

Engine emissions and compliance with IMO Tier I, II & III



Review of MARPOL Annex VI and The NOx Technical Code



Main points:

- New NOx limits, **Tier II & III** (New engines)
- NOx limits for **existing engines** (pre-2000 engines)
- **SOx/PM** (Particulate Matter), new limits, alternative methods (all engines)
- **NOx Technical Code** updates

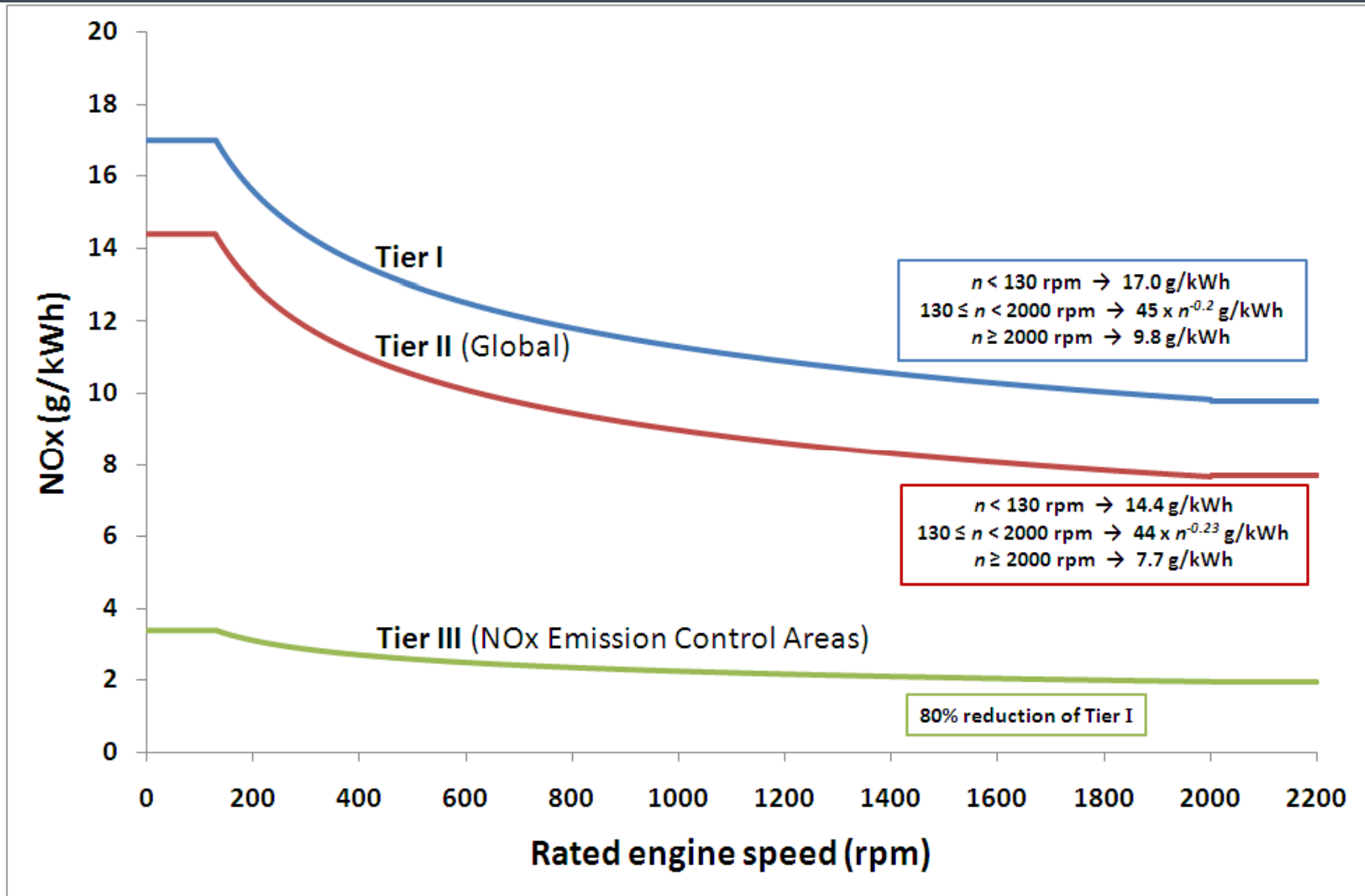


Two tier approach:

Tier II 1st January **2011** (keel laying)
Achieved by in-engine measures

Tier III 1st January **2016** (keel laying)
Advanced NOx reduction methods
(only in defined Emission Control Areas, ECAs)

NOx limits for new build engines



NOx components and parameters, examples



NOx influencing components, examples

Piston

Cylinder liner

Fuel valve nozzle

Fuel and exhaust cams

ECS check sums

+ others

Performance parameters

Maximum cylinder pressure

Maximum compression pressure

Scavenge air temperature

Exhaust gas back pressure



How to meet Tier II



For MAN B&W two stroke engines, Tier II will be met by internal optimisation of combustion process:

- **Injection timing**
- **Fuel injection pressure**
- **Fuel injection rate** (injection profile shaping)
- **Fuel nozzle flow area**
- **Exhaust valve timing**
- **Cylinder compression volume**
- **T/C matching**

