UNOLS Green Boats and Ports Workshop – Portland, OR
Barrett Carpenter
Technical Marine Sales Engineer
Peterson Power Systems
CAT EPA Tier-4/IMO III
Green Emissions Solutions for Research Vessels

EPA MARINE TIER-4 EMISSIONS STANDARDS

Table 8. Tier 4 Standards for Marine Diesel Category 1/2 Engines

<table>
<thead>
<tr>
<th>Power (P)</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>kW</td>
<td></td>
</tr>
<tr>
<td>P ≥ 3700 (4962hp)</td>
<td>2014&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>2016&lt;sup&gt;b,c&lt;/sup&gt;</td>
</tr>
<tr>
<td>2000 (2682hp) ≤ P &lt; 3700 (4962hp)</td>
<td>2014&lt;sup&gt;c,d&lt;/sup&gt;</td>
</tr>
<tr>
<td>1400 (1887hp) ≤ P &lt; 2000 (2682hp)</td>
<td>2016&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>600 (804hp) ≤ P &lt; 1400 (1887hp)</td>
<td>2017&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- a - 0.25 g/kWh for engines with 15-30 dm³/cylinder displacement.
- b - Optional compliance start dates can be used within these model years.
- c - Option for Cat. 2: Tier 3 PM/NOx+HC at 0.14/7.8 g/kWh in 2012, and Tier 4 in 2015.
- d - The Tier 3 PM standards continue to apply for these engines in model years 2014 and 2015 only.
SCR History

- Proven history, reliable and durable technology
- Over 500 Marine SCR installations operating globally
Marine SCR Installations by Year

IMO report MEPC66/6/6
Chemical Reaction

1. Injection of Urea into Exhaust Stream
2. Evaporation of Water – Conversion of Urea to NH₃
3. NOx reduction when ammonia contacts SCR catalyst
4. Output of Nitrogen, N₂
Components of SCR

- Diesel Exhaust Fluid (DEF)
- Pump Electronics Tank Unit (PETU)
- DEF Injector
- Mixing Tube
- SCR Catalyst
U-flow & Z-flow Flexible Installation
Total Backpressure = 75" H2O (18.7 kPa)
Customer piping = 27" H2O (6.7 kPa)

Def injection line
▲29PSI maximum pressure drop

Air flow = 10CFM (4CFM for C32)
Air pressure = 80-150 psi (See A&I guide)
**3500E Mechanical Systems Overview**

Total Backpressure = 75” H2O (18.7 kPa)
Customer piping = 27” H2O (6.7 kPa)

- **Main DEF tank**
- **Filter 100µ**
- **DEF Transfer Pump 480V 3-phase**

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**SCR Module**

- **Dosing Cabinet**
  - (must be below SCR)
  - Pressure = 5–10 psi

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**Def injection line**

- Must be wrapped

- **Def injection line**
  - ▲ 29PSI maximum pressure drop

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**Air line to SCR**

- **Air flow = 10CFM (4CFM for C32)**
- **Air pressure = 80-150 psi (See A&I guide)**
Open vs Closed Loop Systems

• *Open Loop System*
  – No feedback from engine
  – Dosing based on tables

• *Closed Loop Complete System*
  – Continuous condition-based Urea Injection
  – Engine will control dosing based on load factor and exhaust temperature inlet to SCR Module
Complete Closed Loop System

“hello?”

“dude”

“over here”
3500 Marine SCR – Lowest Emissions / Highest Benefits

Integrated
DEF Mixing

Optimized
Air Assisted Dosing provides highest efficiency mixing to lower operating costs

Flexible
Mount in all directions

Closed Loop Control
- Lowest Consumption
- Extended Useful Life
- Ensures Compliance
- Flexible to Urea Quality

