

The Future of Practical Exhaust Emissions Control for Marine Diesel Engines

*Presented by Matthew F. Winkler
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of the Air Resources Board
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Seaworthy Systems, Inc.





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MARINE DIESEL ENGINES

NO_x:

- 1 Million Tons of NO_x per year
- 8.1% of all mobile source NO_x
- 4.8% of total NO_x emissions in U.S.

SO_x :

- 30 to 40 percent of local shore-side emissions
- Percentage will increase from minor to major in next 5 years.

Particulate Matter (P.M.):

- 42,000 tons of P.M. per year
- 4.4% of all mobile source P.M.
- 1.0% of total P.M. emissions in U.S.



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REGULATORY ORGANIZATIONS

- **International: International Maritime Organization (IMO)**
 - MARPOL 73/78 Annex VI, 2000 (Pending approval)
- **Domestic: U.S. Environmental Protection Agency (EPA)**
 - Proposed emission standards for new CI marine engines – 40 CFR Part 94, 2004/2006 & 2008/2010
- **Localized: California Air Resources Board (ARB/CARB)**
 - 2002-2004 (Estimated)



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Comparison of Numerical Emission Limits: EPA's Non-Road Tier 1 Levels and MARPOL Annex VI Levels

Agency	Engine Speed, N (rpm)	HC (g/kW-hr)	CO (g/kW-hr)	NO _x (g/kW-hr)	PM (g/kW-hr)
EPA	All	1.3	11.4	9.2	0.54
MARPOL (Proposed)	N < 130	None	None	17.0	None
Annex VI	130 < N > 2000	None	None	45*N ^(-0.2)	None
	N > 2000	None	None	9.84	None



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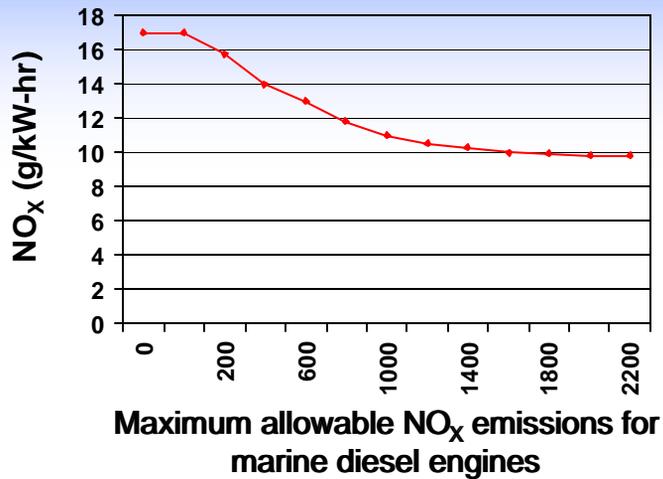
NO_x

- Only new C.I. marine engines put in service after 1/1/2000 must comply.
- All new re-engining after 1/1/2000 must comply.
- All overhauls of compliant diesel engines after 1/1/2000 must maintain emissions compliance.
- NO_x in service can be 7-10% greater than test bed emissions.



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D2/E2/E3/C1 Cycles on Marine Diesel Oil



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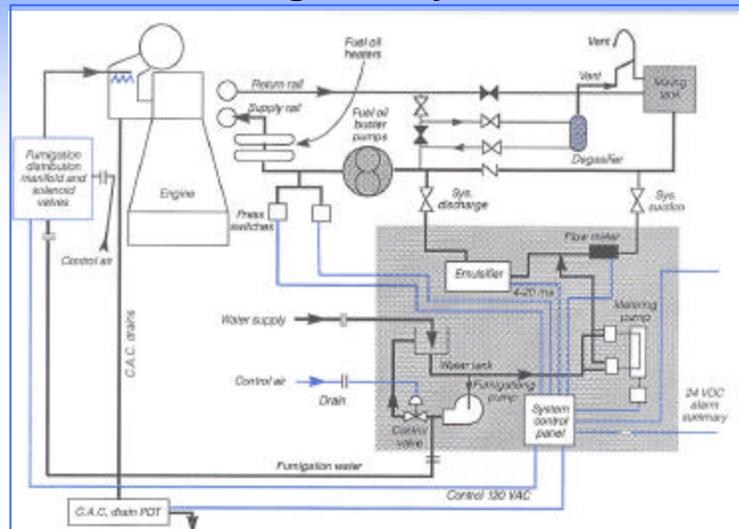
NO_x CONTROLS