Tier II Engine Actions



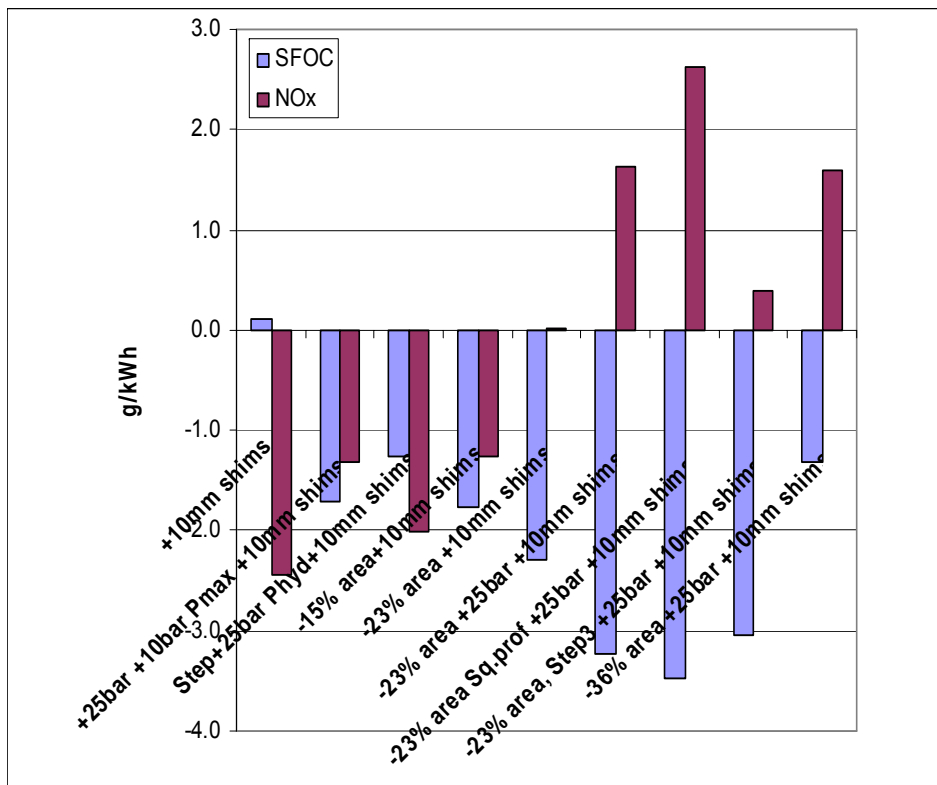
- **Increased Scavenging air Pressure (0.2 to 0.3 bar)**
- **Reduced compression volume**
- **New Exhaust cams for Mechanical engines**
- **New Parameter Setting for electronic controlled engines**
- **Load dependent injection profiles for electronic controlled engines**
- **Possible change in fuel pump/pressure booster design (no cost)**
- **Possible change in Fuel valve atomizer design (no cost)**
- **Inconell clad pistons on large bore engines (>80 bore)**
- **Increased heat load capacity of combustion chamber components**
- **Only latest engine mark combustion chamber design.**

Tier II Engine Results

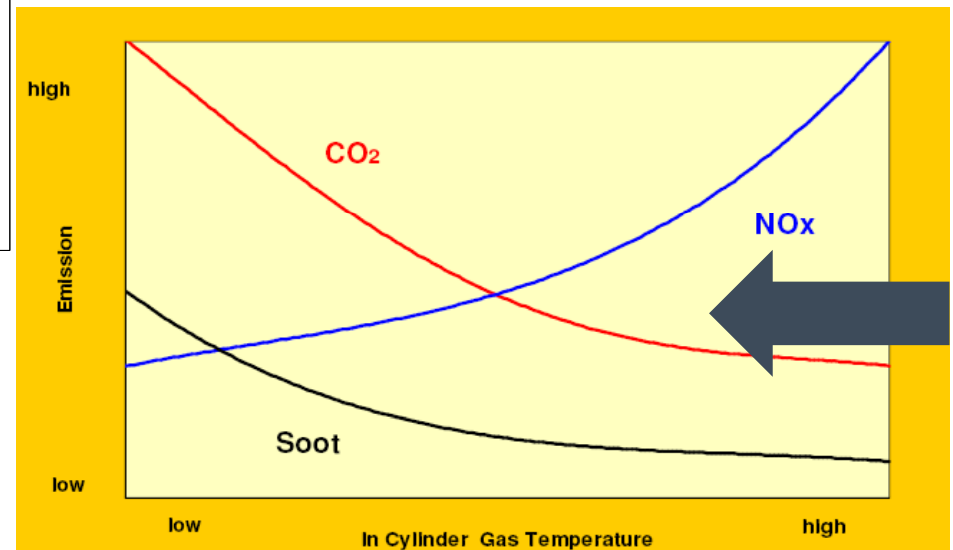


- **Increased SFOC**
 - 1 to 6 g/kWh on Mechanical controlled engines
 - 1 to 4 g/kWh on Electronic controlled engines
- **Unchanged exhaust gas temperatures at MCR**
- **Only minor changes in exhaust gas temperatures in part load**
- **Unchanged exhaust gas amounts at MCR**
- **Only minor changes in exhaust gas amounts in part load**
- **Unchanged capacities for Lub. Oil and Fresh Water**
- **Slightly increased capacity for charge air cooler (approx. 5%)**
- **No change in T/C application in case of TCA/TPL/MET-MA**

6S60ME-C parameter test 75% load



Diesel Dilemma



Summary, Performance parameters



- For large two stroke engine, the general trade-off between SFOC and NOx reduction:

1% SFOC penalty for each **10%** NOx reduction

- **Large potential** for optimising engines, utilising different SFOC/NOx trade-off
- For complying with IMO Tier 2, **more benefit** for ME/ME-C & ME-B models than MC/MC-C (More flexible and lower SFOC - about **2g/kwh**)

