ΝΑΥΤΙΚΟΙ ΚΙΝΗΤΗΡΕΣ ΚΑΙ ΤΕΧΝΟΛΟΓΙΕΣ ΠΕΡΙΟΡΙΣΜΟΥ ΤΗΣ ΑΤΜΟΣΦΑΙΡΙΚΗΣ ΡΥΠΑΝΣΗΣ

Νικόλαος Π. Κυρτάτος
Καθηγητής Ε.Μ.Π.

ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ
ΕΡΓΑΣΤΗΡΙΟ ΝΑΥΤΙΚΗΣ ΜΗΧΑΝΟΛΟΓΙΑΣ
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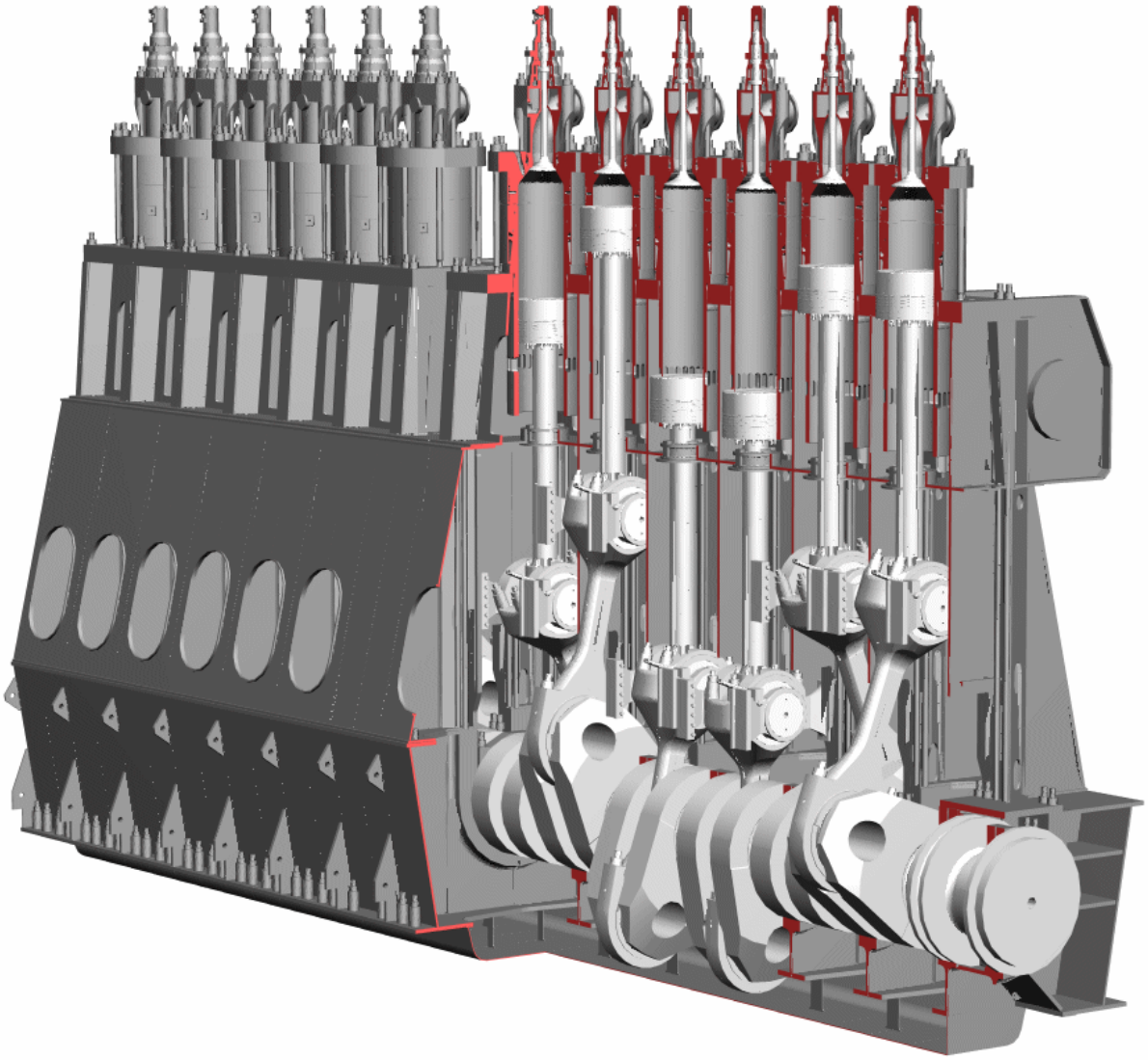
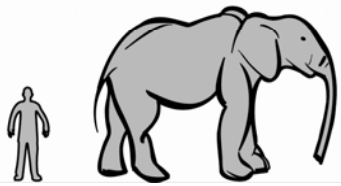
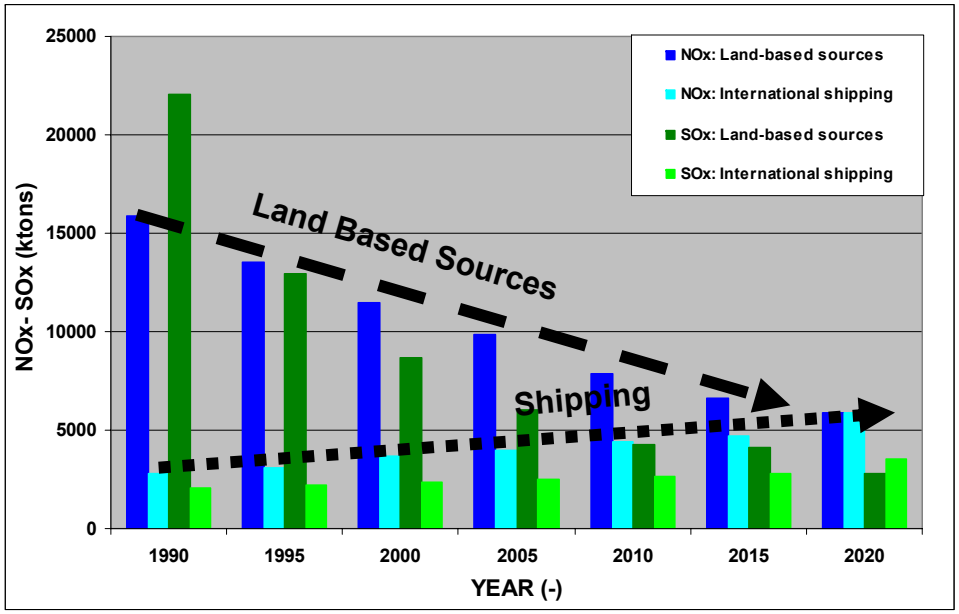


