ENGINE MANUFACTURERS MEET NEW ENERGY AND AIR QUALITY CHALLENGES

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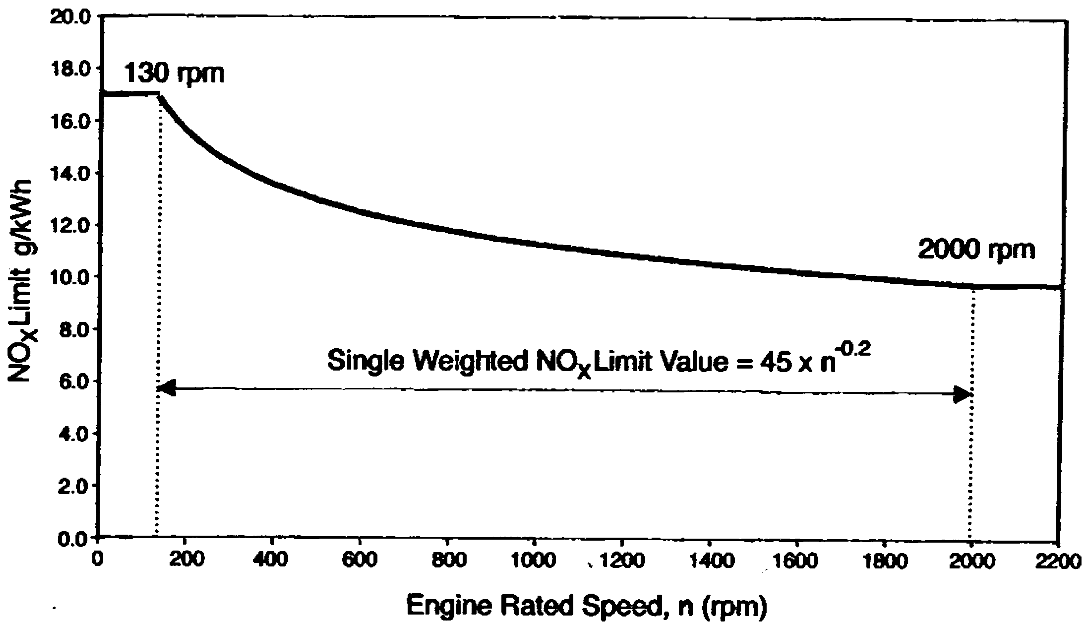
International Maritime Organisation (IMO)

Marpol Annex VI NOx Limits



- Once Annex VI is ratified, all diesel engines >130 Kw in ships built for international shipping operation after Jan 2000 must comply
- Fuel to ISO 8217 Grade DMA, DMB or DMC. Steady state testing. Ambient 25°C, Seawater 25°C

Exhaust Emission Legislation
Possible Future IMO Reduction

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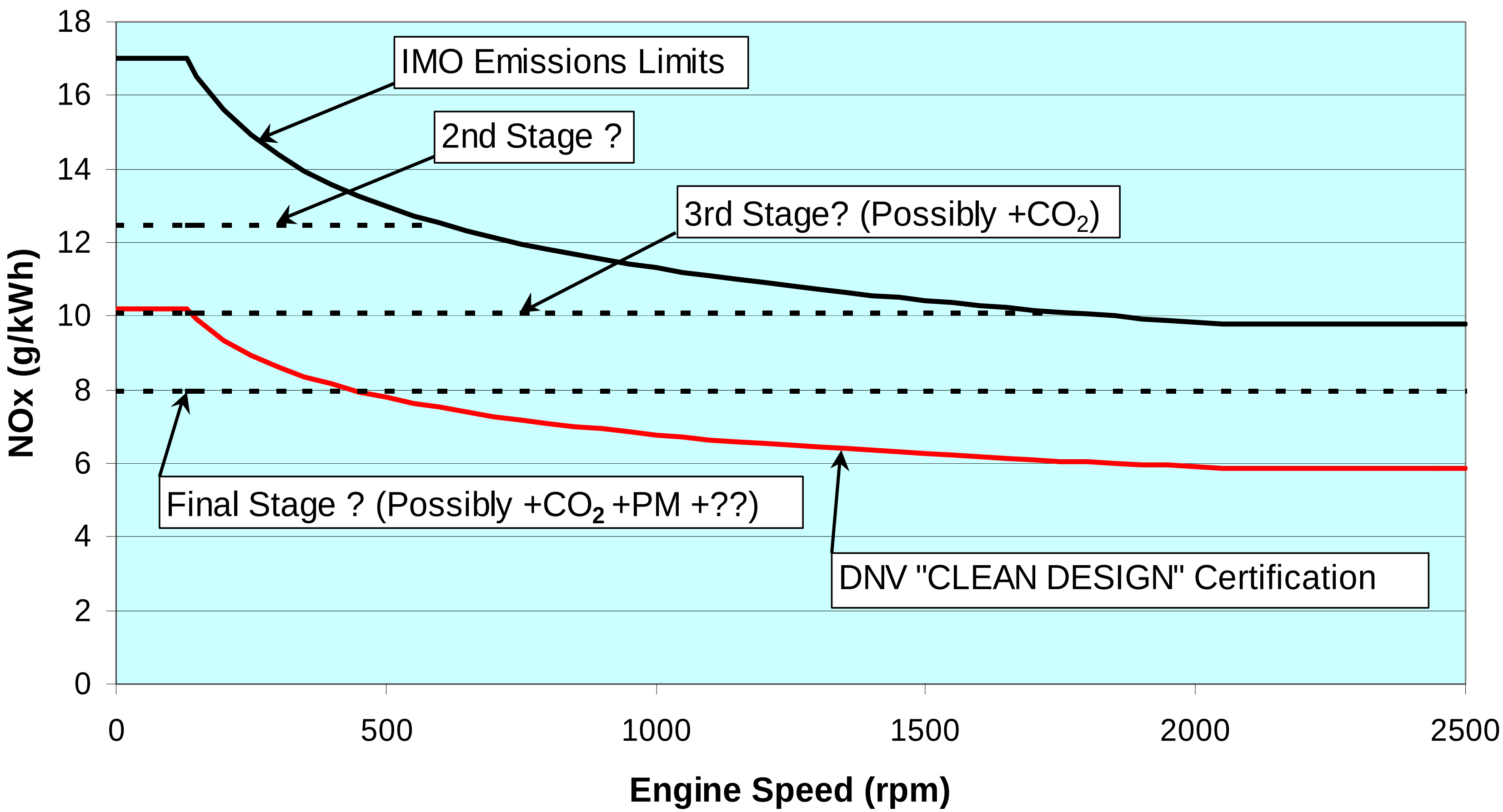
Possible future IMO NOx Regulation Reduction