- Purchase CI marine engine(s) with emission compliant certificate (EIAPP)
- Add emission control technology to older engine
- Selective catalytic reduction (SCR) (90% reduction)
- Water emulsification into marine fuel (20-50% reduction)
- Modified fuel injection components (20% reduction)
- Retarded timing (15% reduction)
- Larger charge air coolers (20% reduction)
- Exhaust gas recirculation (20-50% reduction)
- Combinations of above individual technologies
- Select marine fuels with good ignition properties (Cetane number/or CCAI number)



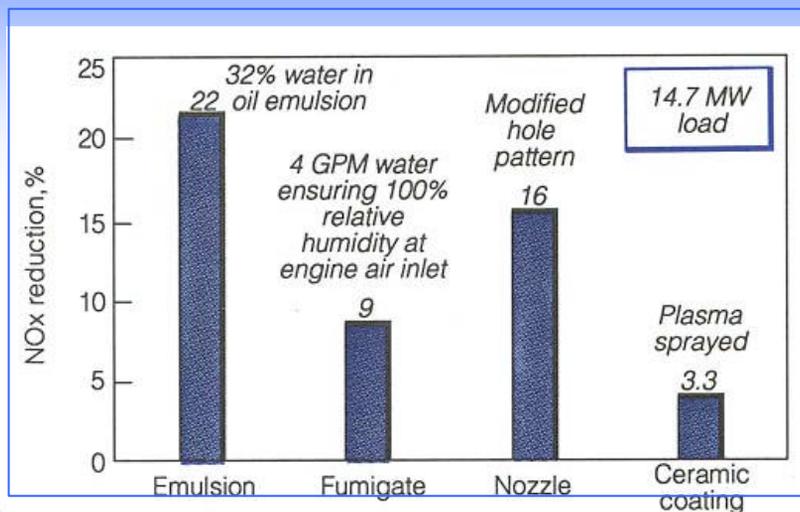
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Water / Fuel Emulsification and Inlet Air Fumigation System



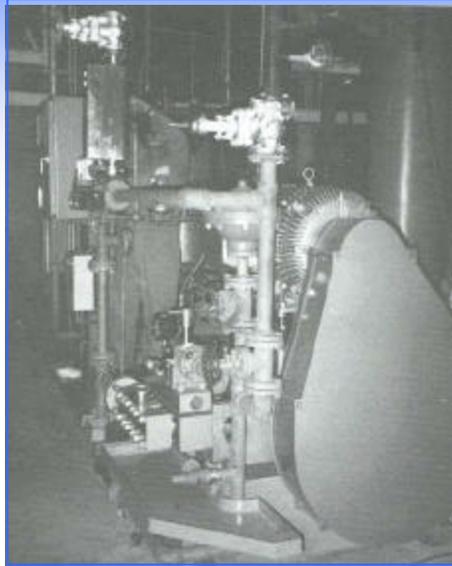
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NO_x Reduction Technologies



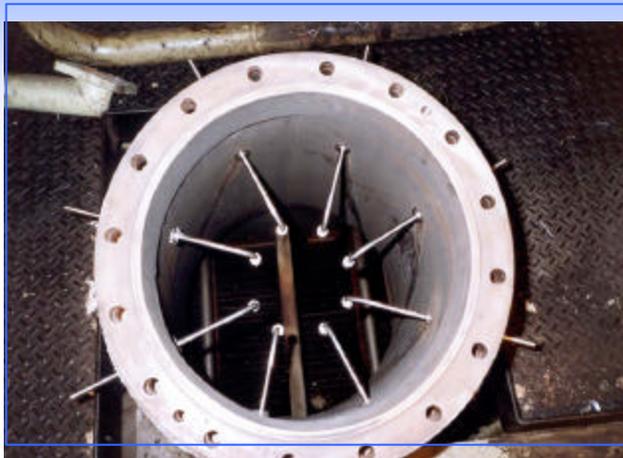
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Water / Fuel Emulsifier System



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Inlet Air Fumigation Spray System



