





FINNING POWER SYSTEMS

Presentation for

Mari-Tech 2004

Marine Diesel Engine Emissions Meeting Tomorrows Challenges

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Agenda

- Why regulate?
- Who regulates?
- What does the customer want?
- Solutions with cost estimates
- MaK technology and results
- Caterpillar's ACERT/the future

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Reality?

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Why Regulate?

- The earth is warming – increase 1 deg C during 20th century. 1998, 2001 and 2002 were three of the hottest years ever recorded

- Growing scientific consensus that this warming is largely the result of anthropogenic emissions of GHG such as carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorcarbons and sulphur hexafluoride

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Why Regulate?

- **CO2: Global Warming Potential (GWP) in 100 years = 1**
- **PFC: man made. GWP 1000 x CO2. Atmospheric Life (AL) 1000 – 10,000 years**
- **HFC: man made. GWP 1000 x CO2. AL 10 – 100's years**
- **SF6: man made. GWP 22,000 x CO2. AL 3,200 years**
- **CH4: GWP 10 x CO2. AL 10 years**
- **NOx: GWP 296 x CO2. AL 100 years**

Why Regulate?

- Studies have shown that CO2 is most abundant GHG.
- Since the 1970, of the known significant air pollutants five of the six have decreased in concentration but NOx emissions have increased by 10%

Why Regulate?

- My simple view of the issue.

Agricultural, industrial and "communication" revolution - the planet was not designed to accommodate the extremes that we impose upon her today

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Why Regulate Shipping?

- "95% of commercial goods imported to the US arrive aboard ships"
- "Between 1983 and 1998 world seaborne trade increased by 70%"
- "Commercial vessel traffic is expected to rise by a further 2.5 times by 2018"
- "Worldwide, ships cause 14% of NOx and 5% of SOx emissions"

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Why Regulate Shipping?

- **"During July the emissions from ships can be responsible for increasing the NOx concentrations in the N. Atlantic by 100x over there background levels"**

- **"Sources of US NOx emissions:**
  - 49% motor vehicles
  - 27% Utilities
  - 19% industrial/commercial/residential
  - 5% all other sources"

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Why Regulate Shipping?

- **Assuming no other changes the EPA Tier II emission standards will reduce marine engine NOx and PM emissions by 32% and 26% respectively by 2030**

Conclusion: It makes sense for shipping to be part of a global effort to reduce hazardous emissions

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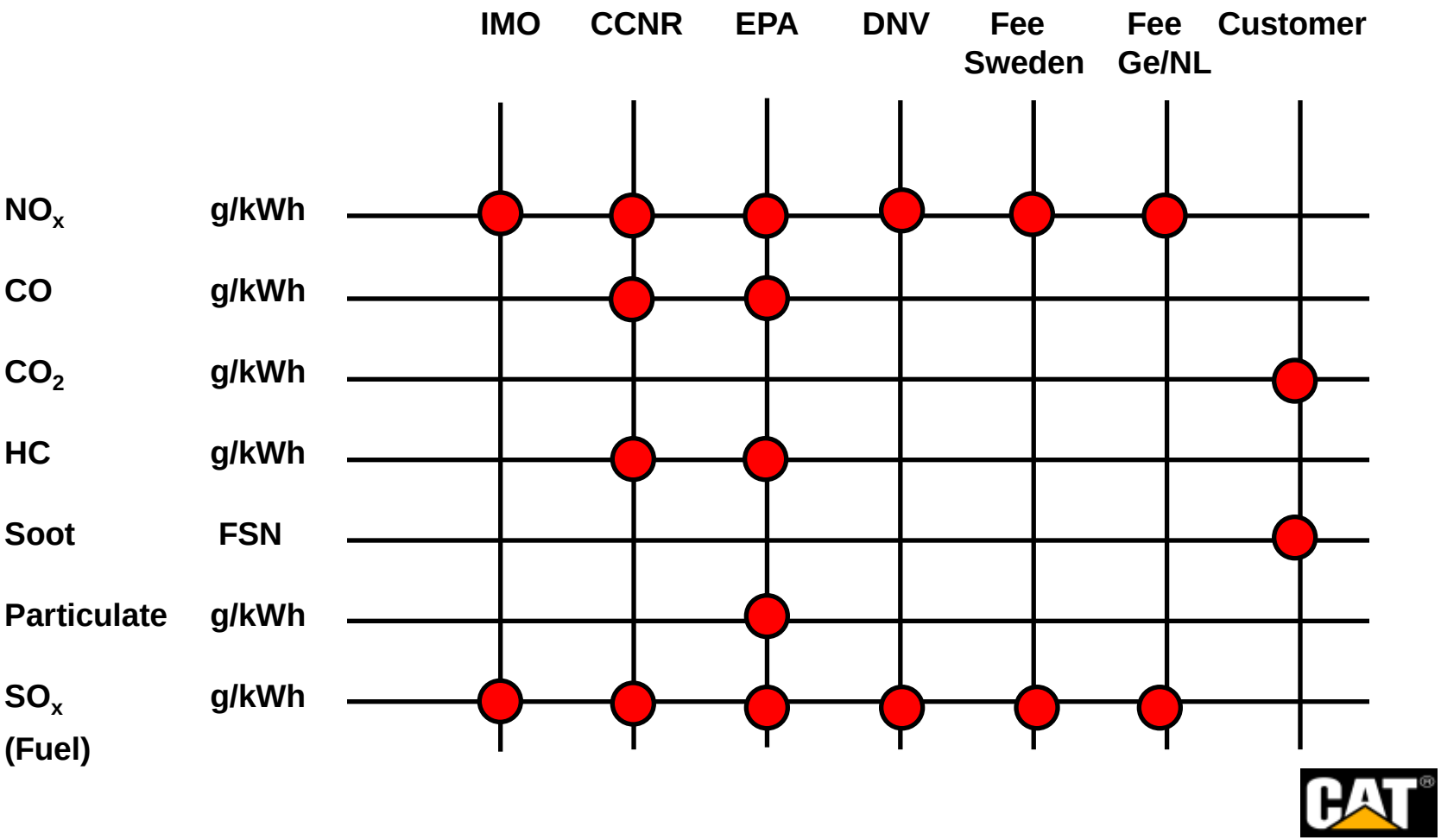
Who Regulates?

