>
<td>0,1</td>
<td>4,3</td>
</tr>
</tbody>
</table>

Example for Emission ratio 4,3:
- SO$_2$: 40 vpm
- CO$_2$: 9,3 Vol-%

EGCS must meet SO$_2$ / CO$_2$ ratio
Examining MEPC 184(59) in more detail

There are 2 compliance plans:

a.) Scheme A  *(unit approval)*
    Certification of the unit with parameter and emission value test

b.) Scheme B  *(continuous monitoring)*

….but even with Scheme A

- In the case that continuous measurement is not installed, a daily analysis on the quality of the system in view to the SO₂ (ppm) / CO₂ (%) ratio is required.
MEPC 184(59) specifies NDIR technology

Important details in chapter 6:

6.2 CO₂ should be measured on a dry basis using an analyser operating on non-dispersive infra-red (NDIR) principle. SO₂ should be measured on a dry or wet basis using analyzers operating on non-dispersive infra-red (NDIR) ….

6.5 SO₂ and CO₂ should be monitored using either in situ or extractive sample systems.

6.8 Where SO₂ is measured by an in-situ system, the water content in the exhaust gas stream at that point is also to be determined …

Resume:

Cold extractive CEMS are the preferred solution of monitoring exhaust gas scrubber emission limit values.
DFDS vessel Ficaria Seaways with exhaust gas scrubber based on CEMS with NDIR technology

Exhaust Gas Scrubber Installed Onboard MV Ficaria Seaways

Public Test Report
Environmental Project No. 1429, 2012
Scrubber integration on the vessel Tor Ficaria carried out by Alfa-Laval

- Height 10.5 Meters
- Length 8.2 Meters
- Weight empty 24T
- Weight with water 32T
- Exhaust gas 192,000 Kg/h
Baltic and North Sea Emission Control Area

SO\textsubscript{X} emission control
SECA introduced in 2006
North American Emission Control Area

Further submittals are being prepared for Korea, Japan, and Singapore (and probably the Mediterranean)
Topic 3 – GHG reduction
New proposal from the European Commission for regulating CO\textsubscript{2} Emissions from ships

• Proposal released in June 2013  (No.525/2013)
• The goal is to reduce GHG emissions below the 50% level in 1990 by the year 2050.
• The main objective of the regulation is to establish a European MRV system for CO\textsubscript{2} emissions from ships
• The guidelines only apply to ships above 5000 GT which represents 60% of the fleet, but 90% of the total emissions

• A ship MRV system can be either based on the calculation of fuel consumed or measurement
• A monitoring plan shall be submitted to the verifiers at the latest by August 2017

MRV – Monitoring, Reporting and Verification
There are four ways of measuring:

1. Bunker delivery note
2. Tank gauging
3. Flowmeters
4. Stack monitoring (method D in Annex 1)

1.-3. Measure fuel consumption
4. Measures emissions
Specification arrangement of an exhaust gas analysis system according to NOx Technical Code (Annex 3)

Legend
- SP: Sampling probe
- HSL1/2: Heated sampling lines
- HF1/2: Heated filters
- HP: Heated sampling pump
- C: NOx Converter
- B: Cooling unit

Arrangement of exhaust gas analysis system
System requirements for Maritime Online Emission Monitoring

- Must be able to handle moisture-saturated gas flows
- Extractive systems must be designed for low concentration measurement of $\text{SO}_2$ and $\text{NO}_2$ (e.g. design with $\text{H}_3\text{PO}_4$ injection or Permapure drier solution for cold extractive CEMS)
- Preferably certified to MARPOL regulations
- Rugged, must be able to withstand vibration
- Simple and easy to service
- Corrosion resistant
### Specification for physical measuring principles according to the “NOx Technical Code”

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<td>Carbon monoxide (CO)</td>
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<tr>
<td>Hydrocarbons (HC)</td>
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Other analyzers may be used – however, they need to be certified to meet specifications!

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**ULTRAMAT 23**

**ULTRAMAT 6**
Solubility of $\text{SO}_2$ in the condensate

$\text{SO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{SO}_3$ (will be taken out with the condensate)

Gas phase $\quad$ liquid phase

$\text{H}_3\text{PO}_4$ injection

This is an equilibrium reaction - which means that by adding $\text{H}_3\text{PO}_4$ the reactants will stay in the gas phase.
### Specification for physical measuring principles according to the „NO\textsubscript{x} Technical Code“

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ULTRAMAT 23

ULTRAMAT 6
SO₂/CO₂ monitoring CEMS for multiple engines

Stream Switching from
4 Pre-Conditioned Sample Systems,
to a Common Analyser Cabinet

Block diagram
System description:

- Continuous monitoring of SO$_2$/CO$_2$ with optional NOx measurement
- IMO Type Approval by Lloyds and DNV acc. to MEPC 184(59)

Consisting of:

- Sample probe
- Sample Handling System
- CEMS cabinet incl. Ultramat 6
Online emission monitoring will become part of efficient shipping!

Thank you for your attention!

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