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SO_x

- Worldwide 4.5 weight percent sulfur cap
- Conditional acceptance of “SOX emission control areas” with sulfur cap with 1.5%
 - Baltic Sea area now
 - North Sea (near future)
 - Area west of U.K. (near future)
- Average marine fuel oil sulfur levels for past ten years are between 2.8-3.0 weight percent
- All marine fuel suppliers to ensure compliance with this sulfur cap = 4.5%



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SO_x CONTROLS

- Purchase marine fuels compliant with near term sailing needs
- Switch to gas oil or MDO for SOX emission control area
- Install exhaust gas salt water scrubbers



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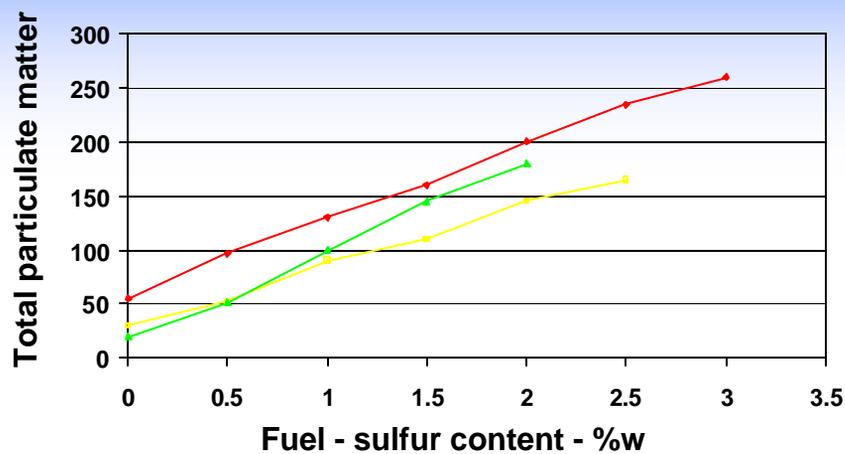
PARTICULATE MATTER (PM)

- Clumps of small particles of partially burned fuel
- Partially burned lube oil
- Sulfates and water (very sensitive to fuel sulfur content) (40% conversion)
- Ash from fuel and lube oil



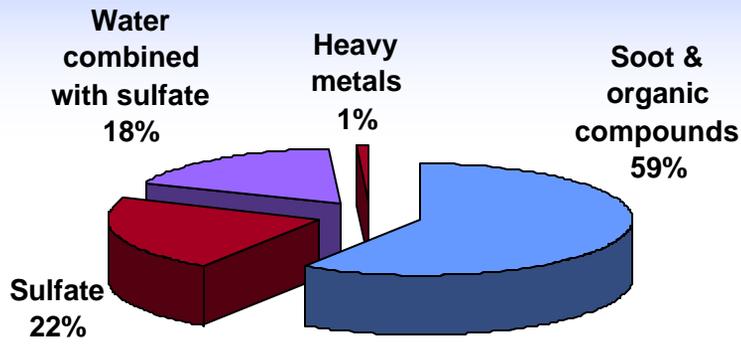
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PM Measurements According to ISO 8178 (mini dilution)



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Particulate composition for MAN B&W 7L40/45 aboard a ferry ship



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P.M. CONTROLS

- Maintain fuel injection equipment at peak efficiency
- Use lower sulfur marine fuels due to approximately 40% conversion to P.M.
- Maintain high jacket water temperatures
- Maintain clean & efficient turbo charger systems
- Maintain automated viscosity control system, clean and efficient
- Limit operations below approximately 60% engine load
- Add fuel/water emulsification to fuel system



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SMOKE

- Visible fraction of the exhaust gases
- Black smoke – primarily carbon
- Blue smoke – incomplete combustion of fuel or lube oil (caution for used oil in marine fuels)
- White smoke – vaporized (unburned) liquid fuel or condensed water droplets
- Transient cycles – 20/50 percent opacity



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SMOKE CONTROLS

- Maintain turbo charger system in clean and efficient condition
- Maintain fuel injection system in clean and efficient condition
- Maintain piston rings/cylinder liners to limit lube oil consumption
- Limit used lube oil in marine fuels
- Maintain clean and efficient automated fuel viscosity control system
- Use fuel limiters on governor system to limit rate of acceleration in cold climates
- Limit heat removal from waste heat boilers



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Thank You for Your Kind Attention



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