Marine Applications & Off Shore Petroleum Market



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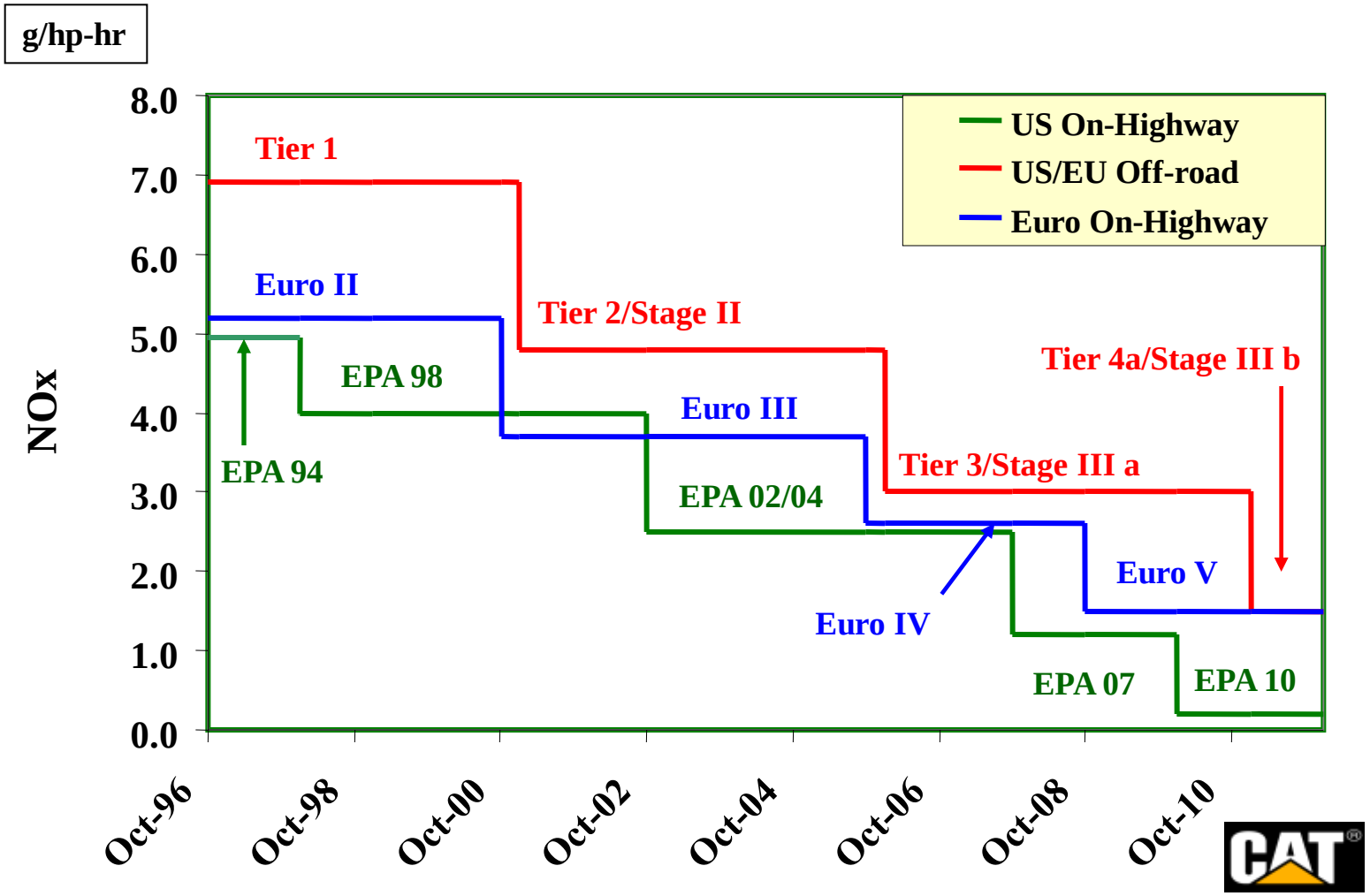
US/EU Emission Standards
Going in the same direction…NOx



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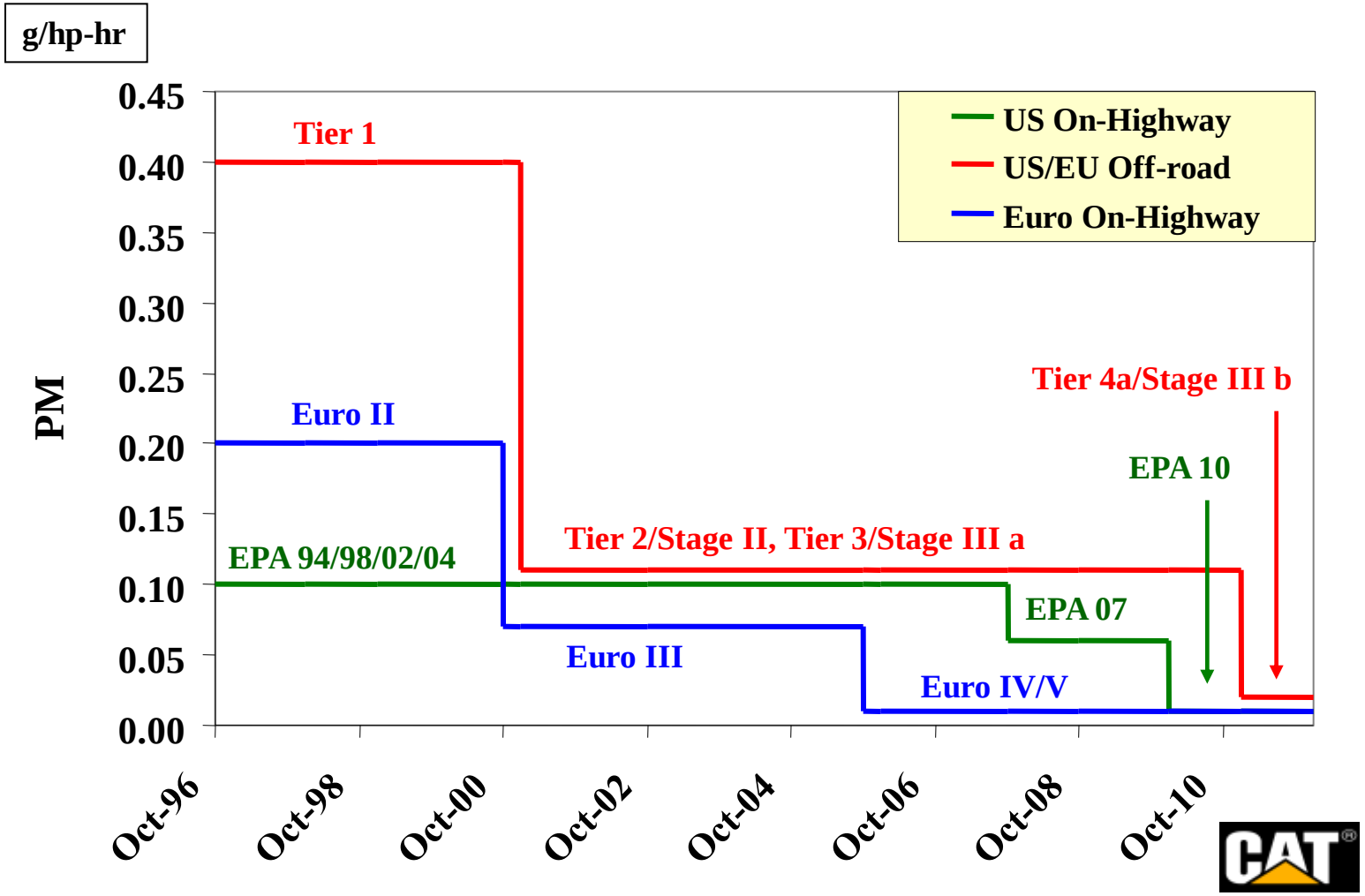
US/EU Emission Standards
Going in the same direction…Particulate Matter