Marine Diesel

- 80 MW
- 300 t/day
- 16m$/yr
- 3% => 0.5m$/yr



Emissions

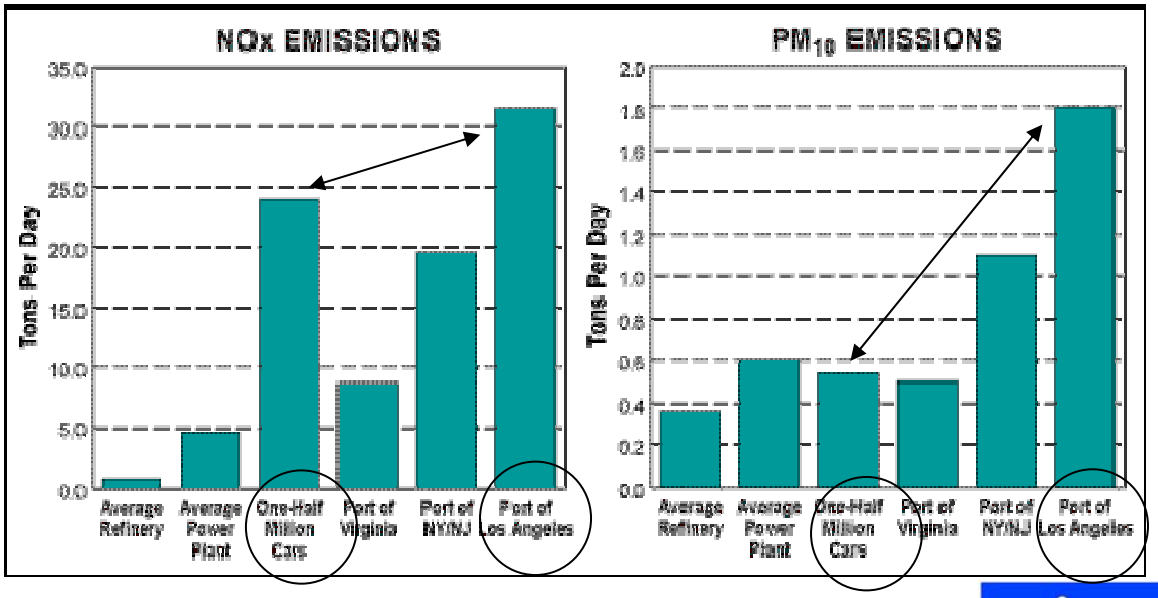


NOx and SOx emissions from Land Based Sources and International Shipping

[The International Council on Clean Transportation (icct), *"Air Pollution and Greenhouse Gas Emissions from Ocean-going Ships"*, 2007. (www.theicct.org)]

GLOBAL MANMADE EMISSIONS/ SHIPS CONTRIBUTION = NOX: 12%, SOX: 6%, CO_2: 3%

NOx and PM from Ports compared to Refineries, Powerplants, Cars



NOx – Nitrogen Oxides

Definitions

Nitrogen monoxide (NO) and nitrogen dioxide (NO_2) are referred as **nitrogen oxides (NOx)**

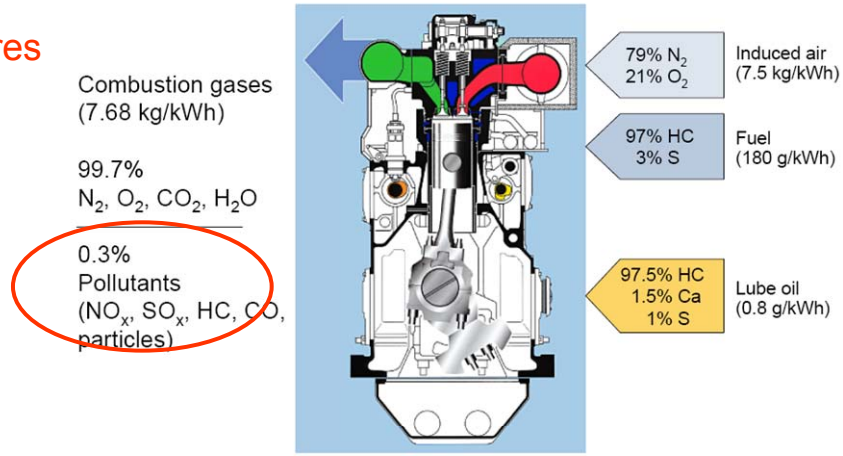
Environmental Impact

Acid rain / Over-fertilization of lakes and soil /

Ozone and smog formation / Small size particulates formation

Diesel process for NOx emissions

- relatively high due to high local combustion temperatures
- NOx formation is thermal
- Main nitrogen source is combustion air
- High temperature results in high NOx formation
- NOx formation process EXTREMELY COMPLEX (hundreds of different chemical reactions)
- 95% NO and 5% NO2



