



CONFERENCE ON MARINE VESSELS
&
AIR QUALITY

1-2 February 2001
San Francisco, CA



ENVIRONMENTAL CONSIDERATIONS
IN COMMERCIAL MARINE INDUSTRY

1 February 2001
San Francisco, CA

AGENDA

- 1. Overview of World Shipping**
- 2. Types of Vessel**
- 3. Sources of Air Pollutants**
- 4. Air Pollutant Species**
- 5. Trends in Ship Systems ⇒ Current vs. Future**



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AGENDA

- 6. Emission Controls ⇒ Design and Technological Advancements**
- 7. Emission Controls ⇒ Regulatory**
- 8. ABS Mission, Policy and Role**



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OVERVIEW OF WORLD SHIPPING

- **World Fleet > 85,000 Ships Over 100 Gross Tonnage**
- **Oceangoing > 40,000 Ships Over 90 Meter (295 Feet)**
- **Motorships ⇒ 99 %**
- **Others: Steam, Gas, LNG ⇒ 1 %**



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TYPES OF VESSELS

- **Oceangoing Vessels ⇒ General Cargo; Containership; Bulk; Carriers; Tankers (LNG, VLCC); Refrigerated Cargo; Passenger Ships**
- **Small Vessels (Inland & Coastal) ⇒ Tugboats; Towboats; Offshore Supply; Fishing and Fisheries Vessels; Ferries- Passengers and Vehicle; Industrial**
- **Drilling Rigs and Platforms ⇒ MODU; FPSO; FSO**
- **Others ⇒ Research, Military & Special Services**



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VESSELS DESIGN (MACHINERY)

1. Motorships ⇒ * Diesel Engines - Slow, Medium and High Speed [99% of Fleet]
2. Steamships ⇒ * Boilers and Steam Turbine Engines
3. Gas Turbine Ships ⇒ * Gas Turbine Engines
4. LNGC, VLCC ⇒ * Dual Fuel-Diesel / Gas Turbine Engines
5. Others ⇒ * Nuclear, Solar, Fuel Cells



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SOURCES OF AIR POLLUTANTS & SPECIES

- Propulsion and Auxiliary Equipment : Diesel and Gas Turbine Engines, Boilers
 - *Exhaust Emissions (CO₂, NO_x, SO_x, HC, CO, and PT)*
- Fuel Oil Types : Gas (Diesel) and Residual Oil
 - SO_x
- Cargoes:
 - *Volatile Organic Compounds (VOC)*
- Other Materials: Refrigerants, Fire Fighting (Halon)
 - *Ozone Depleting Substances (ODS)*

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MAJOR SOURCES OF AIR POLLUTANTS AND SPECIES

- 99% of World Fleet of 85,000 Ships \Rightarrow Motorships
 \Rightarrow Diesel Engines
- Diesel Engines Current Sales \approx 16 Million Units (EST.)
 - *Slow Speed : 1% \Rightarrow 55 million HP [200 x 200 MW Power Stations] \Rightarrow Higher Exhaust Emissions*
 - *Medium Speed : 40 -50 % \Rightarrow Moderate*
 - *High Speed : 50-60 % \Rightarrow Lower*
- Exhaust Gas Stream \Rightarrow NO_x ; SO_x; CO; HC; CO₂; PT

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EXHAUST EMISSIONS FROM SHIPPING

Exhaust Gas Stream Composition [Slow Speed Diesel Engine Around 80% MCR]:

- CO₂ = 5.6 % (i.e. 56,000 ppm)
- O₂ = 13.6%
- SO₂ = 660 ppm
- HC = 122 ppmC
- CO = 45 ppm
- NO_x = 1220 ppm
- PT = 120 mg/m³

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EXHAUST EMISSIONS FROM SHIPPING

Carbon Dioxide:

- Independent of Combustion Process
- 1 Tonne of Fuel Oil = 3.15 Tonne of CO₂
- 140 M Tonnes/Annum = 450 M Tonnes of CO₂
[5% of World Total Equates to a Major Industrialized Country < USA or 25% Higher than EU Combined]
- 2 - 3% of World Total of CO₂ (5 G Tonnes)

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EXHAUST EMISSIONS FROM SHIPPING

Oxides of Nitrogen (NOx):

- Defined as: NO+NO₂
- Diesel Engines:
 - Max. Range of NOx = 800 - 2000 ppm
 - Wider Variation Over Load Range
 - Application of Particular Design of Engine
 - Example: 8,000 kW; Slow Speed ; Residual Fuel
 - 1. Constant Speed, MP (E2 Cycle) = 16.0 g/kWh
 - 2. Propeller Law (E3 Cycle) = 17.7 g/kWh
- Engines; Normal Service; 50-85 MCR
 - 1. Medium Speed Engine = 8.3 - 21.8 g/kWh ;
57 kg NOx/T Fuel ; Brake Specific = 12 g/kWh
 - 2. Slow Speed Engine = 15 - 23.6 g/kWh;
87 kg NOx/T Fuel; Brake Specific = 17 g/kWh