Tier III



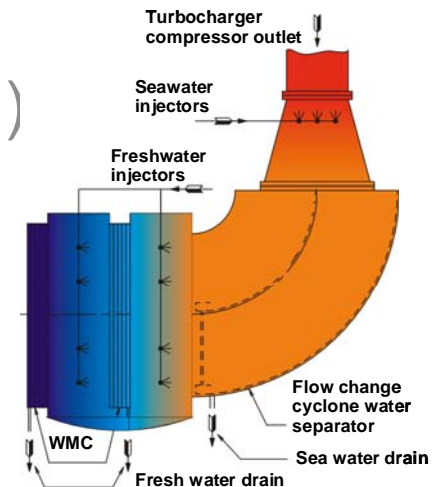
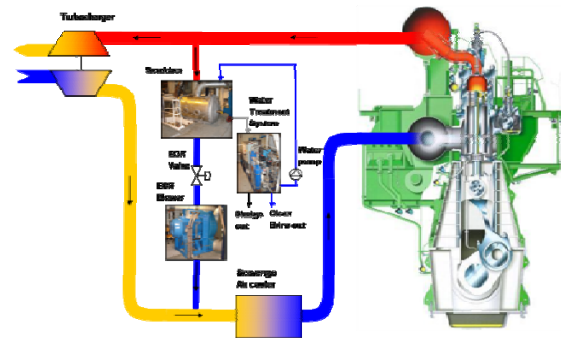
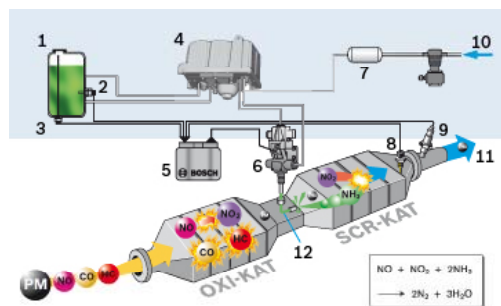
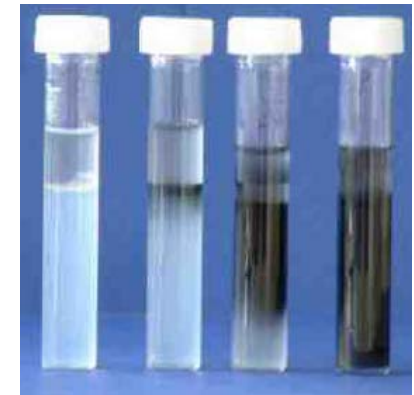
- **Review** of Tier III entry date, start 2012 and no later 2013
- **Not To Exceed (NTE)**. NOx at individual load points in the E2/E3 cycle not to exceed limit by more than 1.5
- **Certification of after treatment systems**