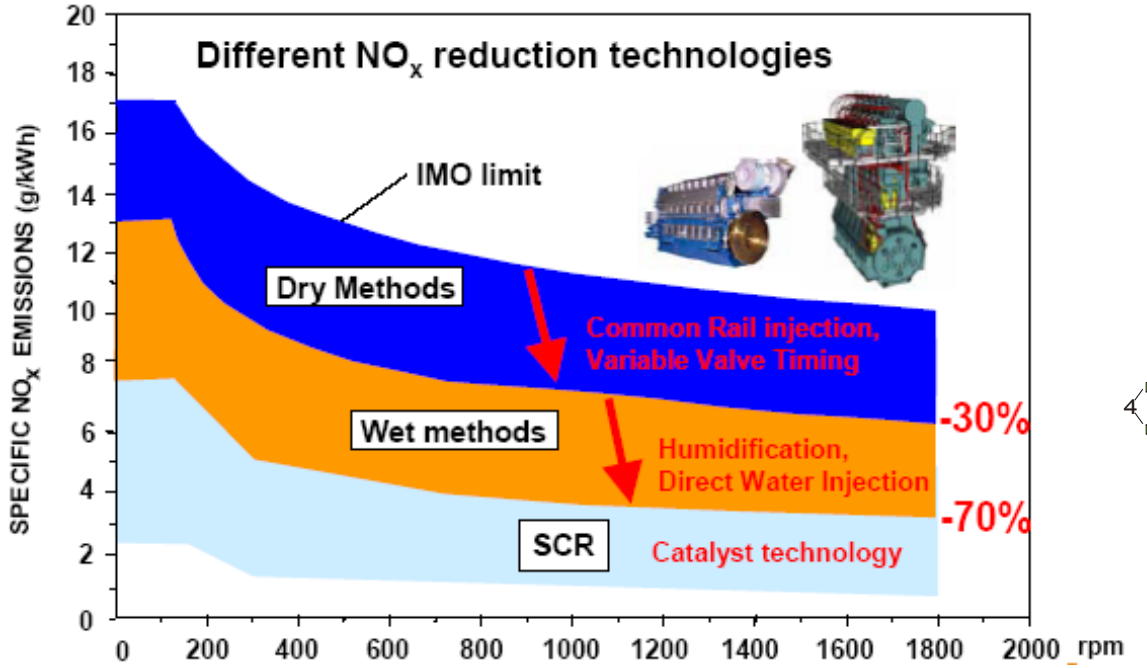
Abatement Technologies

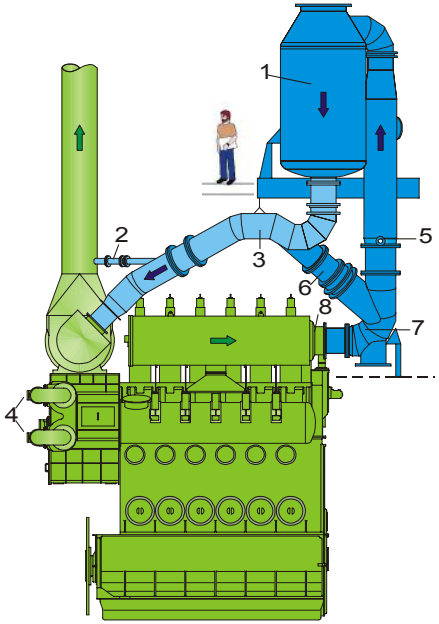
Primary Measures

- Common rail
- Variable valve timing
- Saturation of intake air
- Emulsion

Secondary Measures

- SCR (Selective Catalytic Reduction)
- Sea water scrubbing
- EGR - Exhaust Gas Recirculation
- Fuel Additives





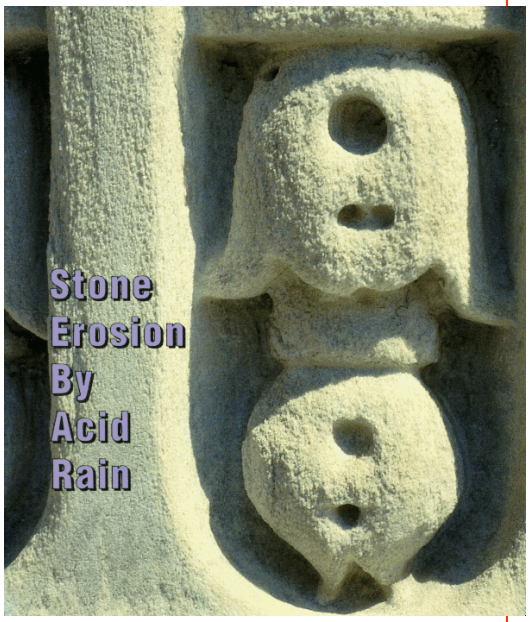
SOx – Sulphur Oxides

Definition

Sulphur dioxide (SO_2) and sulphur trioxide (SO_3) referred to as **Sulphur oxides (SOx)**

Environmental Impact

Acid rain / Small size particulates formation



Diesel process for SOx

All sulphur entering COMBUSTION chamber is oxidized forming SOx (SOx is directly proportional to *fuel sulphur content* and *fuel consumption*)

In Sox, typical SO_2 is 95% and SO_3 is 5%

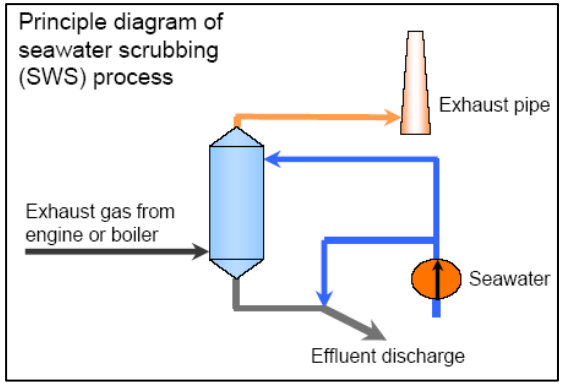
- Manmade SOx ~10% of Volcanic
- Ships SOx ~6% of Manmade (0.6% volcanic)

SOx – Sulphur Oxides

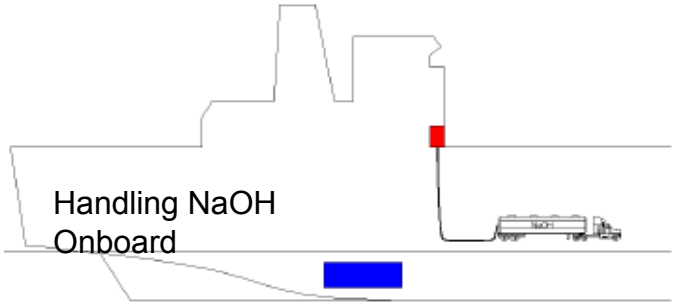
Abatement Technologies

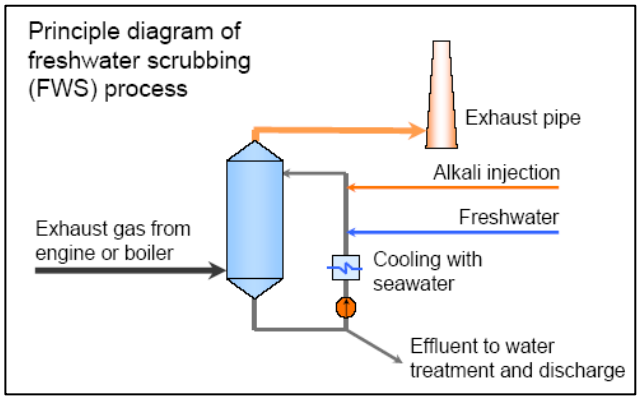
- **Switch to low sulphur fuel**
  Operation on low sulphur residual fuel or distillate fuel or natural gas (LNG)

- **Sea Water Scrubber**
  Reduces SOx by dissolving it and neutralizing it in salt water



- **Caustic soda scrubber**
  Reduces SOx in a closed loop system with fresh water, to which Sodium Hydroxide (NaOH) is added for the neutralization of SOx



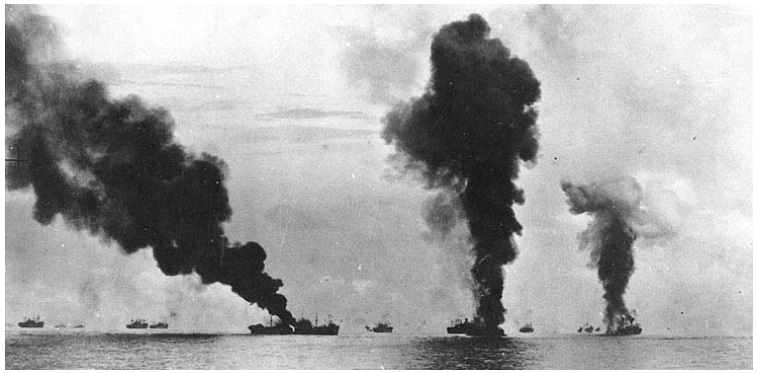


Particulate Matter (PM) and Smoke

Definitions

- Diesel particulate matter (PM)