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EXHAUST EMISSIONS FROM SHIPPING

Oxides of Nitrogen (NO_x):

- **Boiler and Gas Turbine Engines:**

1. Boilers: 5 - 10 Kg/T Fuel [10% of Diesel Engines]

2. Gas Turbine: 3 - 7 g/kWh [50% of Diesel Engines]

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EXHAUST EMISSIONS FROM SHIPPING

Oxides of Sulfur (SO_x):

- **Sulfur Content of Fuel** ⇒ 0.5 - 5.0 % m/m
(2.8% m/m average)
- **Fuel Specific Rate** : 50 Kg SO_x /Tonne Fuel

Hydrocarbons (HC):

- **Diesel Engine** < 100 - 200 ppmC (60-40 % MCR)
- **Fuel Specific Emission Rate:** 2.4 Kg HC/T Fuel
- **Brake Specific Emissions Rate** : 0.5 g HC/kWh

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EXHAUST EMISSIONS FROM SHIPPING

Carbon Monoxide (CO):

- Diesel Engine < 200-300 ppm (Over Full Load Range)
- Fuel Specific Emission Rate: 7.4 Kg CO/T Fuel
- Brake Specific Emissions Rate: 1.6 g CO/kWh

Particulates (PT):

- Gas (Diesel) Oil:
 - Fuel Specific Emission Rate: 1.2 Kg PT/T Fuel
 - Brake Specific Emissions Rate: 0.2 g PT/kWh
- Residual Fuel Oil:
 - Fuel Specific Emission Rate: 7.6 Kg PT/T Fuel
 - Brake Specific Emissions Rate: 1.5 g PT/kWh

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DESIGN TRENDS SHIP SYSTEMS AND EQUIPMENT - CURRENT VS FUTURE

Propulsion and Auxiliary Equipment:

- Diesel Engines ⇒ Diesel Electric
Medium Speed Engines
Gas Turbine Engines
- Fuel Systems ⇒ Low Sulfur Gas Oil
Compressed LNG
Fuel Cells
Alternate Fuels
- Cargo Operations ⇒ No VOC/ CFC Discharged
VOC Control Systems
Alternate Refrigerants
- Use of Emissions Control Systems

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EMISSIONS CONTROLS -TECHNOLOGY

Propulsion and Auxiliary Systems:

- **Combustion Process Optimization**
- **Fuel Injection System Optimization and Advanced Controls**
- **Electronic Controls**
- **Fuel-Water Emulsification**
- **Charge Air Characteristics - Turbocharger and Aftercooler**
- **Exhaust Gas Re-circulation**

Exhaust After-Treatment Devices:

- **Selective Catalytic Reduction (SCR) Method**

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EMISSIONS CONTROLS - REGULATORY

International Shipping :

***** Self-Regulated Bound By**

- 1. Worldwide Organizations - Conventions**
 - **IMO MARPOL 73/78, Annex VI & NOx Technical Code**
[Ships of 400 Gross Tonnage or above;
New, Converted, Up-rated, or Replacement
Engines above 130 kW]
 - * **Chapter I - General**
 - * **Chapter II - Survey, Certification & Means of Control**
 - * **Chapter III - Requirements for Control of Emissions**

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EMISSIONS CONTROLS - REGULATORY

2. National Level

- State and Port Control Maritime Administrations
[e.g. Administration; EU Directive; USEPA; USCG]

- 40 CFR Part 89 et al. , 94 - Control of Emissions
of Air Pollution From New Marine Compression -
Ignition Engines at or Above 37 kW; Final Rule

3. Incentives - National

[E.G. Swedish Maritime Administration]

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MARINE INDUSTRY SELF-REGULATION **ABS ROLE AND OBJECTIVES**

Emissions Controls Implementation Concern:

- **Pre-Certification** ⇒ **Certification During Service Life of Ship [20 - 30 Years]**
- **Large Diesel Engines** ⇒ **Manufacturer vs. Ship Owner Responsibility**
[Adjustments, Modifications, Routine Maintenance, Upgrades, Replacements, etc.]
- **Flag Administration Resources** ⇒ **Authorization of Recognized Organizations** ⇒ **Classification Societies**

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MARINE INDUSTRY SELF-REGULATION **ABS ROLE AND OBJECTIVES**

ABS Role and Objectives:

- **Mission to Protect the Marine Environment**
- **Develop International Standards to Avoid, Reduce or Control Marine Pollution to the Environment**
- **Committed to Operate Consistent with Applicable Environmental Legislation and Regulations; and**
- **Provide Framework for Establishing and Reviewing Environmental Objectives and Targets.**

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QUESTIONS?



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