Tier III candidate technology

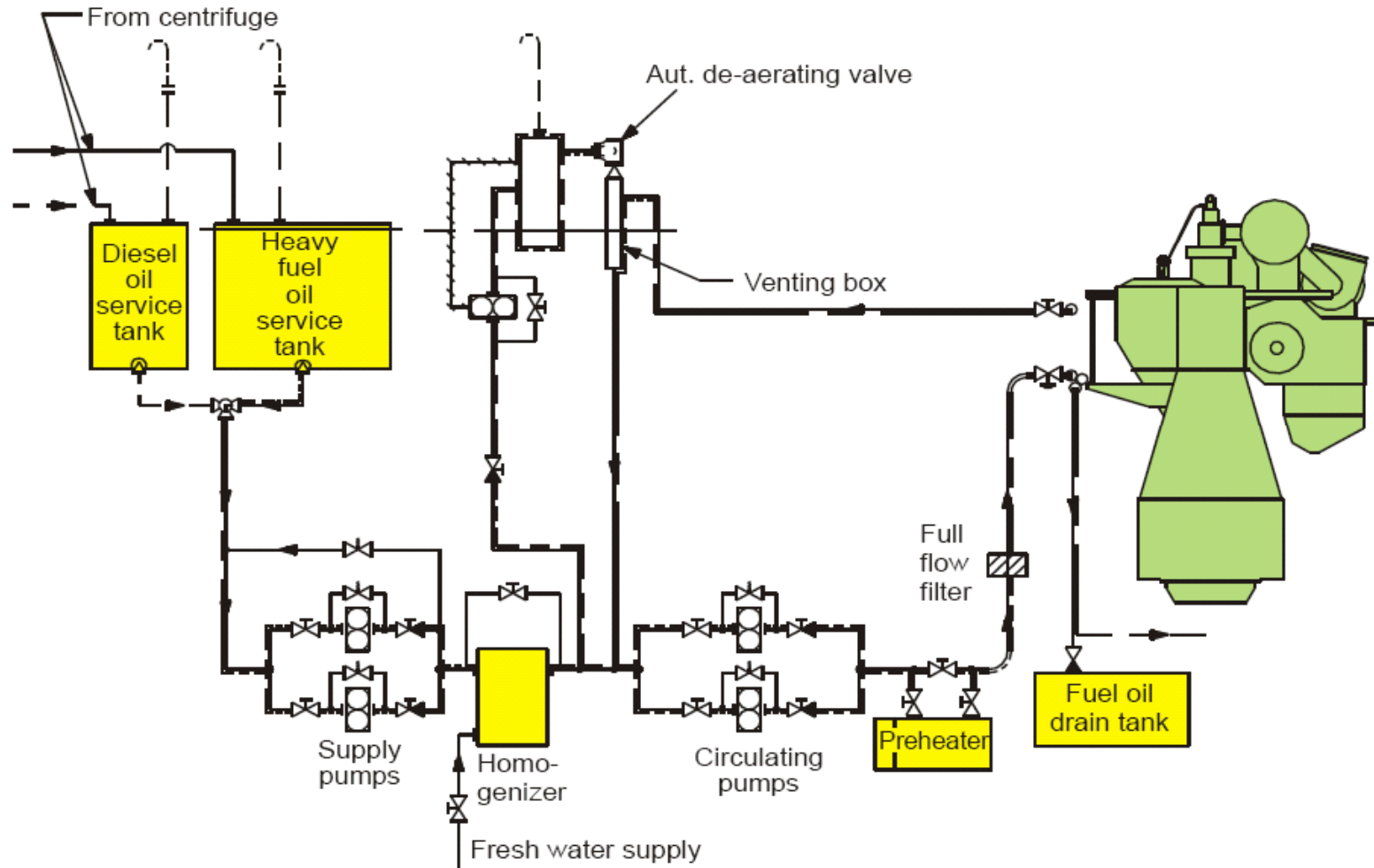


Tier III candidate technology:

- WFE (Water/Fuel Emulsion)
- SAM (Scavenge Air Moistening)
- EGR (Exhaust Gas recirculation)
- SCR (Selective Cathalytic Reduction)



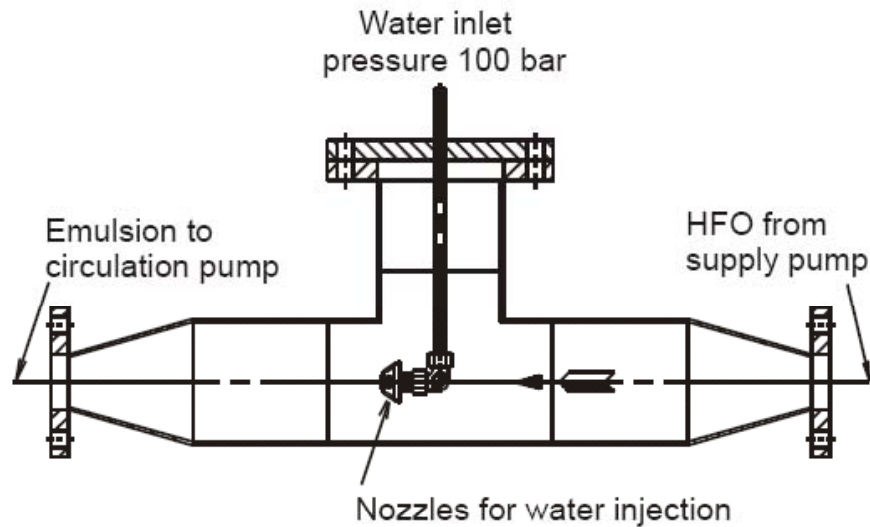
Water Emulsion



WIF Unit - Mechanical



High Pressure Water Injection Unit



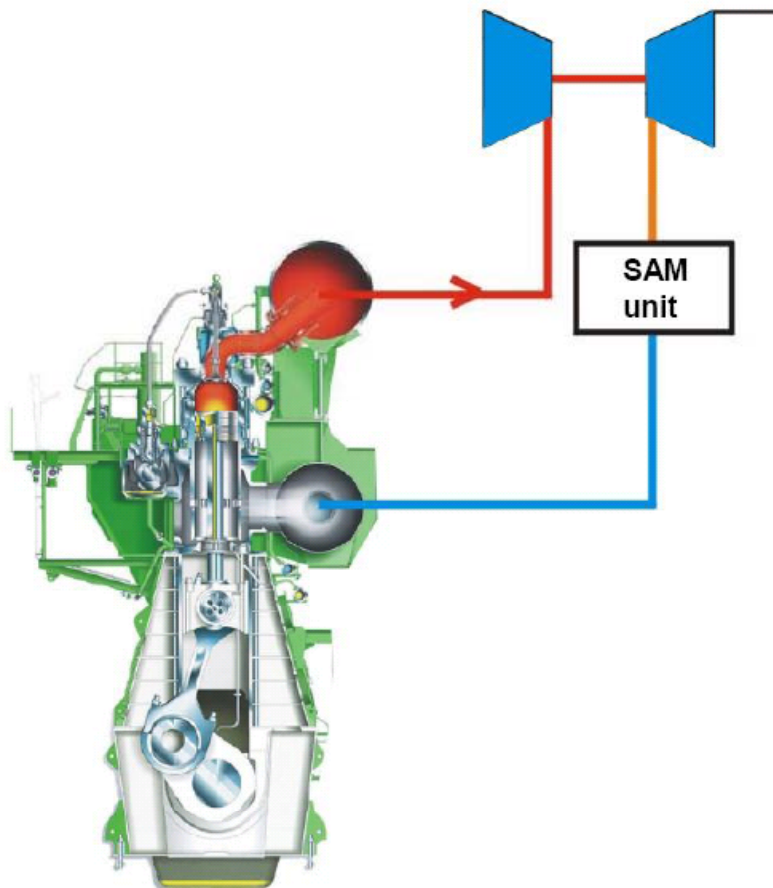
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SAM