Marpol Annex VI SOx Limits

- Sulphur in HFO capped at 4.5%

- In SOx control area (SECA) fuel sulphur limited to 1.5% or with secondary control devices <6.0 g/Kwh emissions

Port State Control

- California, Scandinavia and Japan have decided that their air quality standards are not sufficiently protected by IMO NOx and SOx codes. They have imposed their own regulations to control marine emissions on a local basis. These include:-
  - Shutting down all engines and connecting to shore supply
  - Using low sulphur fuel
  - Using exhaust aftertreatment
- The incentives are lower port fees

Challenges Facing Engine Builders

- NOx
  - High levels in performance (bsfc) optimised engines

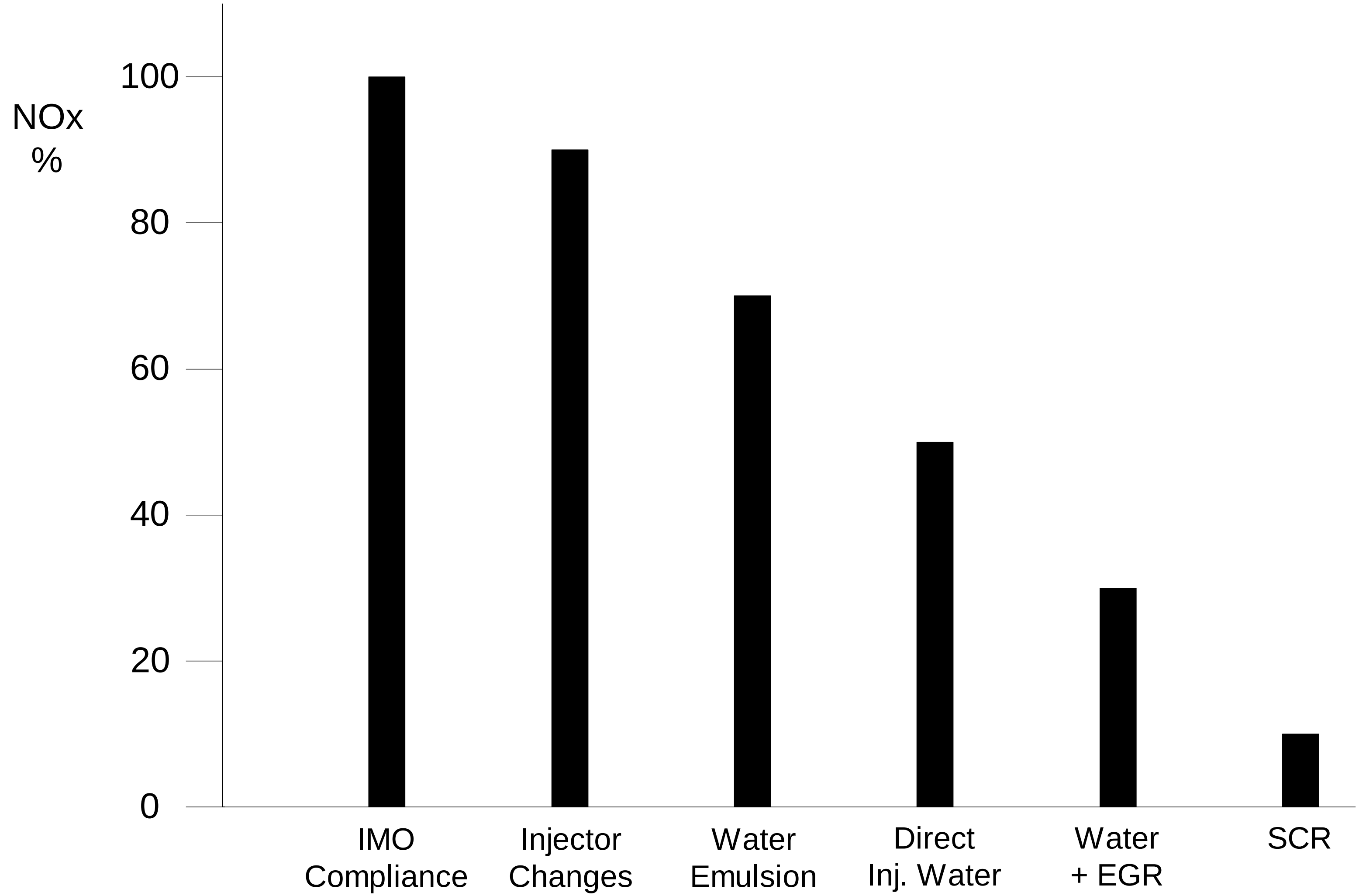
- Particulate
  - High levels due to use of HFO
    - Sulphur 4.5% max
    - Asphaltenes
    - Ash
    - Residues from lube oil additives
  - Low load smoke

- Legislation and Standards
  - Proliferation of legislation
  - No common method of measurement of some key parameters, e.g. smoke