  (Complex mixture of solid carbonaceous material, unburned hydrocarbons and inorganic compounds)
- Particulate emissions (PM) are defined by the measurement method



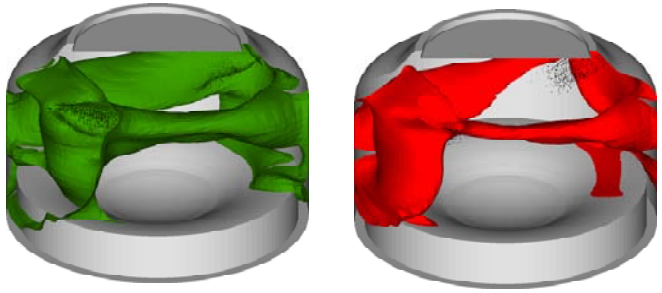
Environmental Impact

- Small particles considered detrimental to human health (able to penetrate into human lung)
- Visual impact – smoke

Diesel process

- Soot produced from incomplete combustion
- All liquid & gas fuel operated combustion processes generate small size particulates

Isosurface representation of predicted soot for 4T50ME-X two-stroke engine



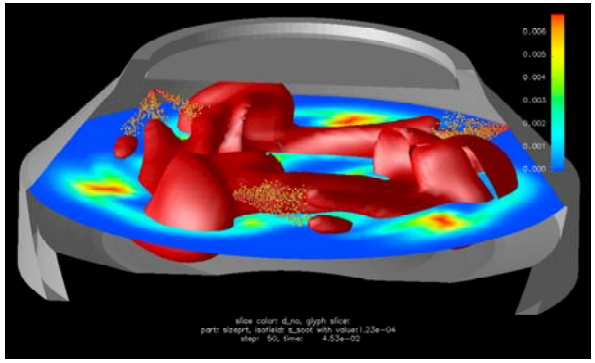
Abatement Technologies

Primary technologies

- Combination of increased fuel injection pressure and advanced fuel injection timing
- Increased boost pressure
- Optimized combustion chamber
- Common Rail
- Variable valve timing
- Variable turbine area

Secondary technologies

- Water-in-Fuel Emulsions
- Scrubber Technology
- Particulate Traps and Oxidation Catalysts
- Bag Filters and Electrical Precipitators
- Fuel Additives



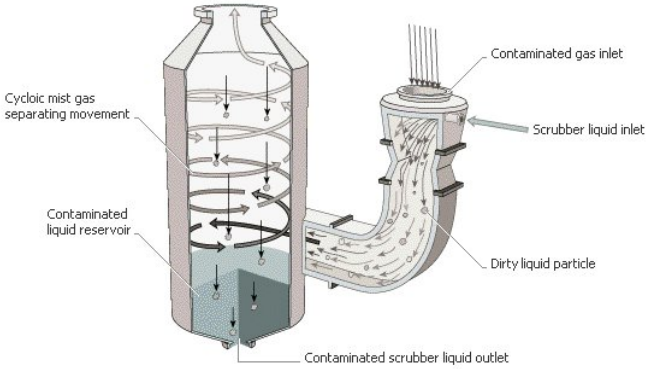
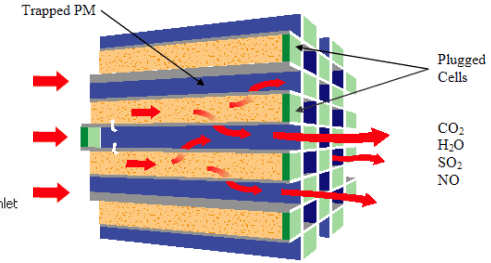


