Regulation 13.7.1 Approved Method

Application: Ships constructed 1 Jan 1990 to 31 Dec 1999
Marine diesel engine power output >5,000 kW
Per cylinder displacement 90 litres

If a method has been approved by Party according to chapter 7 of the NOx Technical Code 2008 then ship is required to fit the “approved method” to enable the engine to meet Tier I limits.

IMO to be notified of approved method

The approved method to be installed at first renewal survey 12 months or more after IMO notified the “method” is approved

<table>
<thead>
<tr>
<th>Tier</th>
<th>n &lt; 130 rpm</th>
<th>130 ≤ n &lt; 2000 rpm</th>
<th>n ≥ 2000 rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>17.0 g/kWh</td>
<td>45.0*n^{(-0.2)} g/kWh</td>
<td>9.8 g/kWh</td>
</tr>
</tbody>
</table>
Technology for meeting IMO III NOx limits
Mexico Sept 26th Sept

Joseph Mc Carney
Johnson Matthey
International Association for Catalytic Control of Ship Emissions to Air
International Association for Catalytic Control of Ship Emissions to Air
A Major Player

- Speciality chemicals – advanced materials
- 1817  1942  2002  2008  2012
- Core skills in Catalysis, PGMs & Process Tech.
- Invest in R&D and Manufacturing Technology
- Operate in over 30 countries, 10000 employees
- Focus on Growth Opportunities - environment
- Technology & Market Leadership
- 160 SCR systems on ships – large and small
A Major Contribution NOx

- Formed in the heat of the engine
- SMOG & Particulates
- Acidifies the environment
- Lung and heart disease
- Economic costs
  - Medical care
  - Lost Productivity
  - Cost of pain / ill health / premature death

- US EPA – ECA application
  - 14000 lives saved p.a
  - 5m experience relief – respiratory symptoms

Inputs
- Fuel 36 tons
- Air 1770 tons
- Lub 200 kg

Outputs
- \( N_2 \) 1570 tons
- \( H_2O \) 115
- \( CO_2 \) 110
- NOx 5.4
- SOx 2.14
- CO 0.21
- HC 0.64
- PM 0.29
“Beginning in 2012 and completed no later than 2013, the Organization shall review the status of the technological development s to implement the standards set forth in paragraph 5.1.1 of this regulation and shall, if proven necessary, adjust the time periods set forth in that subparagraph.”

Regulation 13.10 of Annex 13, Resolution MEPC 176 (56)
IMO Review-Terms of Reference

Exception & Exemptions

Range

NOx Review
Of Technology Solutions
To Meet IMO III

Applicability & Suitability

Status / Readiness
Technology Trajectory
Supply Chain Issues
## Contributors

<table>
<thead>
<tr>
<th>Canada</th>
<th>Japan</th>
<th>BIMCO</th>
<th>ICOMIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>Liberia</td>
<td>CLIA</td>
<td>ICS</td>
</tr>
<tr>
<td>Estonia</td>
<td>Netherlands</td>
<td>CSC</td>
<td>IMarEST</td>
</tr>
<tr>
<td>Finland</td>
<td>Norway</td>
<td>Euromot</td>
<td>INTERTANKO</td>
</tr>
<tr>
<td>France</td>
<td>Sweden</td>
<td>IACS</td>
<td>IPIECA</td>
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<tr>
<td>Germany</td>
<td>United Kingdom</td>
<td>IADC</td>
<td>OCIMF</td>
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<tr>
<td>Ireland</td>
<td>United States</td>
<td>IAPH</td>
<td>WSC</td>
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<tr>
<td>European Commission</td>
<td></td>
<td>Integer</td>
<td>IACCSEA</td>
</tr>
</tbody>
</table>

Disclaimer – The views set out in this document reflect the interpretation of the author – and do not necessarily concur with the interpretation of the IMO or other stakeholders.
Technology Options

**LNG**
Fuel Combustion – controlled to Low NOx

**SCR**
NH3 neutralises NOx on Catalyst

**Other**
Water Based / Valve Timing / TC Control combustion process in Diesel engine - Low NOx

**EGR**
Lower O2 content & lower Combustion Temperatures
Technology Options

Meeting IMO III NOx limits

LNG
Fuel Combustion – controlled to Low NOx

SCR
NH3 neutralises NOx on Catalyst

Other
Water Based / Valve Timing / TC Control combustion process in Diesel engine - Low NOx

EGR
Lower O2 content & lower Combustion Temperatures
## Technology Options - SCR

### State of Technology Readiness

<table>
<thead>
<tr>
<th>Issue / Concern</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Conditions</td>
<td>Flexibility -</td>
</tr>
<tr>
<td>e.g. Temperature</td>
<td>SCR reactor placement</td>
</tr>
<tr>
<td>Catalyst Fouling – ABS</td>
<td>Charge Air, Timing, Burner</td>
</tr>
<tr>
<td>Low Load Performance</td>
<td>Below 25% Load – SCR off</td>
</tr>
<tr>
<td>SCR System - design</td>
<td>Experience-</td>
</tr>
<tr>
<td>Catalyst Lifetime</td>
<td>&gt;16000 hours / 2 years</td>
</tr>
<tr>
<td>Ammonia Slip</td>
<td>Mobile, Stationary, Ships – 500</td>
</tr>
<tr>
<td>Small Vessels</td>
<td>Compact SCR – Design Phase</td>
</tr>
<tr>
<td>Supply Chain Concerns</td>
<td>Competitive Global Supply Chain</td>
</tr>
<tr>
<td>Urea</td>
<td>AUS 40 Standard</td>
</tr>
<tr>
<td></td>
<td>US Supply Chain - by 2014</td>
</tr>
</tbody>
</table>
## Technology Options - EGR