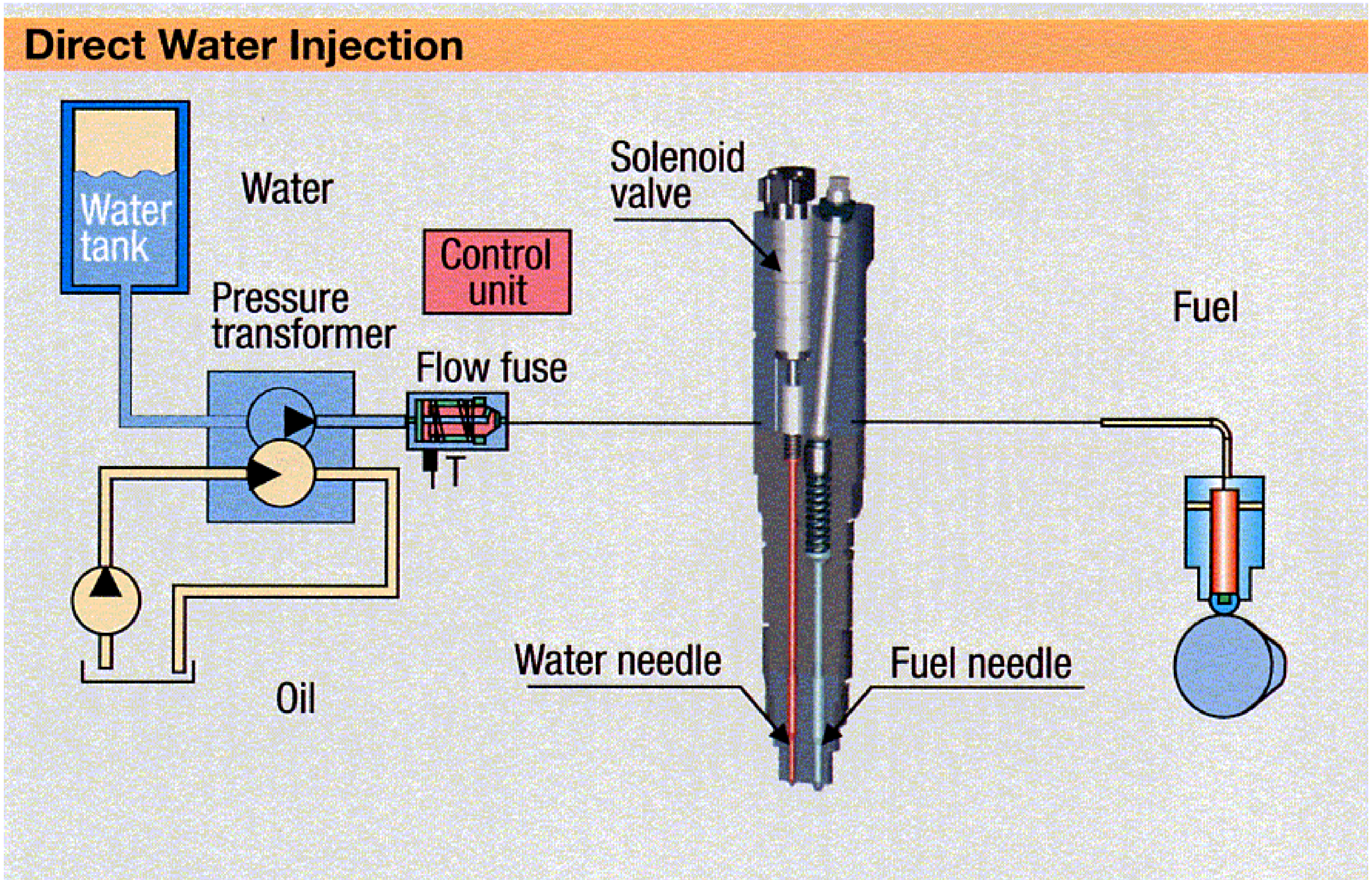
Manufacturers Responses to NOx Reduction

Engine	Injection timing retard + higher compression ratio + more air
Fuel Injection System	Changes to injection strategy. Rate shaping nozzle changes
Water Addition	As emulsion Direct Injection Fumigation (HAM)
EGR	not currently used due to particulate levels, but use being reviewed
Aftertreatment	SCR very effective

Approximate NOx Reduction For Different Control Strategies



Direct Water Injection

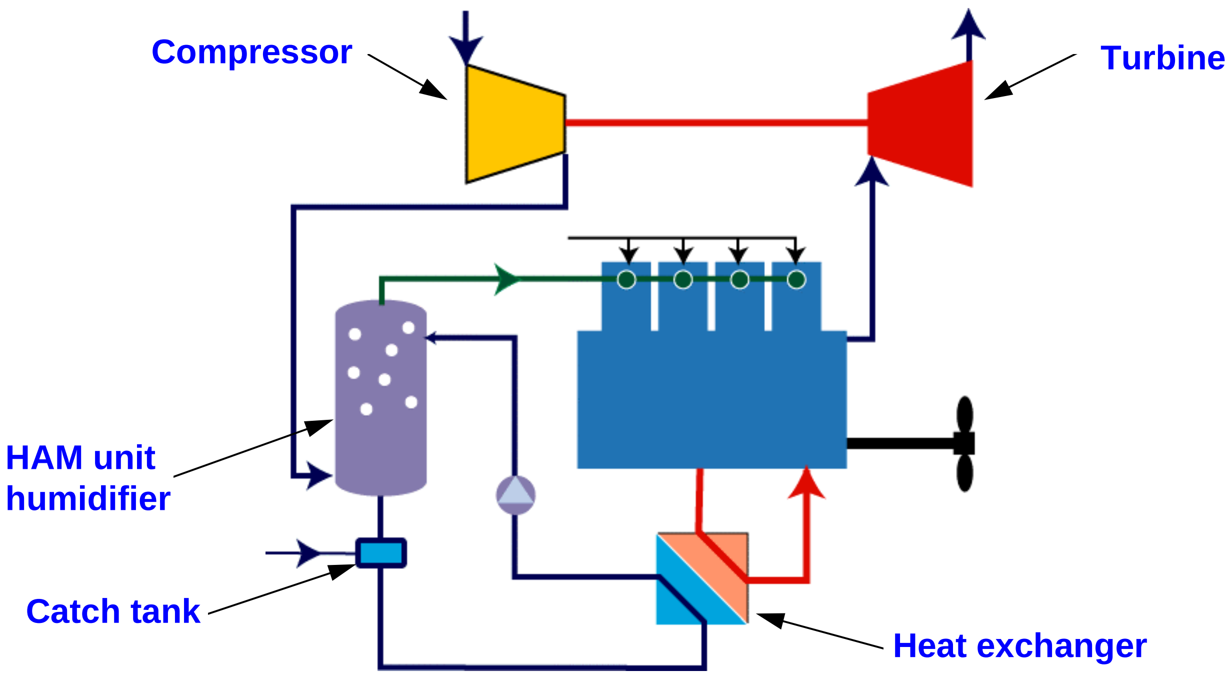


State-of-the-art Direct Water Injection system.