In 2003, a Survey of Caterpillar Sales Organizations around the World uncovered the following Facts:

- Customers want **no visible smoke** during transient operation

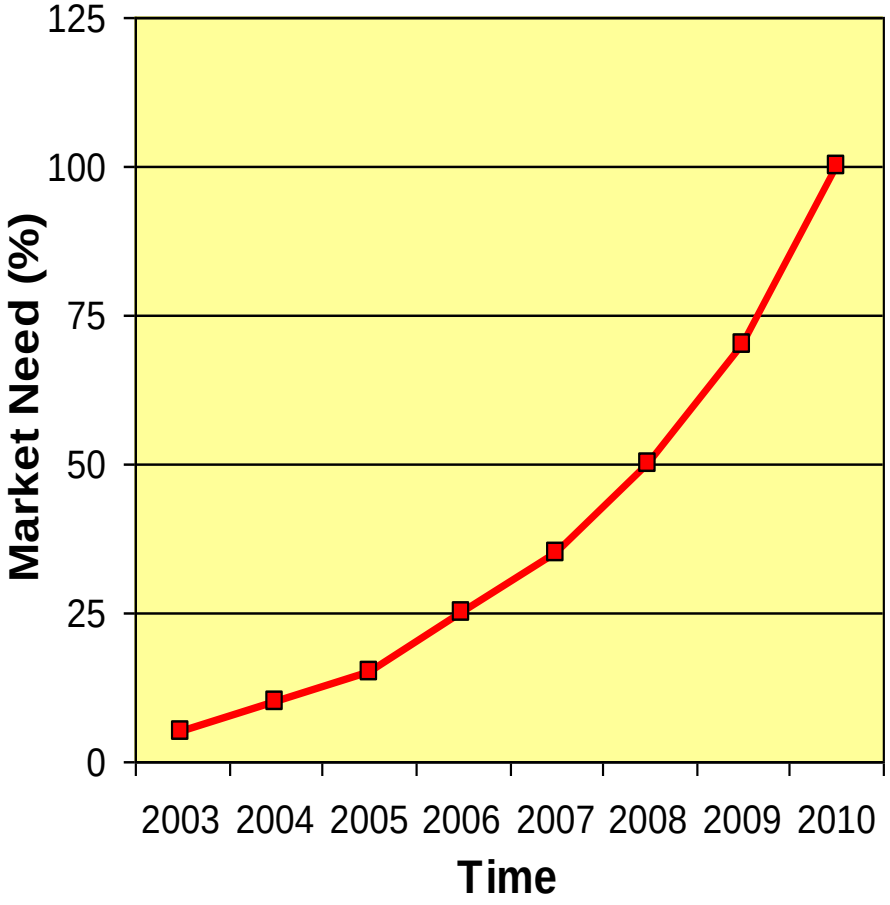
- 30 % of engine sales in 2005 are expected to be **with** lower than IMO emissions

- Retrofit kits are **desired** for sale in 2005

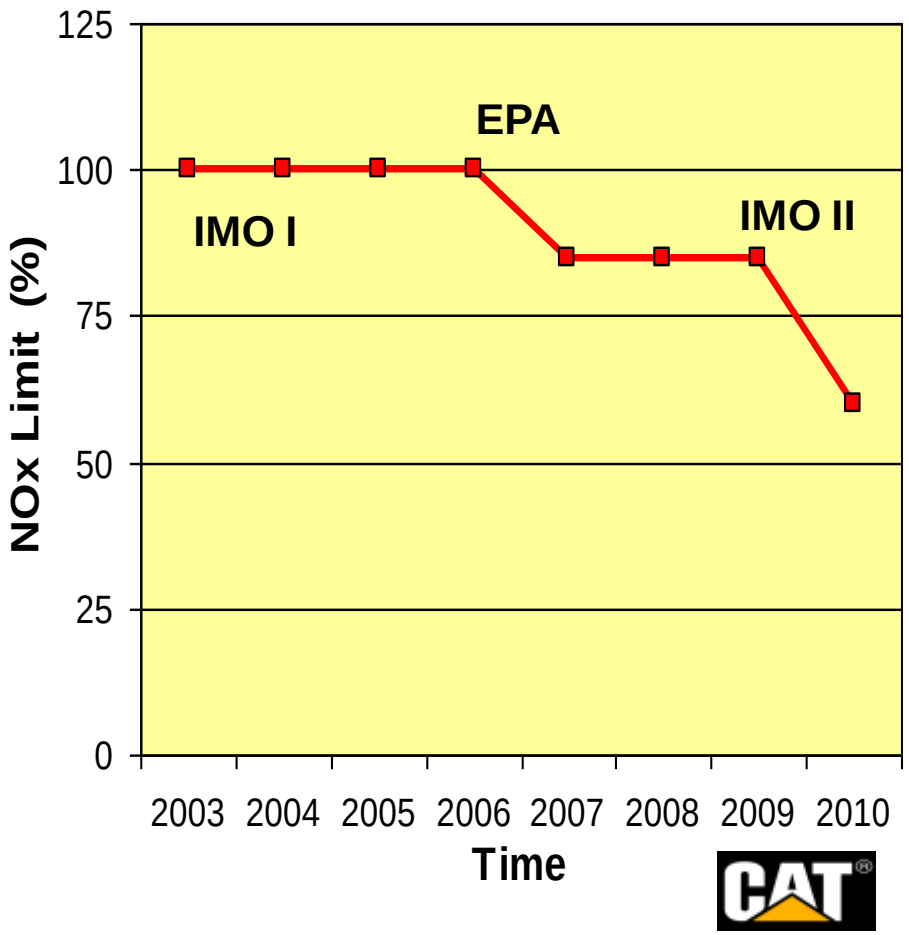
- A 2 - 3 year amortization of the extra system costs **is acceptable**