<table>
<thead>
<tr>
<th>Issue / Concern</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Readiness Combined with other technology? Not available for most engines</td>
<td>Capability Demonstrated High NOx reduction – IMO III Development Focus Engine OEMs</td>
</tr>
<tr>
<td>H2SO4 / PM Reagent / wash water</td>
<td>Low operating costs Mg(OH)2</td>
</tr>
<tr>
<td>Scrubber Developing Experience</td>
<td></td>
</tr>
<tr>
<td>Issue / Concern</td>
<td>Response</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
</tr>
<tr>
<td>Low emissions – dependent on Engine size / duty cycle / pilot fuel</td>
<td>Experience 100’s Gas engines – low emissions 20 Vessels Meets IMO III Lower Fuel Costs</td>
</tr>
<tr>
<td>Energy Density</td>
<td></td>
</tr>
<tr>
<td>Issue / Concern</td>
<td>Response</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Not Tier III Compliant</td>
<td>Can be used in combination</td>
</tr>
<tr>
<td>30% - 50% - 65%</td>
<td></td>
</tr>
<tr>
<td>DWI – HAM – FE</td>
<td></td>
</tr>
<tr>
<td>Miller Timing</td>
<td>Loss over come with 2-stage TC</td>
</tr>
<tr>
<td>Decreased Power</td>
<td></td>
</tr>
</tbody>
</table>
### Technology Options - summary

**LNG**
- Fuel Combustion – controlled to Low NOx
- Practical

**SCR**
- NH3 neutralises NOx on Catalyst
- Panacea

**Other**
- Water Based / Valve Timing / TC
- Control combustion process in Diesel engine - Low NOx
- Partial

**EGR**
- Lower O2 content & lower Combustion Temperatures
- Potential
Technology to meet IMO III limits is available
There are a number of options / combinations

Greater collaboration between Engine OEMs and other technology providers will deliver efficient, economical, environmental solutions, for cleaner shipping

Greater collaboration between technology providers and regulators will maximise the gain to society at an “efficient” cost
SCR installation – Alice Austen

Engines: 2 x CAT 3516 A
Temperature: 752°F
NOx Reduction: < 3 g/kWh (~ 70%)
SCR installed: 2004
SINOx® Installed: 1999
Type MaK 8M32 (Main)/ MAN 6L16/24 (Aux.)
Power 3,840kW / 540 kW (Aux.)
Exhaust Gas Flow 21,000 / 3,000 Nm³/h
Fuel HFO / MDO
Temperature 320 / 336° C
Urea Consumption: 97 / 8 l/h (@40%)

Catalyst Type SW 30 Honeycomb
Catalyst Volume 3 m³/engine (Main)
Exhaust NOx: 2g/kWh
SCR installation – Kleven

**Project:** Supply Vessel/Work ship Kleven

**Exhaust gas flow:** 8.790 m³/h

**Engine type:** 2 x MAN 6L 32/40, 2 x MAN 8L 21/31

**Fuel:** MGO

**Temperature:** 335° C

**SINOx® Installed:** 2007

**Catalyst type:** SW 40

**Catalyst volume:** 3.8 m³

**NOx Reduction:** 86%
Project: 2 x LNG Carrier, Exmar Excellence/Excelerate
SINOx® Installed: 2007
Exhaust Gas Flow: 2 x 70.100 Nm³/h
Application: 2 x 70t/h Regas Boiler
Fuel: HFO/MDO
Temperature: 380°C

Catalyst Type: SW 30 Honeycomb
Catalyst Volume: 10,62 m³
Exhaust NOx: 30 mg/Nm³
Reduction Rate: 93%
De-NOx - Selective Catalytic Reduction

1. Combustion → pollution inc. the acidic pollutants - NOx & SOx
2. NOx is dangerous, & increasingly its emission is regulated.
3. NOx can be controlled in the engine or neutralised in the tailpipe – via catalytic after treatment such as SCR
4. SCR is a proven technology (power-plants, HDD and auto)
5. The SCR process produces Nitrogen as its end product
6. Marine SCR – >500 Case studies – yachts to container ships
7. SCR needs a reducing agent – Urea / Ammonia
8. The catalyst is robust but requires the correct conditions for optimum operation
9. Sulphur is not a poison to Marine SCR Catalysts – but its effects need to be considered – e.g. limiting temperature.
10. After-treatment can allow an increase in efficiency (fuel
11. SCR on its own can meet IMO III or as a top up technology
Technology for IMO III
Mexico Sept 26\textsuperscript{th} Sept
For Further information please contact
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Johnson Matthey
mccarj@matthey.com