Courtesy of Wärtsilä Corporation

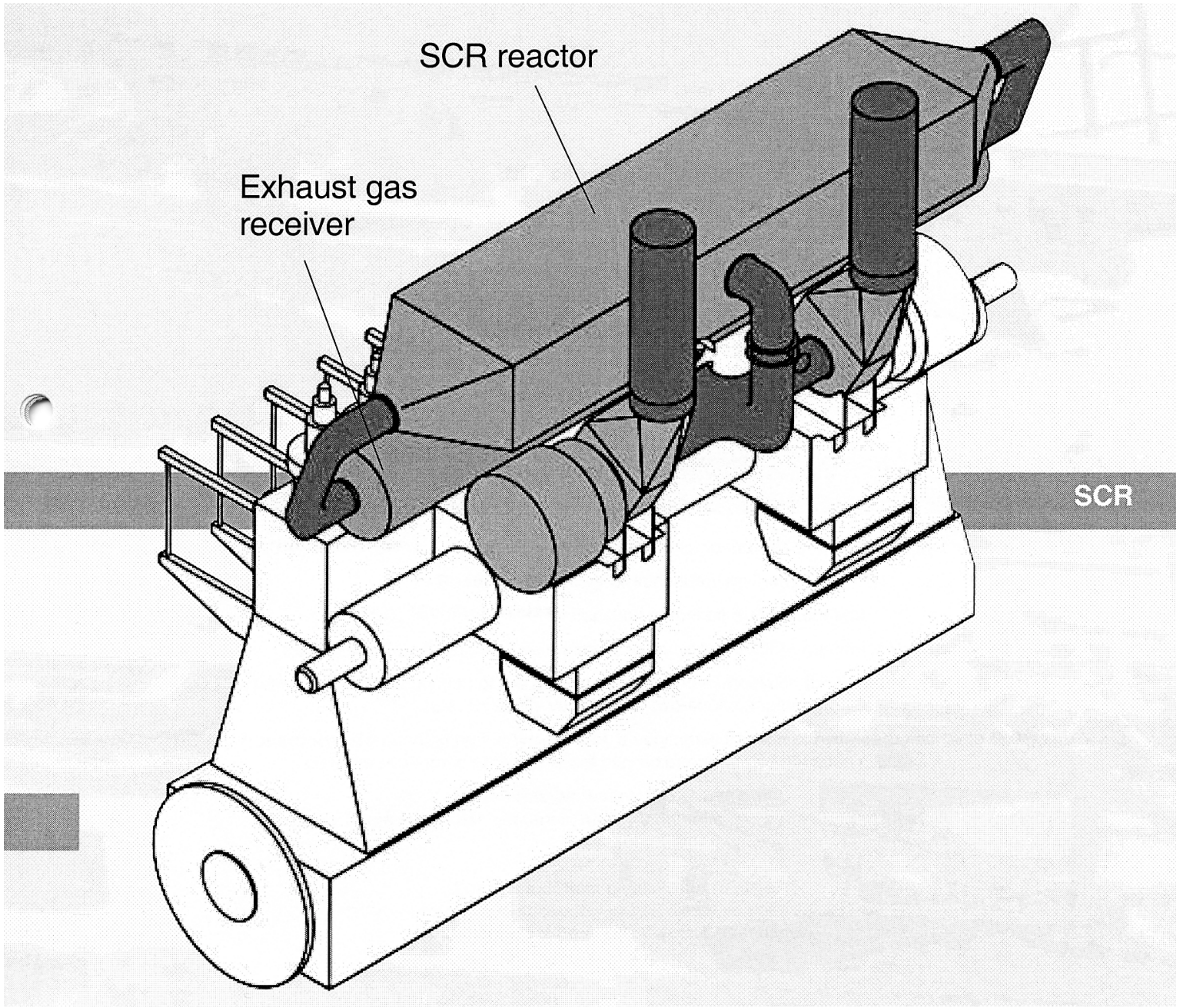
Humidification

HAM - Principal Layout



Courtesy of MAN B&W

SCR Installation on Slow Speed Engine



Particulate (Smoke) Reduction

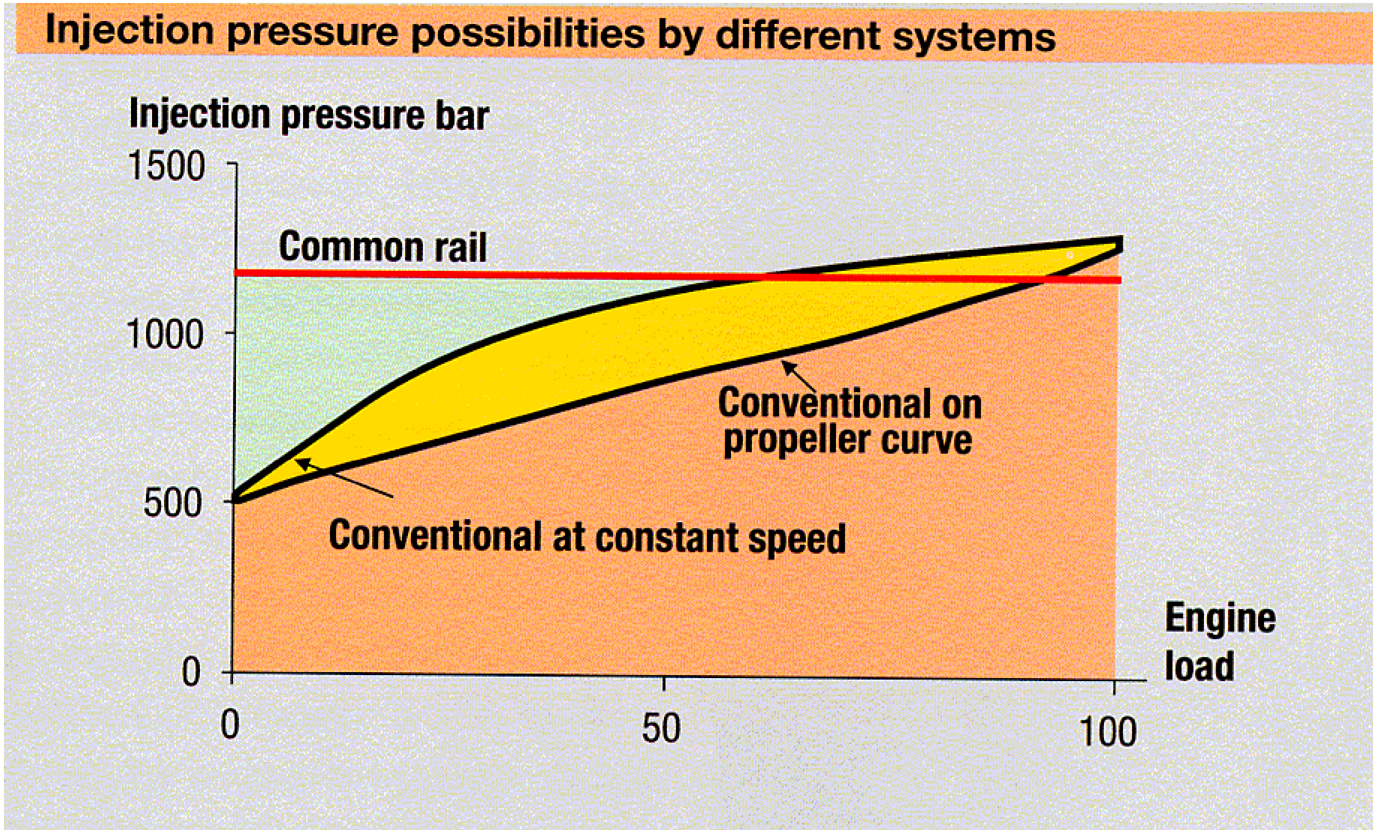
- Problem with propulsion engines at low load, low speed
  - Due to : low injection pressure
    low turbo boost pressure