SAM influence on NO_x formation



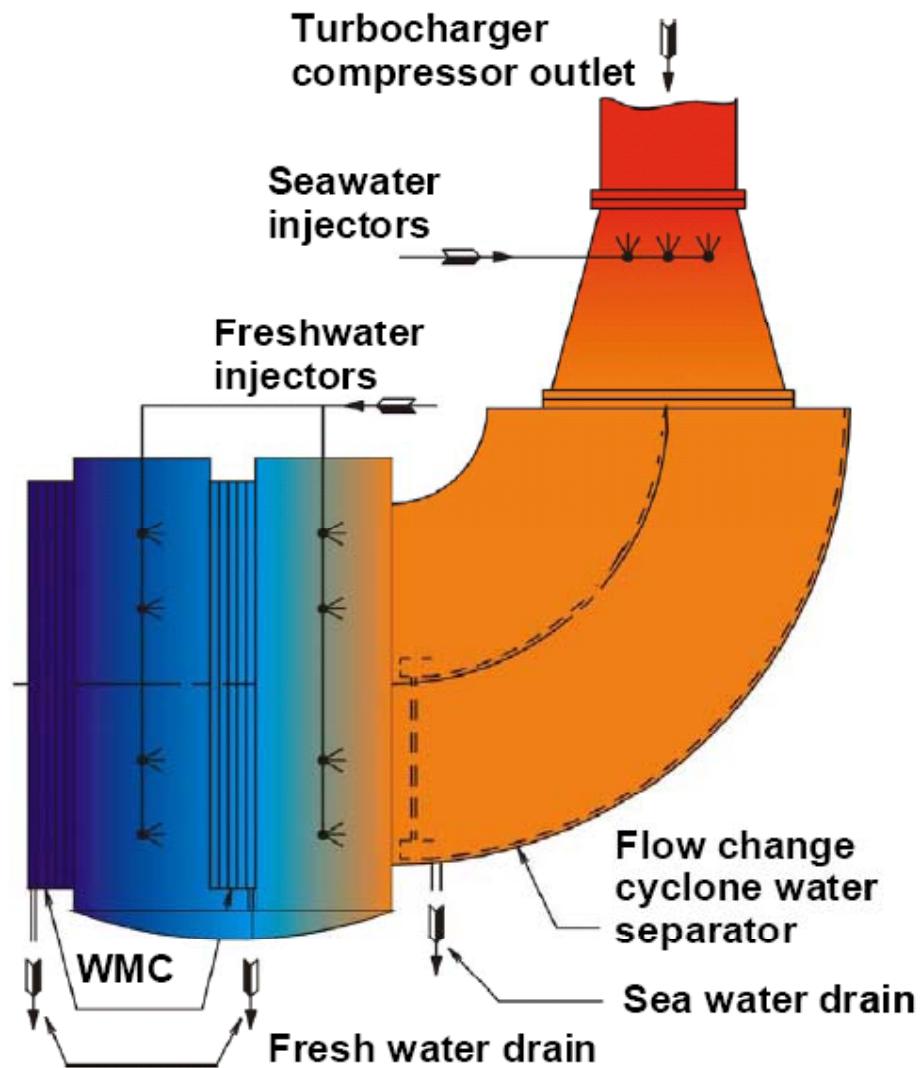
Humidification of scavenge air increases heat capacity and lower the O₂ content