Demands for low Emission Engines

Soot Emission



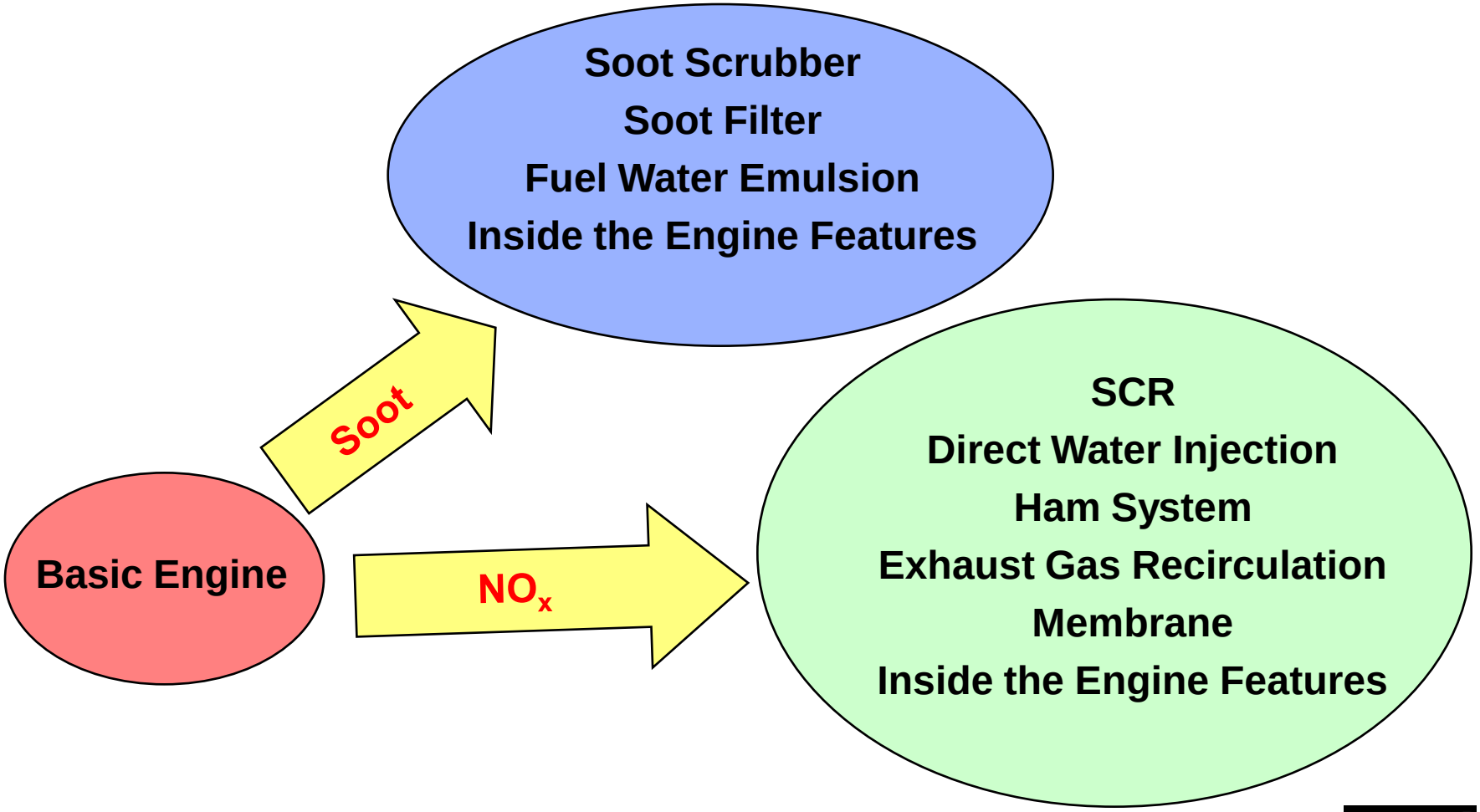
NOx Emission



The Emission Phenomenon

- Noxious Constituents = 0.3% of exhaust gas (99.7% = CO_2, H_2O, O_2 and N_2)
- High pressure/temperature during combustion leads to good fuel efficiency and low soot levels
- For low NOx levels a low combustion temperature required

Emission Reduction



Emission Reduction Technologies

	NO_X	Soot	SO_X	First Costs (Euro / kW)	Operation Costs (Euro / MWh)
FCT Equipment	+	+	○	3 - 4	0
Water Injection	+	-	○	10 - 20	0,5 - 1,5
SCR Catalyst	+ +	○	○	20 - 40	3 - 5
SO_X Scrubber	○	○	+ +	120 - 140	2 - 3
Soot Filter	○	+ +	○	40 - 50	????