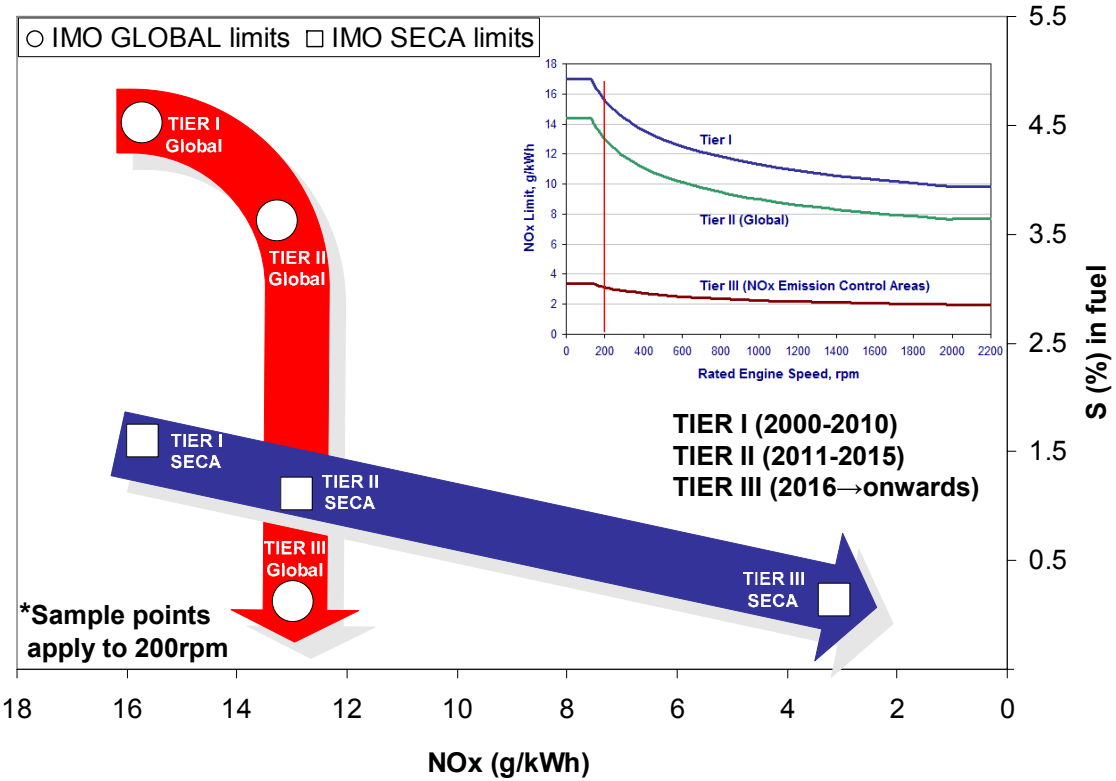
Figure 2: Diesel Particulate Filter



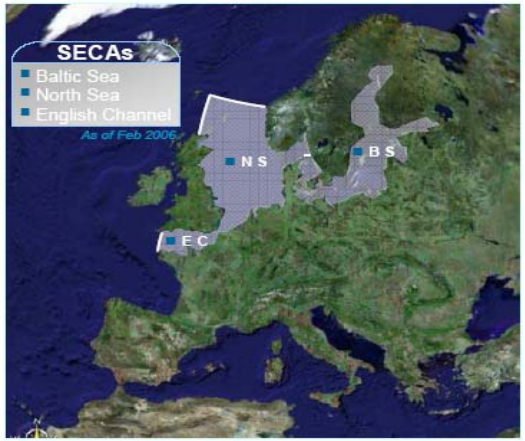
Present and Upcoming IMO Legislation

Emission legislation limits by IMO (International Maritime Organisation) /MARPOL MEPC are becoming more stringent .

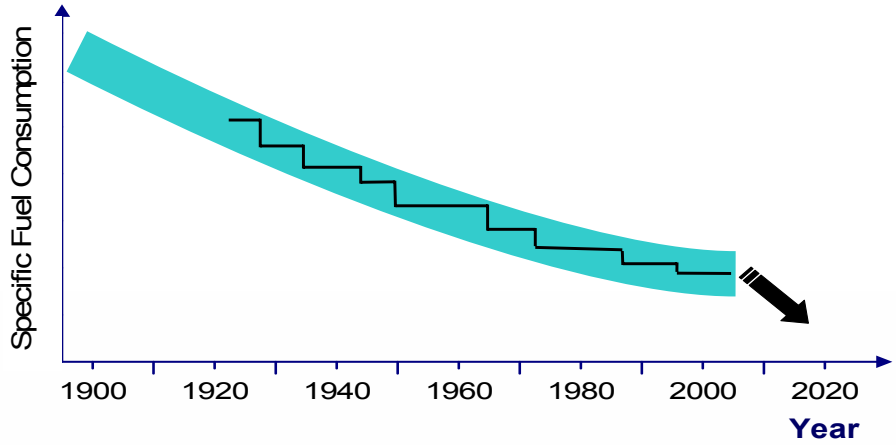
Present TIER I limits are reduced to TIER II (lower by 20%), and subsequently to TIER III limits (lower by 80%).



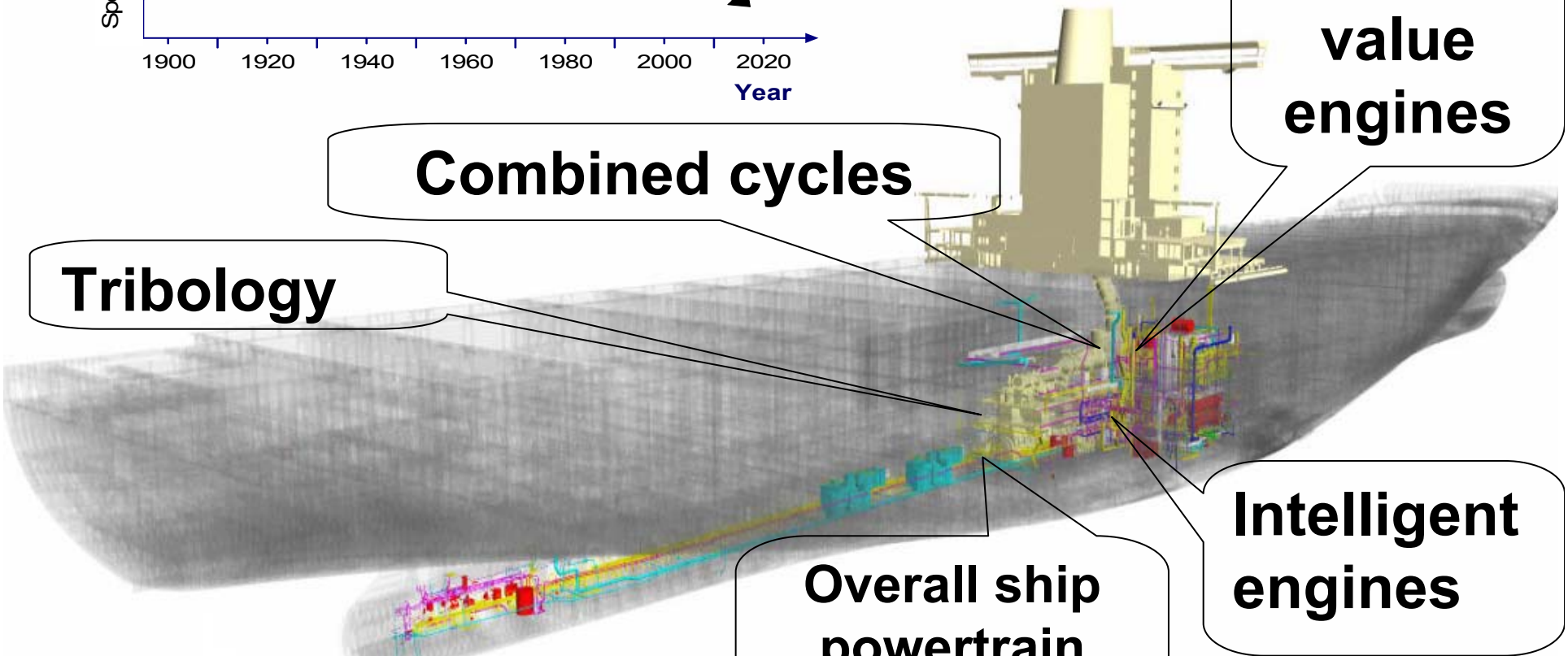
SECA regions
(Sulphur oxide Emission Control Areas),