High heat capacity and low O₂ in scavenge air give low combustion temperatures

Low combustion temperatures give low NO_x

Influence on reliability and safety: Field test

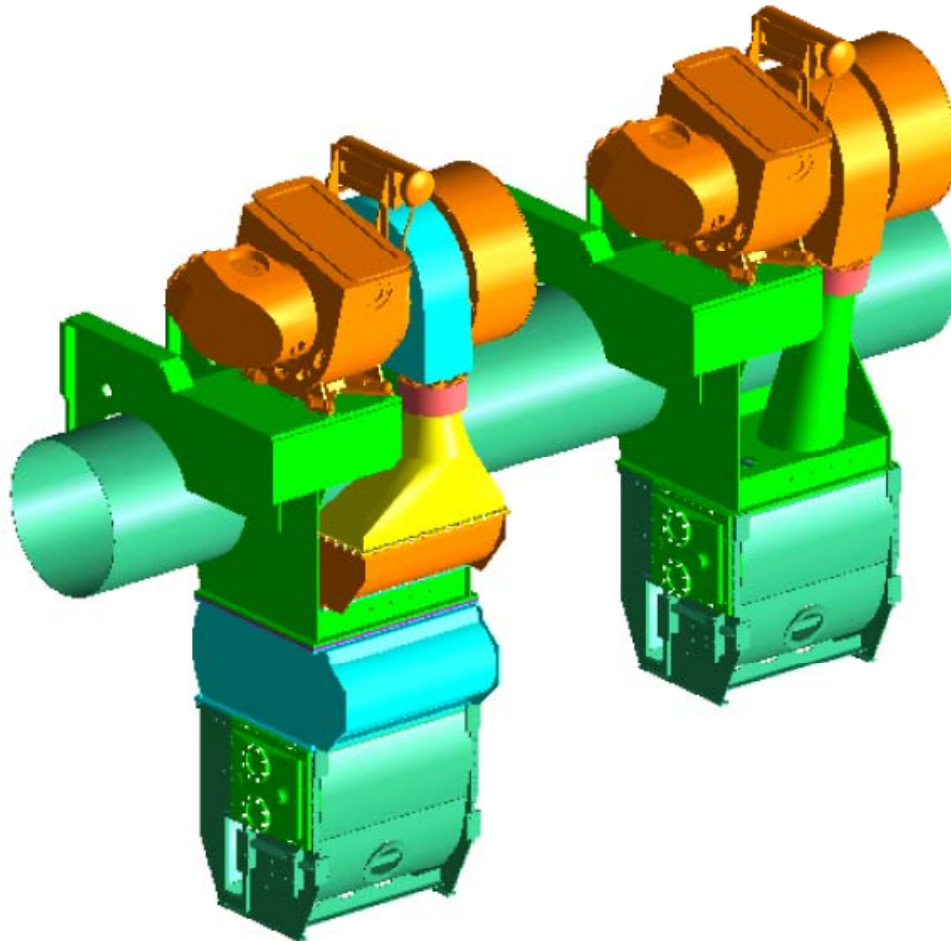
SAM System



SAM



New SAM application versus normal cooler

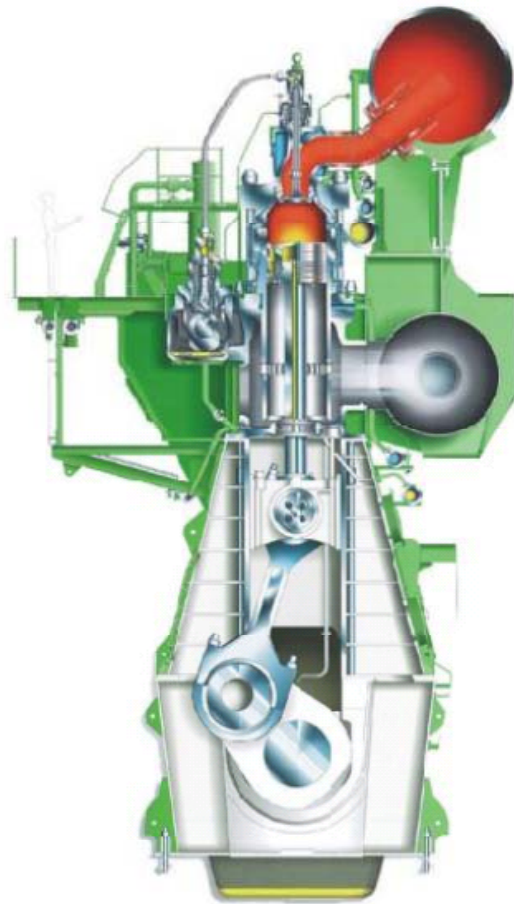


- Compressor Housing
Outlet turned to be
vertical
- Diffusor and SW - Spray
- Transition piece with
humidification and
Flow Straightener
- S-Bends with SW
Residue separation
- FW 1 & FW 2 stages
with SW Carryover
Elimination

Exhaust Gas Recirculation



EGR influence on NO_x formation



EGR
unit

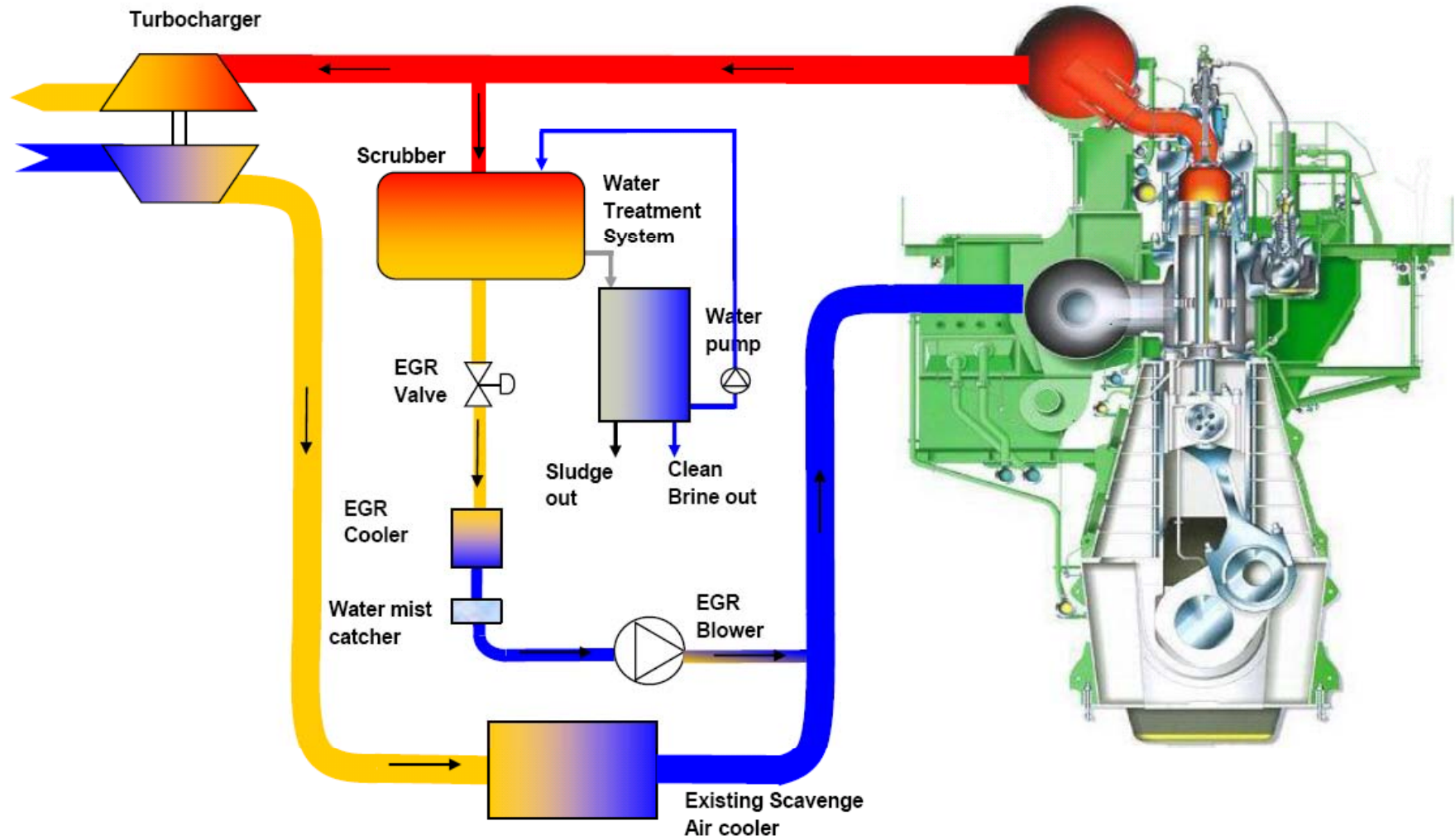
Re-circulation of exhaust gas lowers O₂ in scavenge air