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MaK Technology

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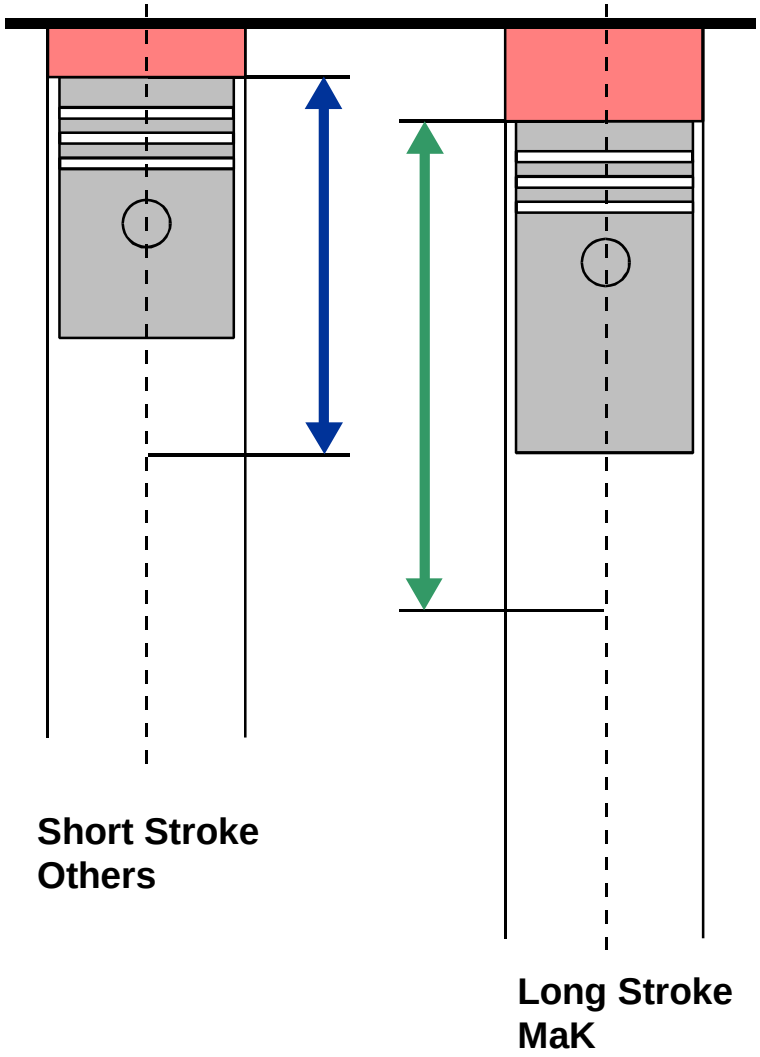
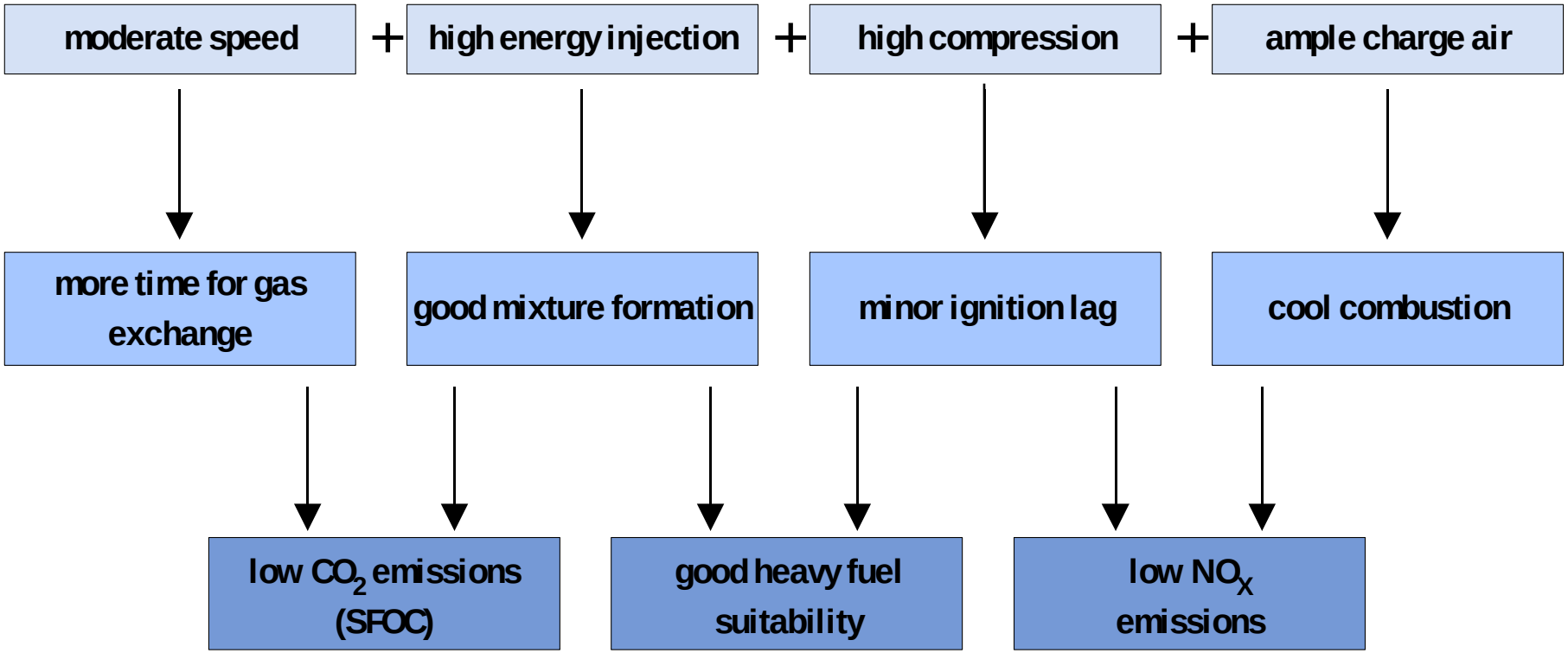
Long-Stroke and Low Speed



The benefits:

- Minimum wear due to high compression, small rise of the ignition pressure, low speed and long piston
- Long service life due to cool combustion chamber components and low speed
- Extreme heavy fuel capability due to spacious combustion chamber and low speed
- High economy due to long component life and low fuel consumption
- Environmentally compatible due to low NO_X and CO_2 emissions