- Solutions
  - Common rail injection system
  - More efficient turbochargers
  - Redesigned combustion chamber
  - Use of water emulsion

Manufacturers Response To Particulate & Smoke Reduction

Fuel Injection System	Higher injection pressures Common Rail (CR) Nozzle changes
Air Supply System	More air at higher pressures
Base Engine	Improved combustion chamber design
Aftertreatment	Few, if any, systems in production, non-thermal plasma is showing potential for future

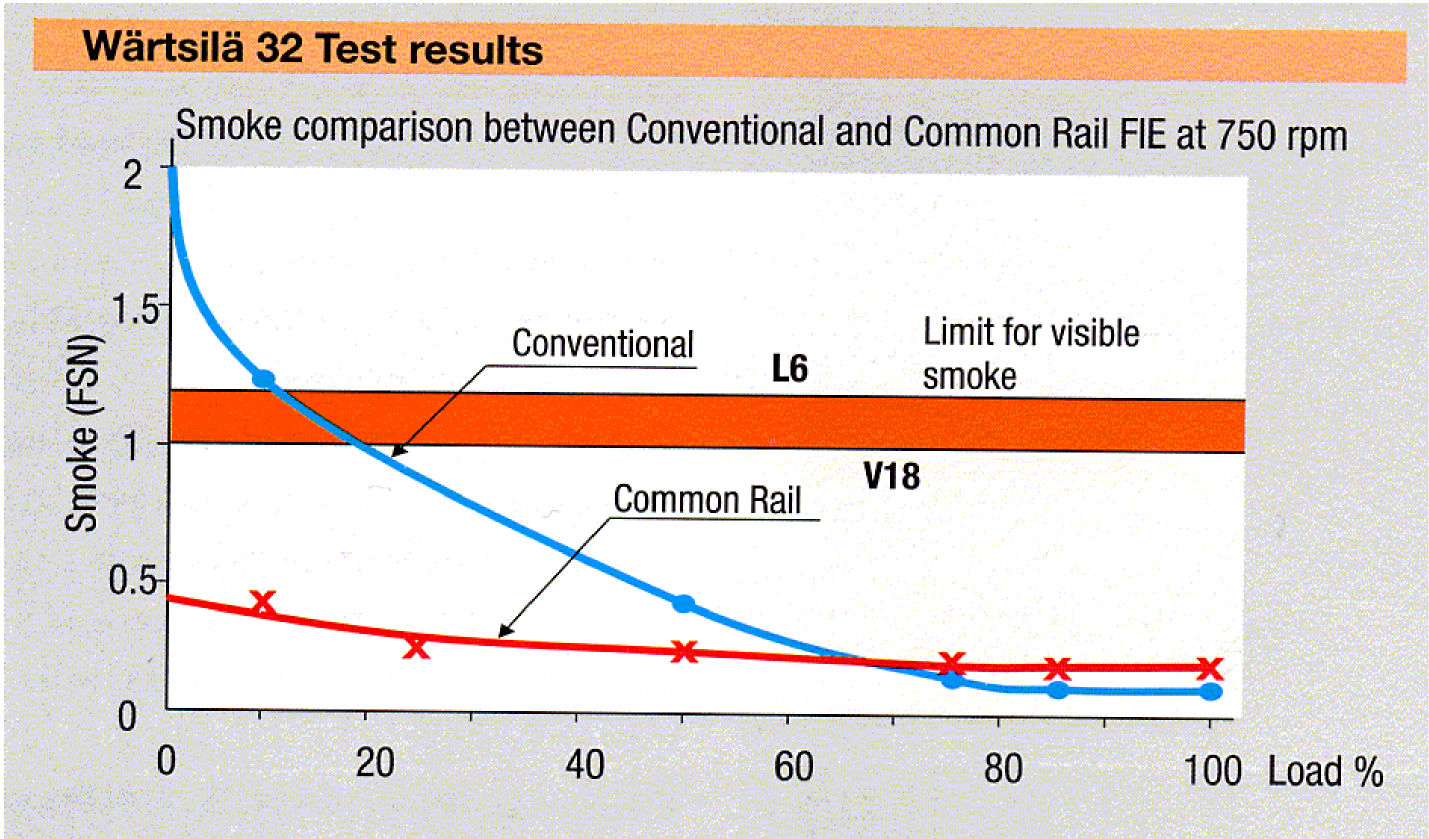
Injection Pressures For Different Systems



Common rail injection technology opens the possibility to maintain high injection pressure and small fuel droplets all the way down to idling.