Low O₂ in scavenge air gives low combustion temperatures

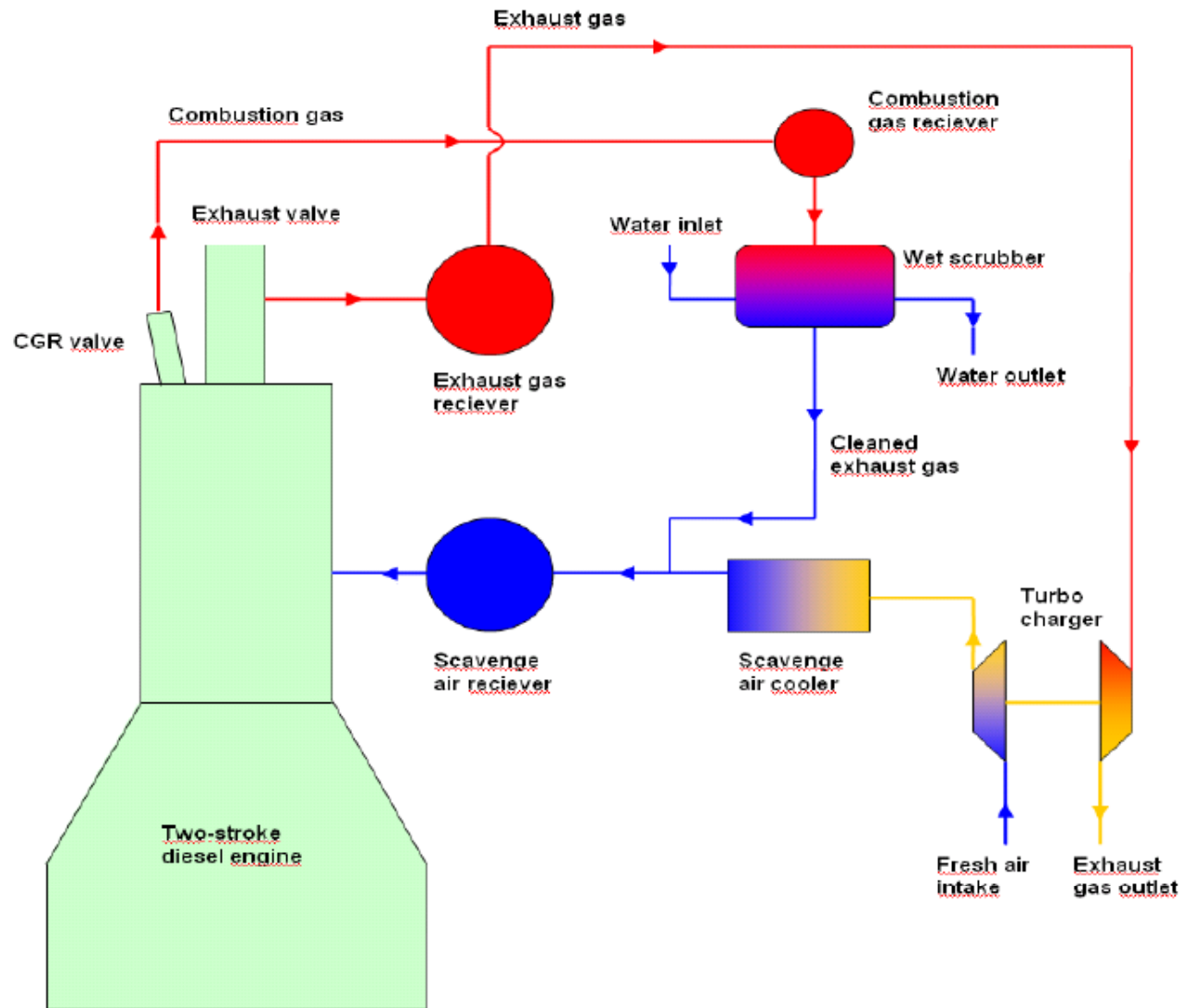
Low combustion temperatures give low NO_x

Influence on reliability and safety:
Field test

Exhaust Gas Recirculation



Exhaust Gas Recirculation



CGR Valve



Regulation of pre-2000 engines



Based on MEPC57 the following is decided and approved:

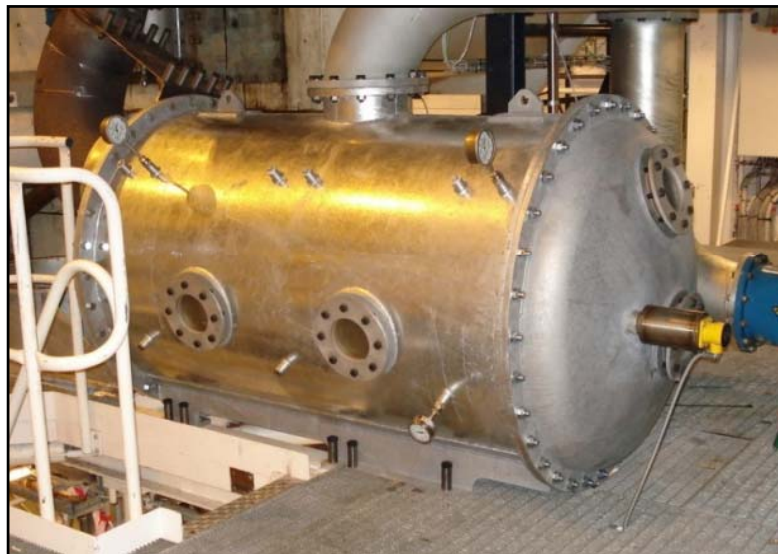
Engines are limited to:

- installed on ships built 1st January **1990** to 31st December **1999**
- and with a per cylinder displacement at or above **90 litres**
- and with a rated output at or above **5000kW**
- and if a 'Kit' or '**Approved Method**' is **available** (at first renewal survey. Renewal survey is every 5 years)

SOx and Particulate Matter



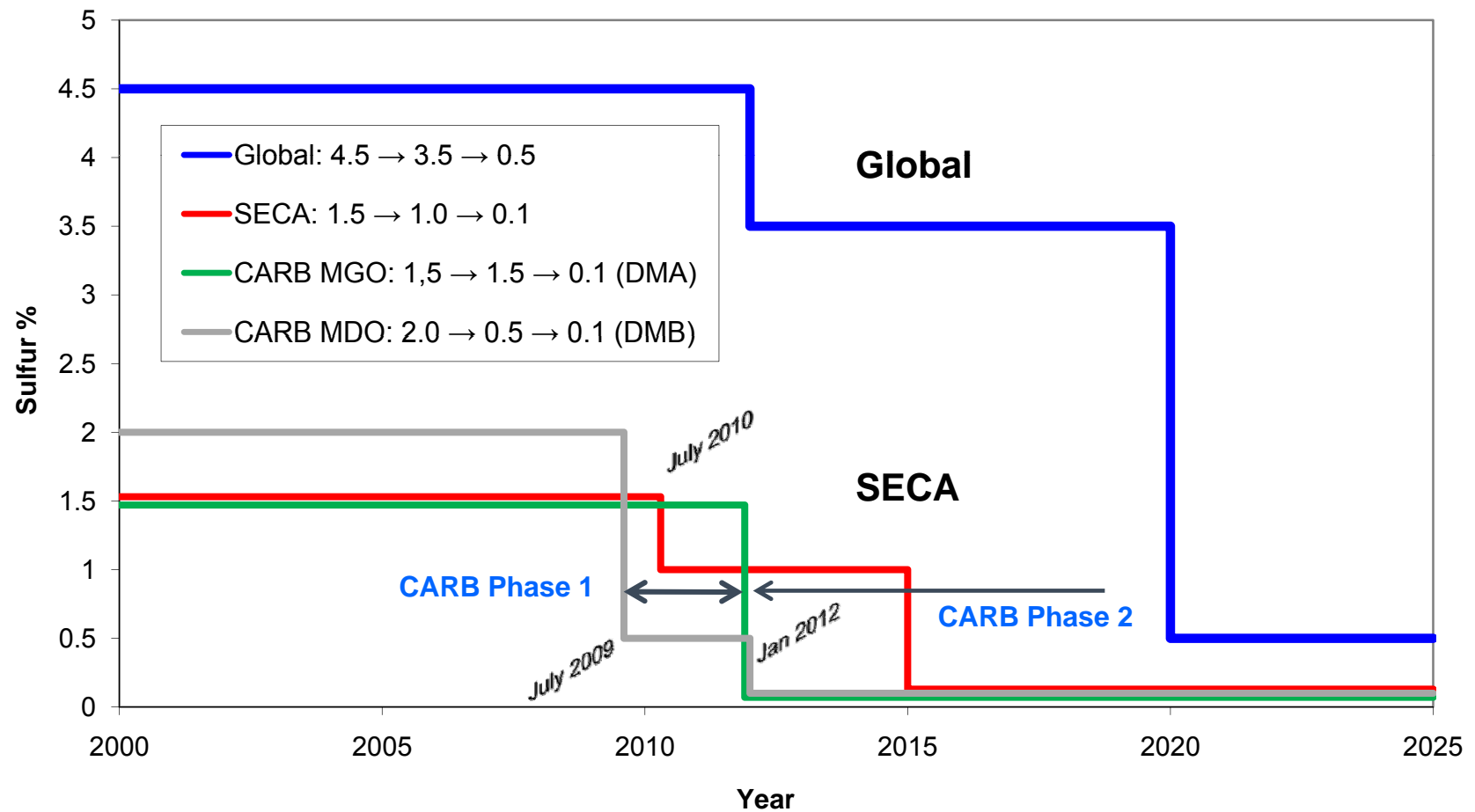
- **Particulate Matter** regulated by Sulphur content of fuel
- **HFO** still allowed
- Alternative measures (**scrubbers**) allowed



Proposed CARB regulation



MEPC 57 IMO & CARB Fuel-Sulfur Content Limits



MAN B&W Two-stroke Engines



Thank you for your kind attention