Global manmade emissions/ Ships contribution = NOx: 12%, SOx: 6%, CO2: 3%



CO_2



Extreme value engines

Combined cycles

Tribology

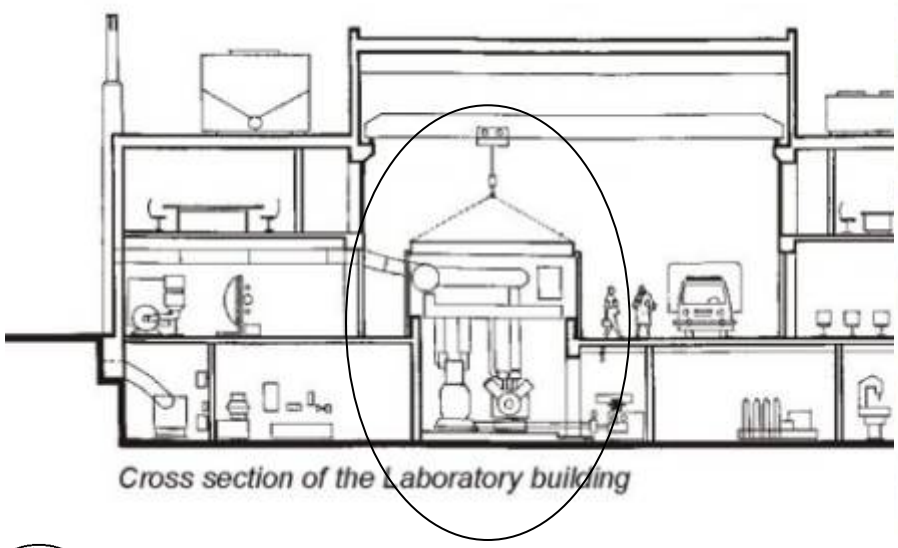
Intelligent engines

Overall ship powertrain optimization

FOR 70MW, EVERY 1% LOWER SFC/CO2 , SAVE 150,000 $/YR !!

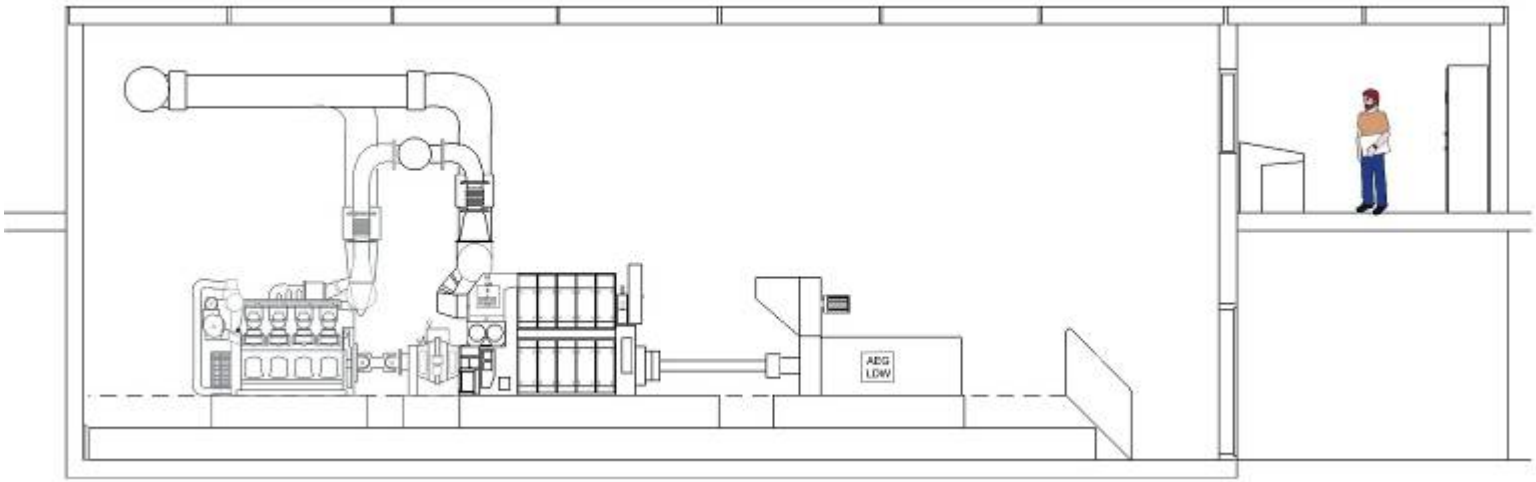
Laboratory of Marine Engineering (LME)

- Marine Engine research facility
- Computer simulation for marine engine performance prediction
- Modelling & Control of Propulsion Systems
- Field measurements of engine performance and emissions
- Development of advanced exhaust emission measuring methods



Exterior of the Laboratory Building at NTUA

Engine Testing Facility



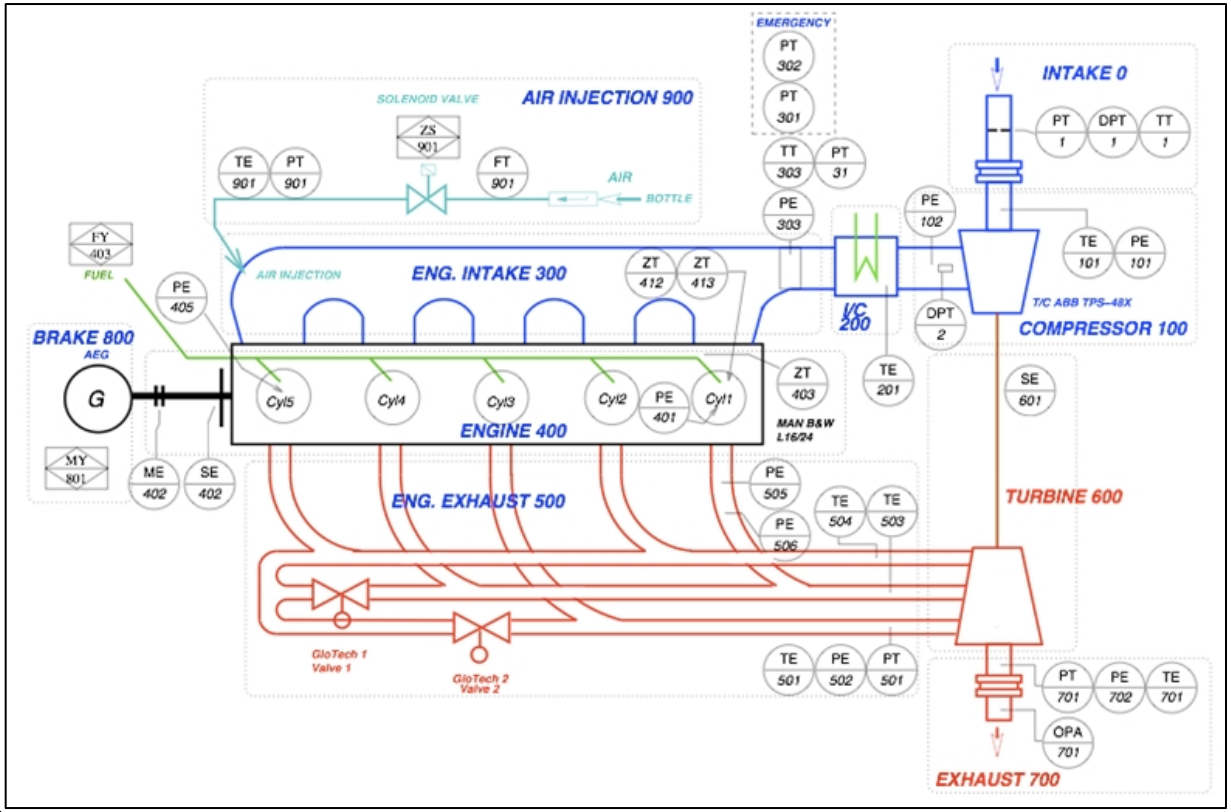
Cross section of the test cell and the control room