Courtesy of Wärtsilä Corporation

Smoke Values For Different Injection Systems

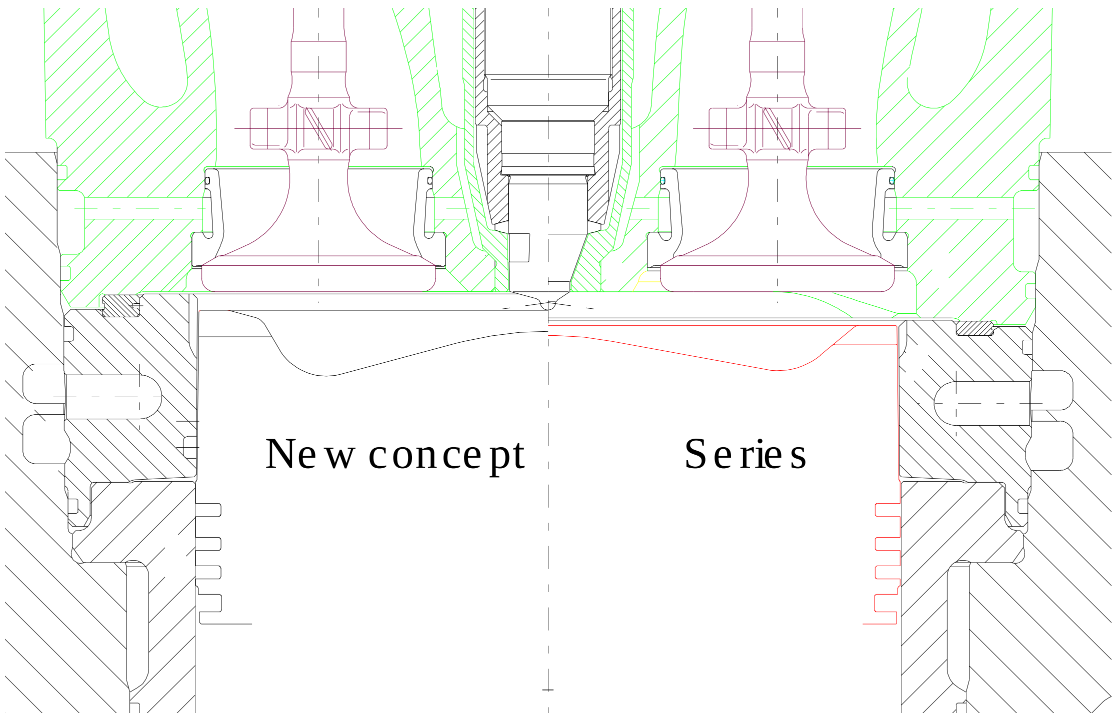


With common rail it is possible to achieve "no smoke at any load". Shown here are test results from the Wärtsilä 32.

Courtesy of Wärtsilä Corporation

Smoke Reduction

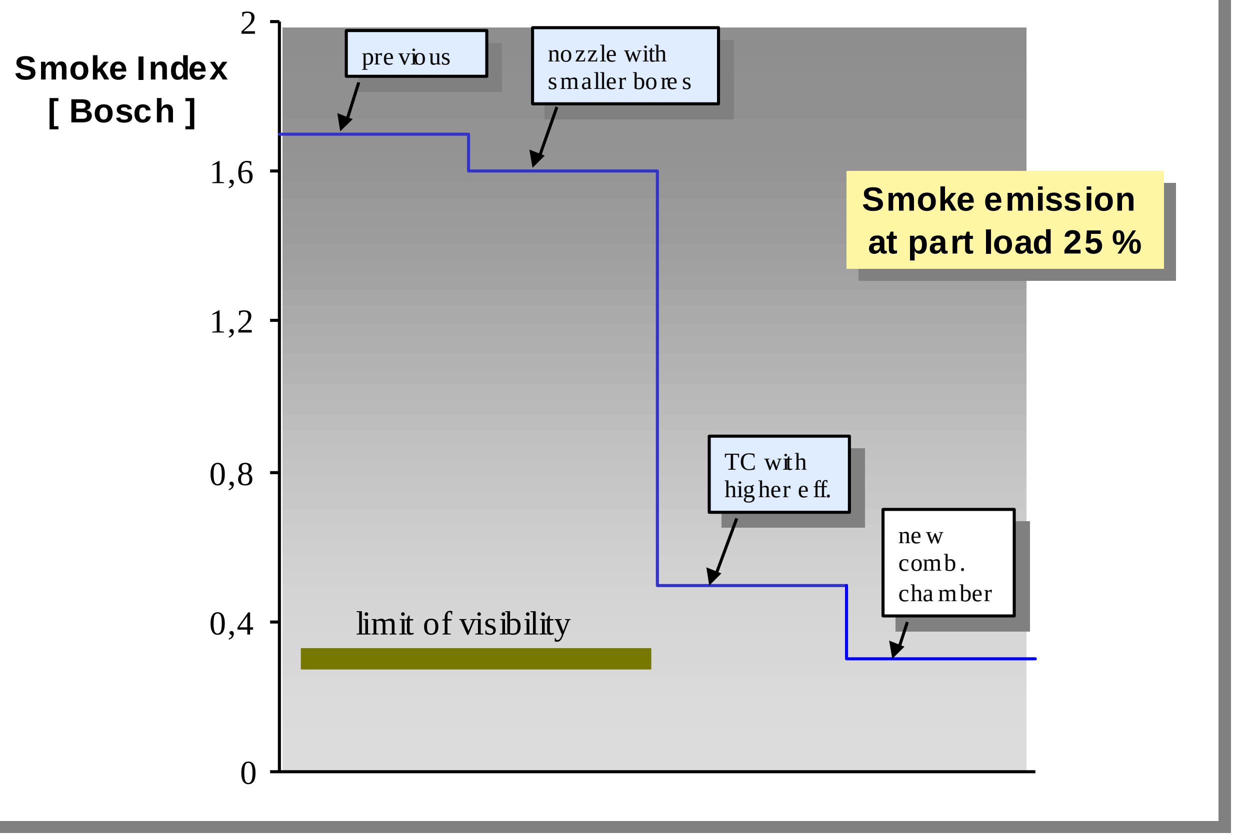
New cylinder head concept with new combustion chamber geometry