Sound Reduction
Up to 25dbA

Ease Of Service
One Door/One Person

Vanadia Catalyst
High Fuel Sulfur Tolerance

300 CPSI Catalyst
High Nox Conversion Efficiency
- Compact
- Ensures Compliance w/ extended Useful Life

MaK

Caterpillar Marine
**Catalyst Lifetime**

*EPA requirement for lifecycle of the Catalyst is 10,000 hours*

<table>
<thead>
<tr>
<th>Average Application Load Factor (%)</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCR Replacement Interval (hrs)</td>
<td>20,000</td>
<td>16,000</td>
<td>13,000</td>
<td>11,000</td>
<td>10,000</td>
</tr>
</tbody>
</table>
DEF Tank Sizing - *No One Size Fits All...*

**Straight Forward Inputs**
- Operating Load Profile (% time, % power)
- Operating Hours per Year
- DEF Type (32.5% vs. 40% urea conc.)

✔️ Use EVA™ to calculate DEF consumption

**Less Straight Forward Inputs**
- Number of DEF tanks per vessel?
- Multi-Compartment tank(s)?
- Location of tank(s)?/ space constraints
- Typical bunkering frequencies?
- % Volume fill of DEF tank(s)?
- Tank cooling/heating capability?

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### Year 1 Diesel Fuel Consumption & Cost

<table>
<thead>
<tr>
<th></th>
<th>per engine</th>
<th>per vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons / hour</td>
<td>31.8</td>
<td>63.5</td>
</tr>
<tr>
<td>Gallons / day</td>
<td>305</td>
<td>609</td>
</tr>
<tr>
<td>Gallons / week</td>
<td>2,133</td>
<td>4,265</td>
</tr>
<tr>
<td>Gallons / month</td>
<td>9,267</td>
<td>18,534</td>
</tr>
<tr>
<td>Gallons / year</td>
<td>111,202</td>
<td>222,404</td>
</tr>
<tr>
<td>Cost / year</td>
<td>$278,005</td>
<td>$556,011</td>
</tr>
</tbody>
</table>

### Year 1 DEF Consumption & Cost - (32.5% conc.)

<table>
<thead>
<tr>
<th></th>
<th>per engine</th>
<th>per vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons / hour</td>
<td>2.3</td>
<td>4.7</td>
</tr>
<tr>
<td><strong>Gallons / day</strong></td>
<td><strong>22.5</strong></td>
<td><strong>45.0</strong></td>
</tr>
<tr>
<td>Gallons / week</td>
<td>158</td>
<td>315</td>
</tr>
<tr>
<td>Gallons / month</td>
<td>685</td>
<td>1,370</td>
</tr>
<tr>
<td>Gallons / year</td>
<td>8,221</td>
<td>16,443</td>
</tr>
<tr>
<td>Cost / year</td>
<td>$9,866</td>
<td>$19,731</td>
</tr>
</tbody>
</table>

### YEAR 1 TFC COSTS / VESSEL

$575,742
3500E – Flexible IMO II / III Switchable

3500E Base Engine:
- Multiple fueling Calibration Capability
- Base Calibration – IMO II engine out Nox
- Backpressure and Exhaust temperature Optimized for Cat SCR
- Can be sold as Engine Only with IMO II certification

3500E IMO III:
- 3500E Base Engine with integrated Caterpillar SCR

Operational Modes
- Mode 0 - IMO II engine out Nox fuelling map
- Mode 1 – IMO III: BSFC optimized Nox calibration with Caterpillar SCR
- Mode 2 – IMO II: BSFC optimized Nox calibration with Caterpillar SCR only dosing to IMO II levels

Contact ASC for Tactical Availability
Oregon State University “UNOLS RCRV”
3 x CAT Tier-4 C32/Siemens VDEP Gensets
Provided and Commissioned by Peterson Power Systems

Harley Marine Tug "Earl Redd"
First Tier-4 Final Tug
Operational in United States

2 x CAT 3516E Engines
Provided and commissioned by Peterson Power Systems

Foss Maritime Tug “Caden Foss”
Second Tier-4 Final Tug
Operational on the West Coast

2 x CAT 3516E Engines
Provided and commissioned by Peterson Power Systems

CONTACT US TODAY!
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bcarpenter@petersonpower.com