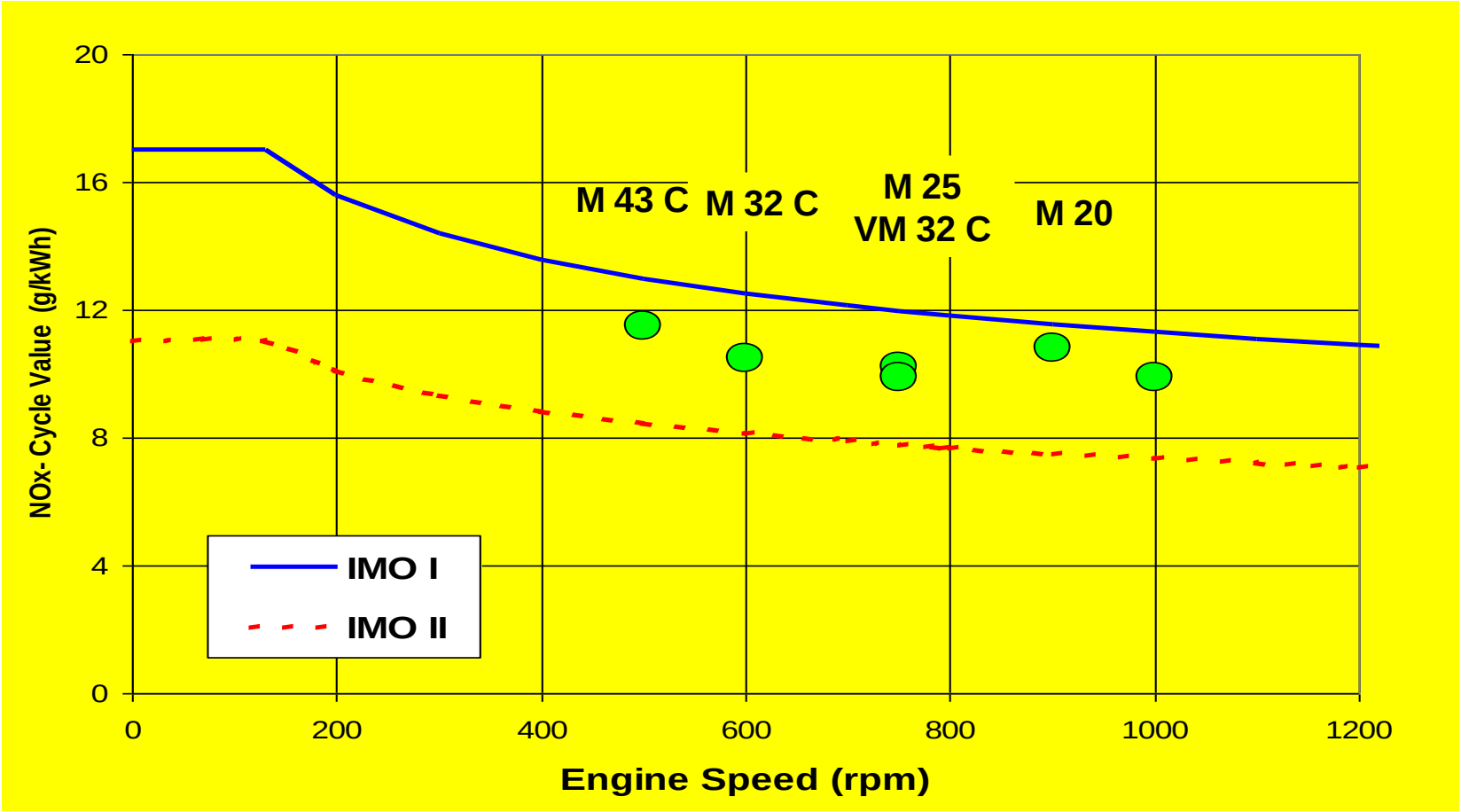
The Long-Stroke Concept



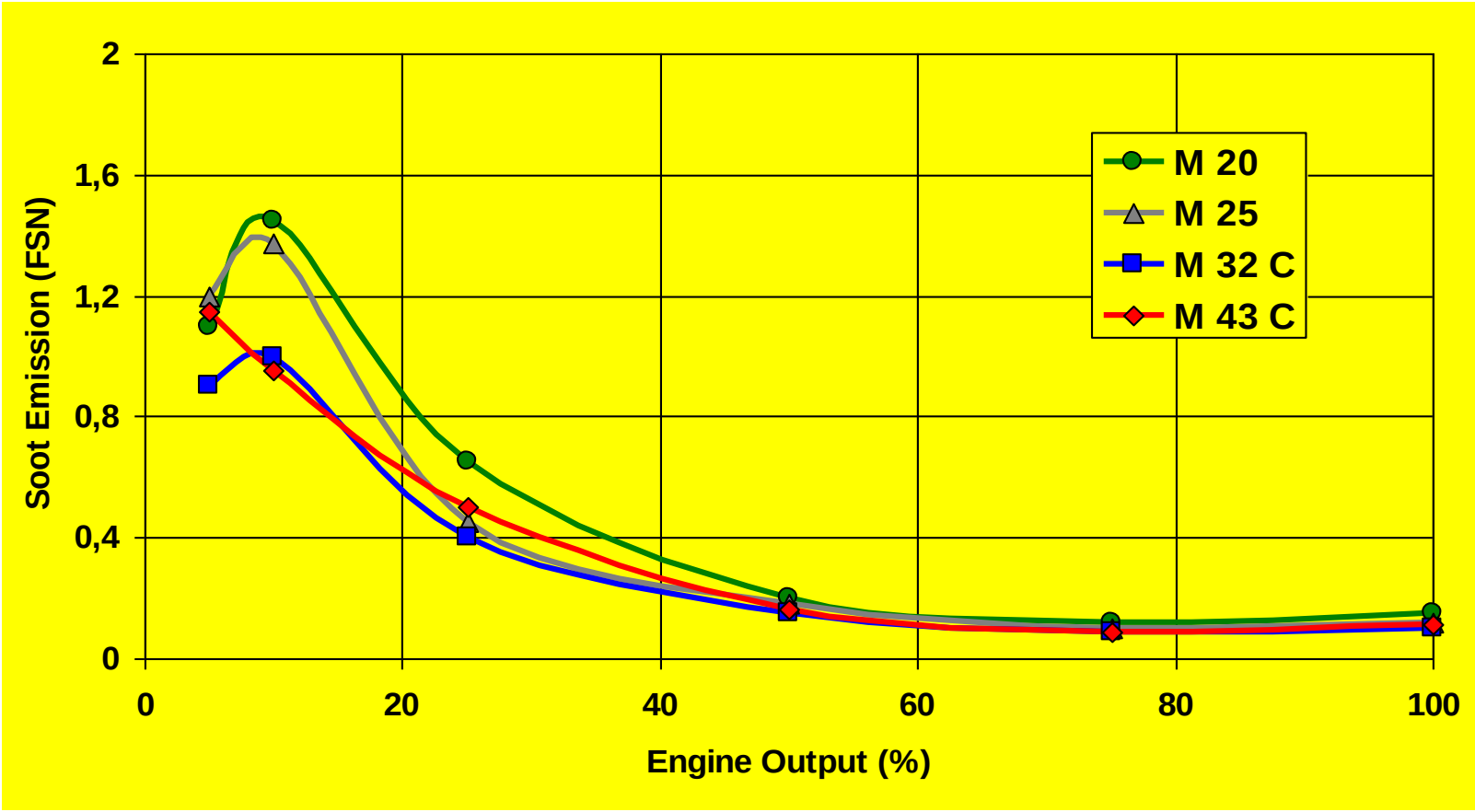
IMO Compliant Engine

NOx & Soot Values

NO_x Emission Values of MaK Marine Engines



Soot Emission of MaK Parent Engines @ constant speed



IMO Compliant Engine
+
Improvements (LEE and FCT)