Courtesy of MAN B&W

Smoke Reduction

Improved combustion
6L32/40 test engine, propeller operation



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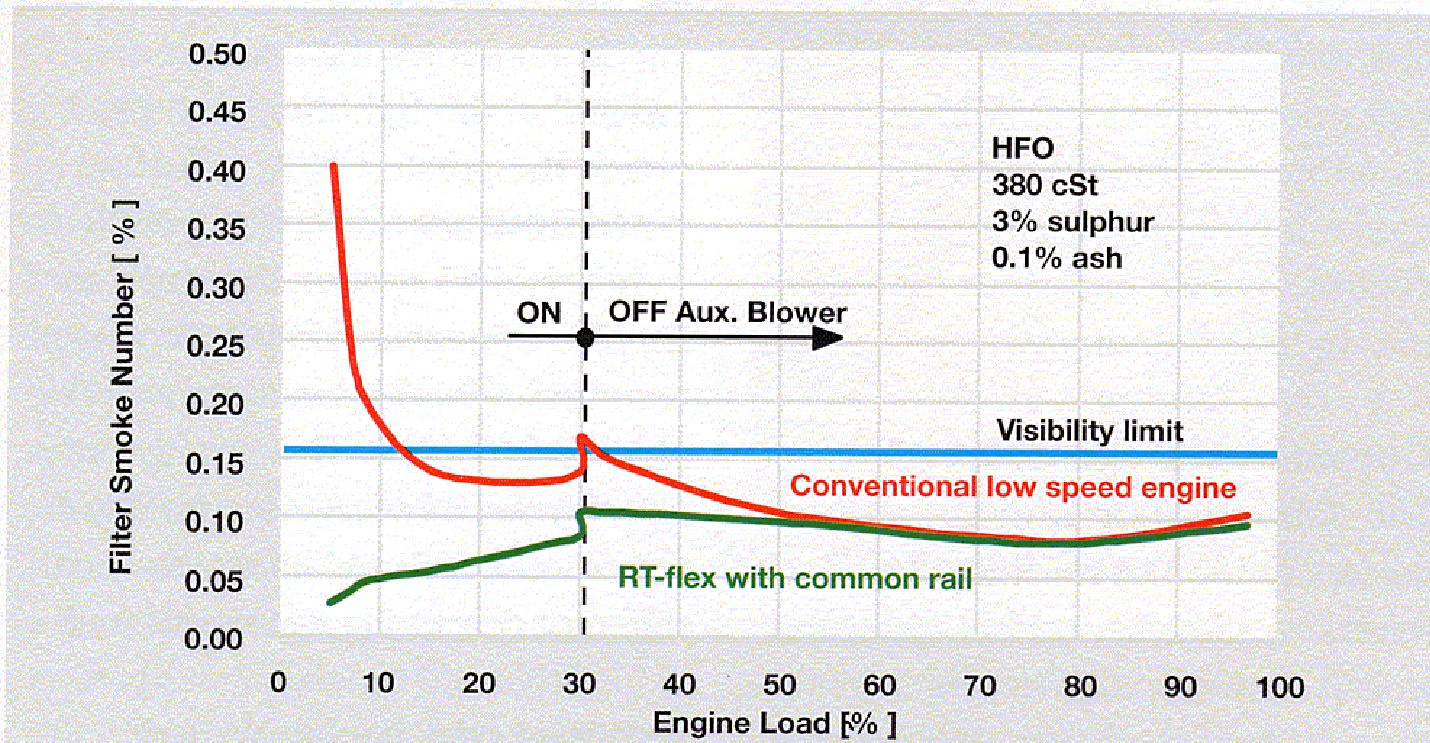
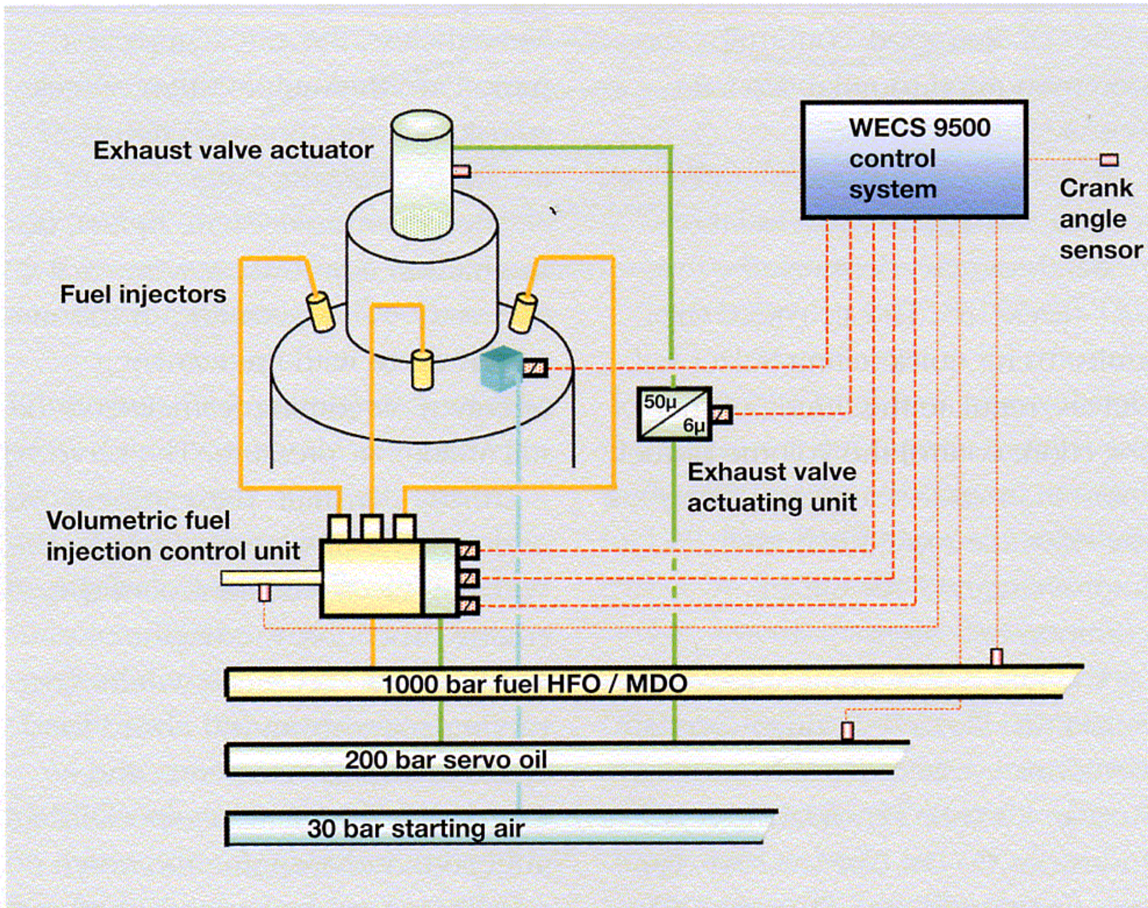
Slow Speed Smoke Visibility For Different Injection Systems



Smoke measurements from the sea trials of the Gypsum Centennial demonstrate the complete absence of visible smoke at all engine loads.