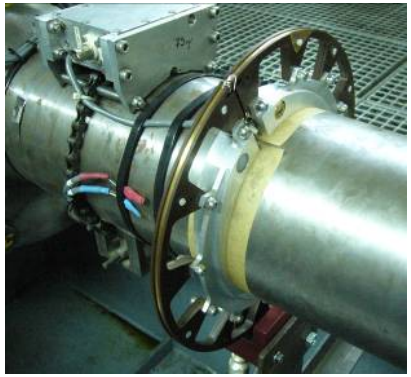
- **Electric Dynamometer, 500 kW, 4-quadrant operation**
- **Hydraulic Dynamometer, 1200 kW**
- **Engine Monitoring, Control and Alarm systems**
- **Data Acquisition system , 50 channels**
- **Heavy Fuel conditioning facility**
- **MAN 5L16/24 research engine**
- **Caterpillar 3508 test engine**

The test cell superstructure

Engine performance measurements

- Pressure , temperature, flow sensors on engine
- Torque feedback control of brake
- Measured data processed to DAQ





LME Research Activities / Projects on Emissions (1990 – 2008)

1990 - 1993 **DEFOS** *Diesel Engine Operation with Variable Quality Fuels* / LR, SULZER, BP, SHELL…

1995 - 1997 **CCMS** *Air Pollution from Marine Engines* / LR, MAN B&W, WARTSILA, PIELSTICK …

1996 - 2000 **ACME** *Adaptive Control of Marine Engines* / ABB, MAN B&W …

1997 - 2003 **PREMTECH I & II** *Emissions Reduction* State of Art / FIAT, RENAULT, VW…

1998 - 2000 **SORPTEC** *NOx removal techniques* / DAIMLER…

2000 - 2003 **ATECS** *EGR Scheduling* / DEUTZ, VOLVO…

2000 - 2004 **FUNIT** *Injection technologies, NOx models, EGR* / VOLVO, AVL …

2000 - 2004 **LIFETIME** *NOx onboard estimator* / MAN B&W, HAPAG-LLOYD, ABB…

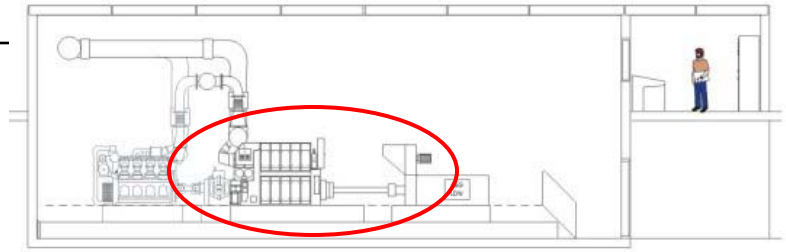
2002 - 2005 **CLEATRANS** *Emissions control for Gas Engines* / IVECO, DAIMLER.

2002 - 2006 **SMOKERMEN** *Smoke Control for Marine Engines* / ABB, WOODWARD,GL…

2004 - 2007 **HERCULES** *Ultra Low Emissions Engine* / MAN, WARTSILA + 40 partners

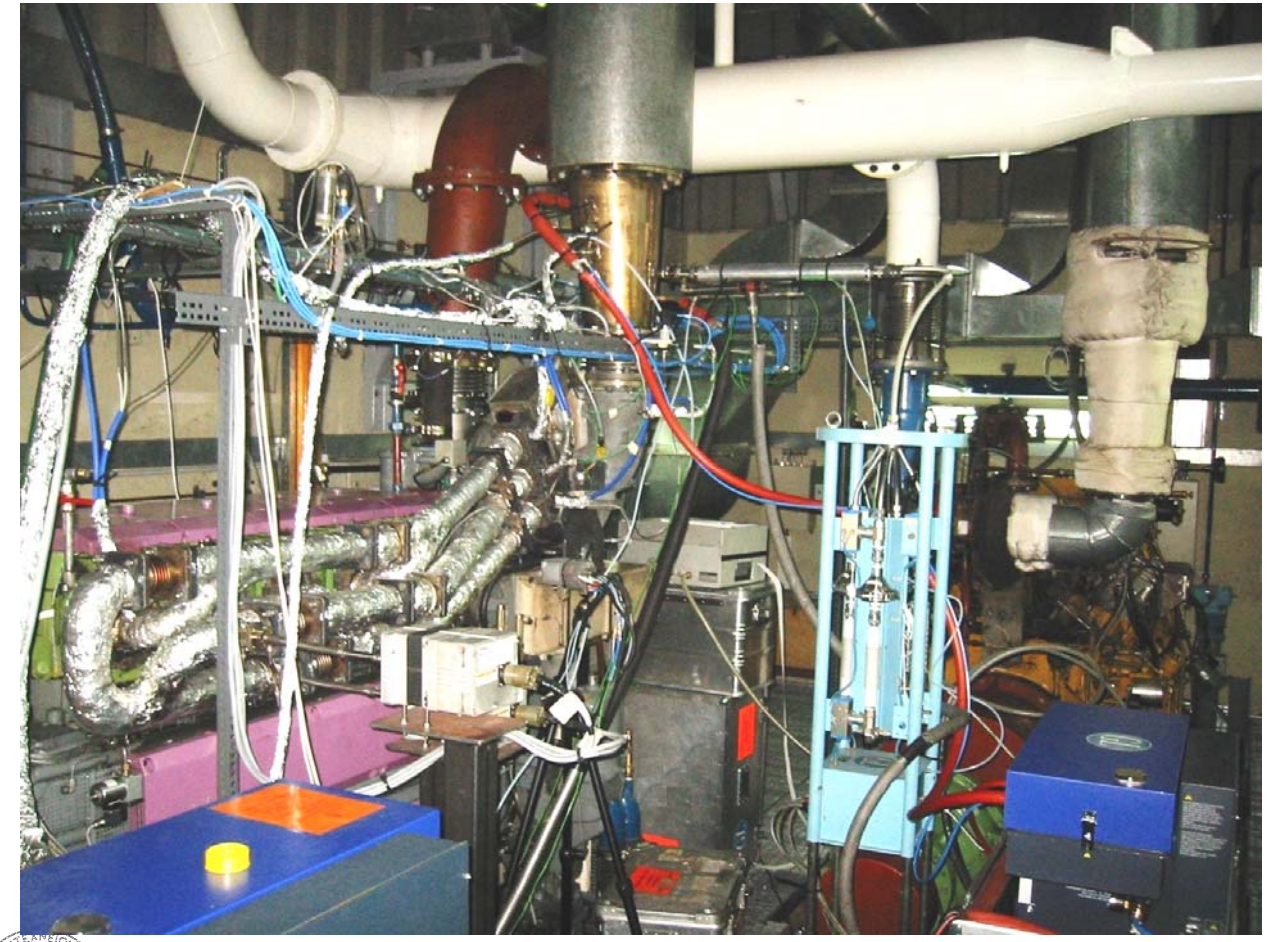
1990 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 **2008**