Low Emission Engine (LEE)

- **A modified IMO Compliant Engine:**

  - Increased compression ratio
  - Modified camshaft design
  - Turbo efficiency improvements
  - Improved fuel injection process

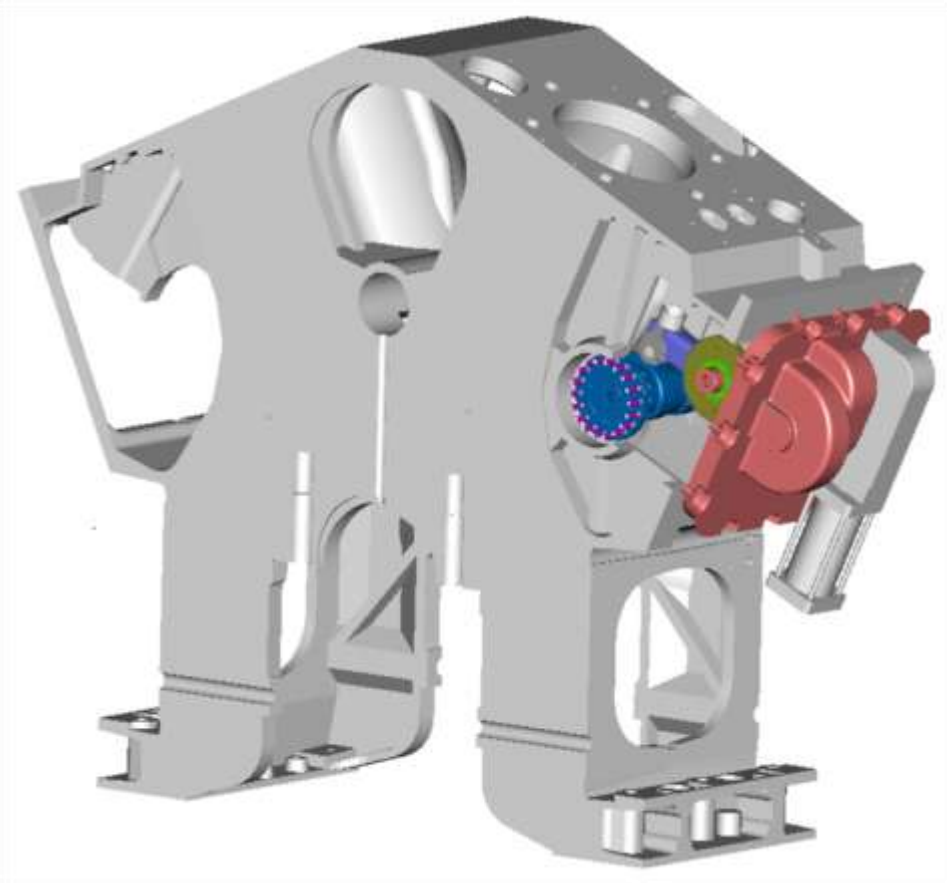
LEE =
NOx Reducer

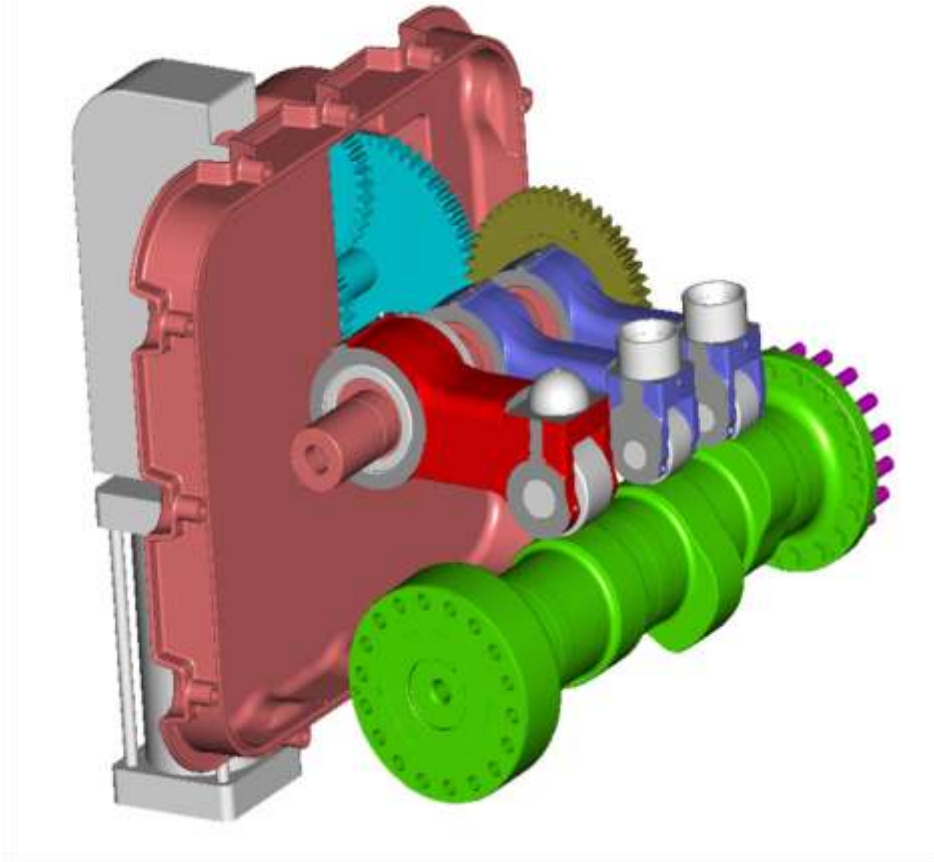
Flexible Camshaft Technology (FCT)