Courtesy of Wärtsilä Corporation

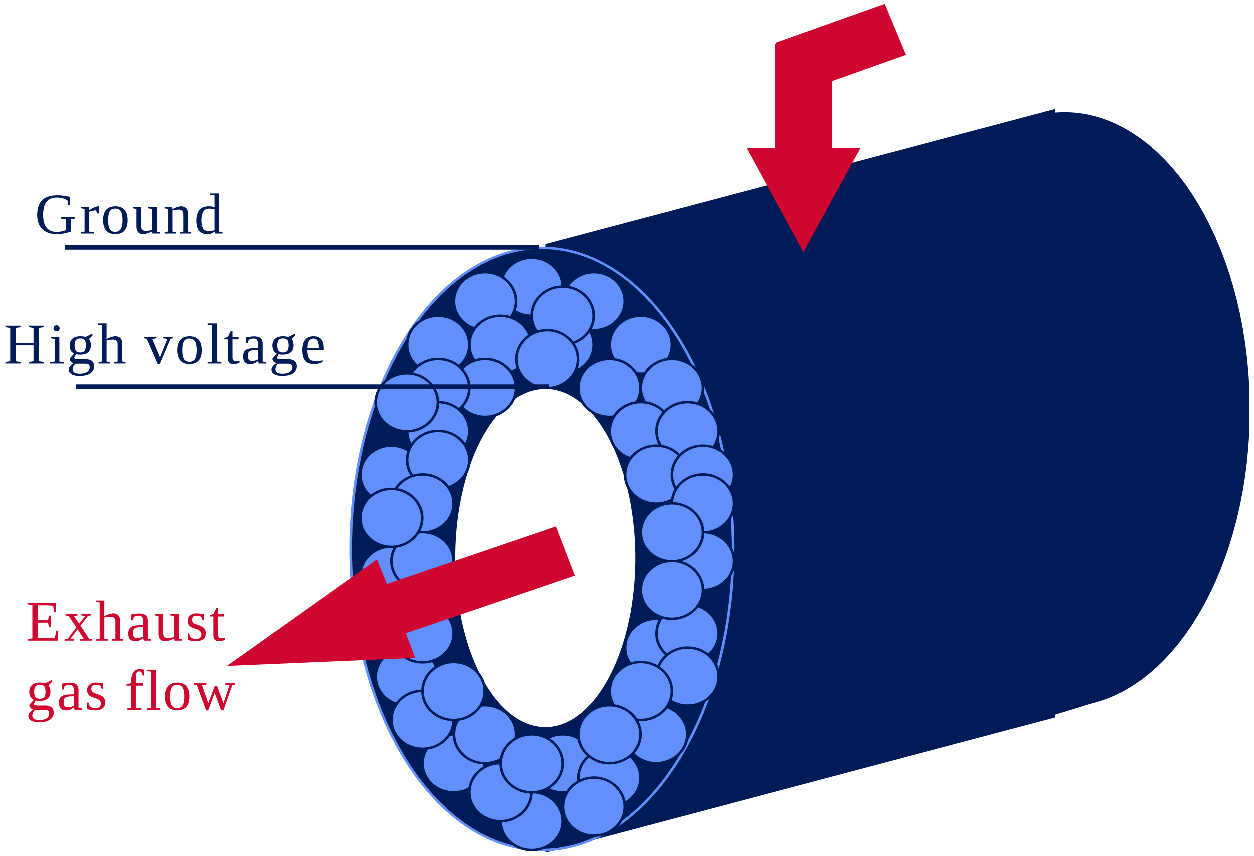
Wärtsilä Common Rail System for Slow Speed Engines



Schematic of the common-rail systems for fuel injection and exhaust valve actuation on the Sulzer RT-flex engine.

Courtesy of Wärtsilä Corporation

AEA Technology's Electrocat™



Courtesy of AEA Technology

Energy Savings

- Current thermal efficiency levels
  - Medium speed 45-50%
  - Slow speed 48 - 51.5%
- Marine installations use waste heat recovery boiler to heat process steam, further increasing efficiency
- Increases in overall engine efficiency depend on maximum cylinder pressure, turbocharger efficiency levels and fuel injection performance
- Work on reduced cooling loss combustion components can increase efficiency by up to 4%
  - Wartsila ‘Hot combustion’ is an example of this
  - Other similar work is ongoing
- Use of steam bottoming cycles can significantly improve efficiency but at significant cost
- Ultimately price and availability of fuel will dictate use of post-engine energy recovery devices

Alternative Fuels

- LNG carriers
  - Reliquifaction of boil-off gas to use them in existing diesel engines is now proven technology
  - LNG fuelled oil rig supply vessel recently put into service in Norway
  - Diesel engines can be converted to run on gas, but usually have to derate by 30% or more to avoid “knock”. Direct injection of gas avoids this derate but carries a significant cost and fuel consumption penalty

Conclusions

- Technologies are becoming available to significantly reduce NOx levels without an excessive fuel consumption penalty. However, their effect on the long term durability of the engines has still to be quantified
- Significant reductions in the reduction of visible smoke emissions are now possible with new technologies, but more work is needed
- Gas fuelled ships offer significant reductions in emissions levels, but their use will be restricted to coastal traffic due to fuelling restrictions
- Increases in engine thermal efficiency are possible, but the emergence of these will be driven by economics

Recommendations

- Implementation of Marpol Annex VI needs to be concluded as soon as possible
- An internationally recognised body should be tasked to come up with single exhaust smoke measuring procedure that is acceptable to engine builders, legislators and users
- Engine builders and users should be encouraged to come up with retrofit packages to improve the emissions of their existing ships