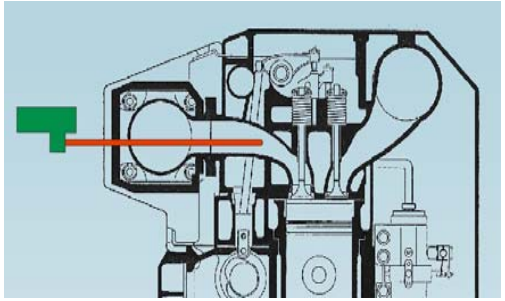
ΕΝΜ R&D

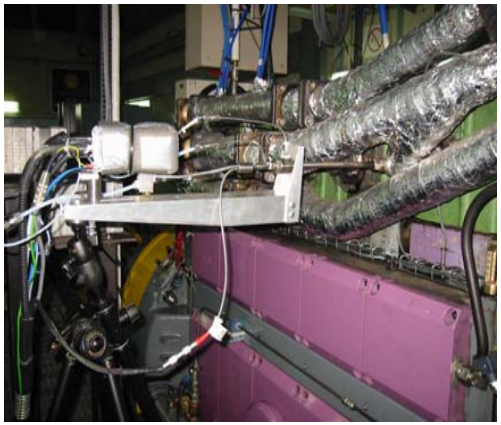


Μετρήσεις επιδόσεων και αερίων ρύπων πειραματικού ναυτικού κινητήρα diesel

μεταβλητής γεωμετρίας εξαγωγής και turbo
για μείωση εκπομπών καπνού σε μεταβατική φόρτιση

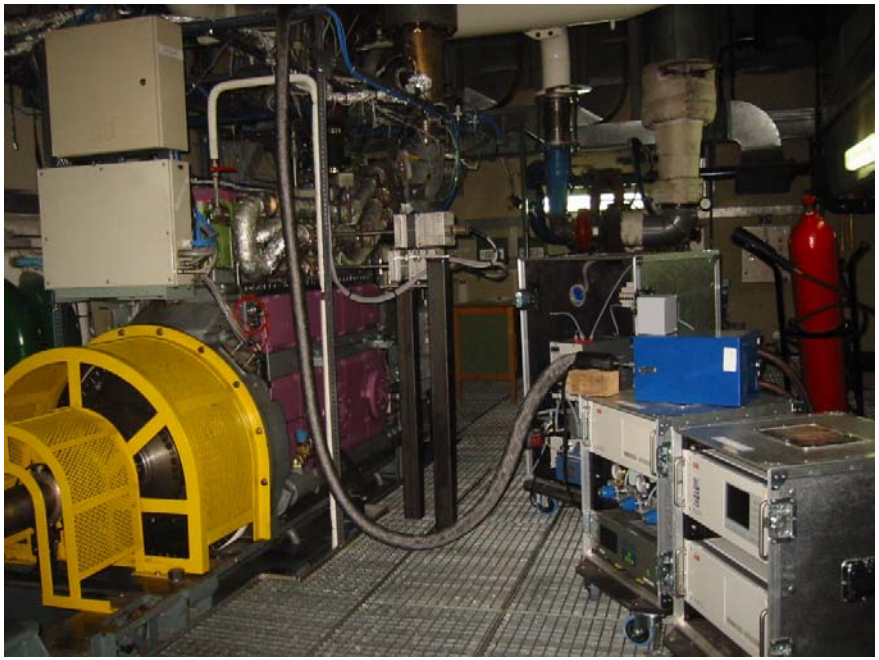






Μέτρηση NOx με μεθόδους υπερταχείας δειγματοληψίας <10ms

LME Shipboard Emissions Measurements



A transportable unit has been developed for **measurements of ALL Gaseous emissions**:

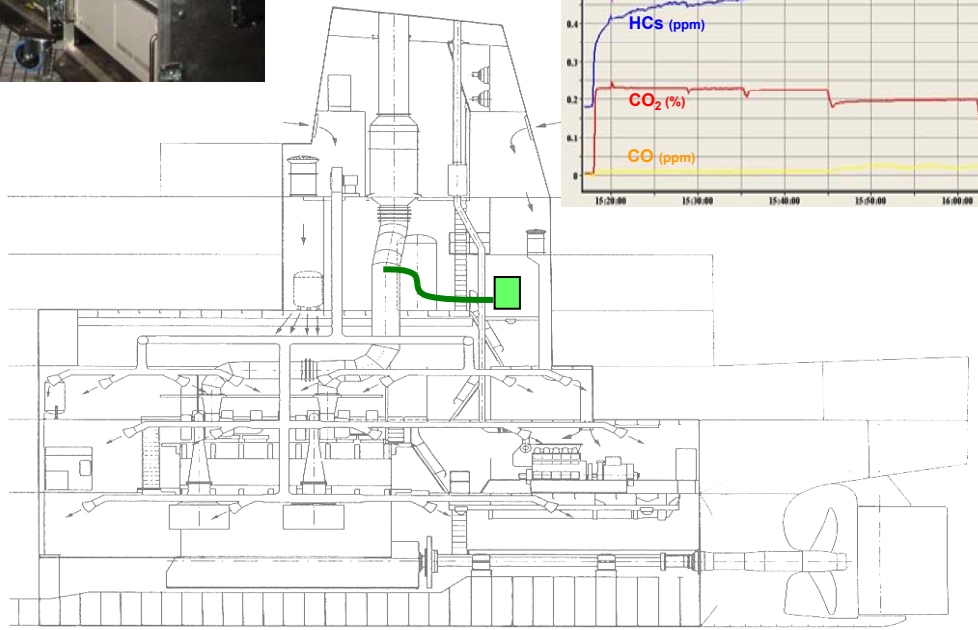
– NO, NO2, NOx, HC,CO, CO2, SO2, O2

(according to IMO MARPOL)

– Smoke (Opacity, Smoke Number-FSN)

- **ISO 17025 certification process**

This is supported by a small chemical analysis lab.facility.



THE END