- **A part of the LEE concept**
  - Optimised timing

FCT =
Soot Killer

The Elements of the FCT System





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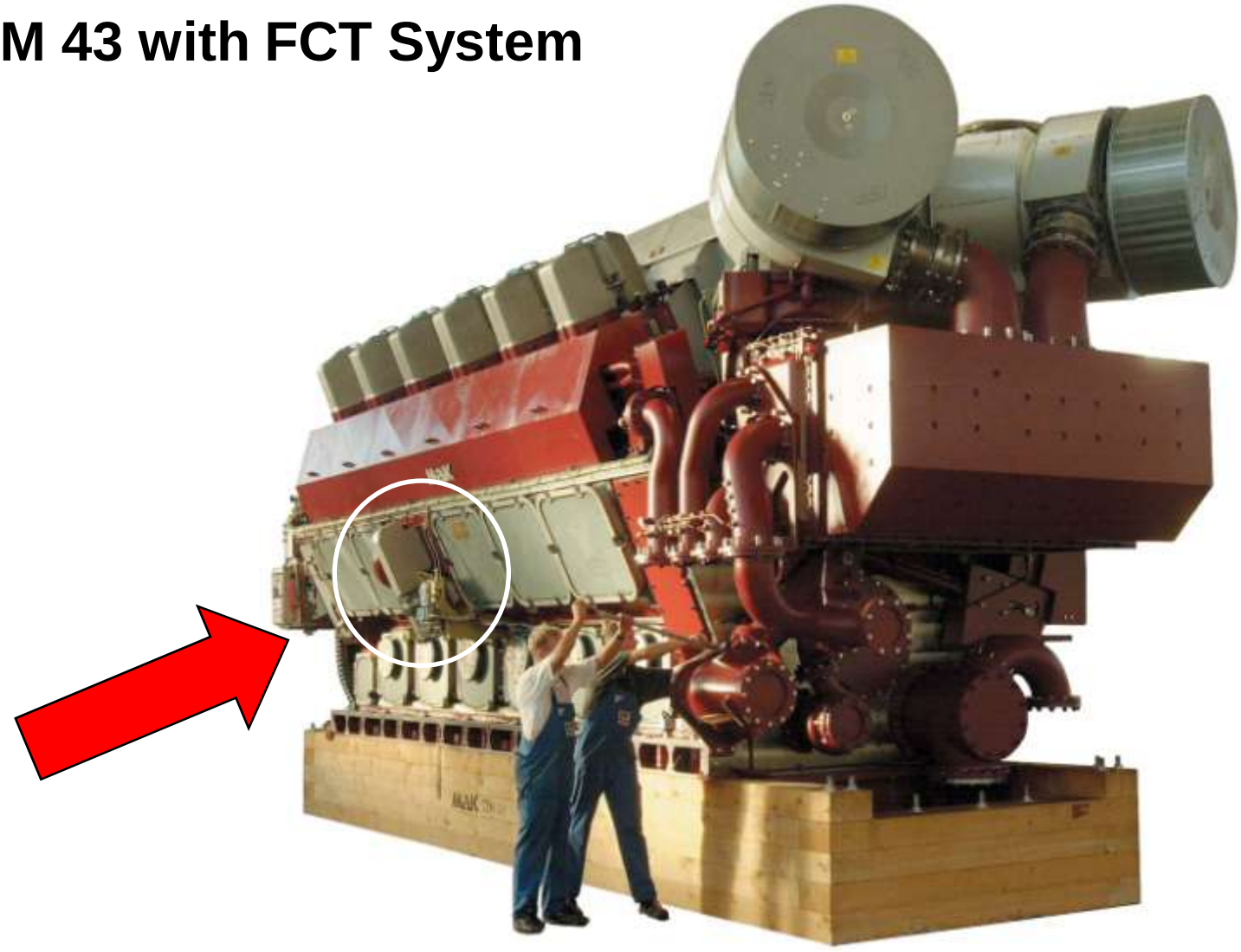
12 M 43 with FCT System



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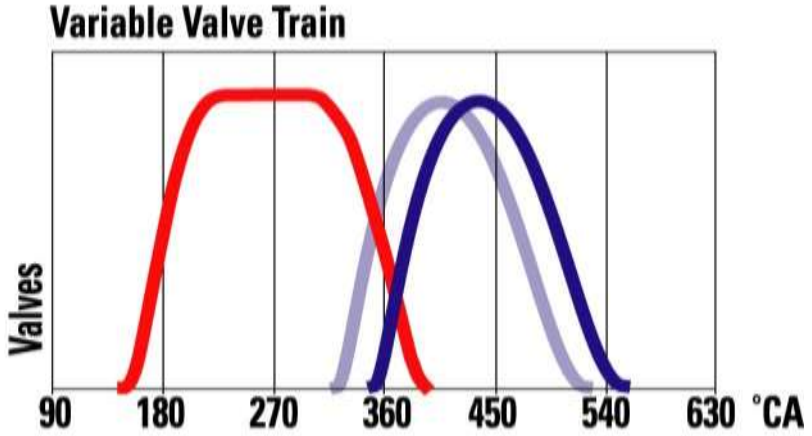
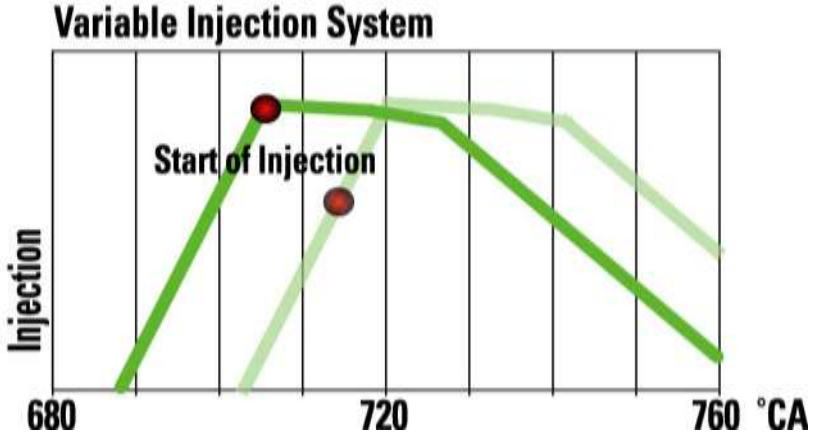
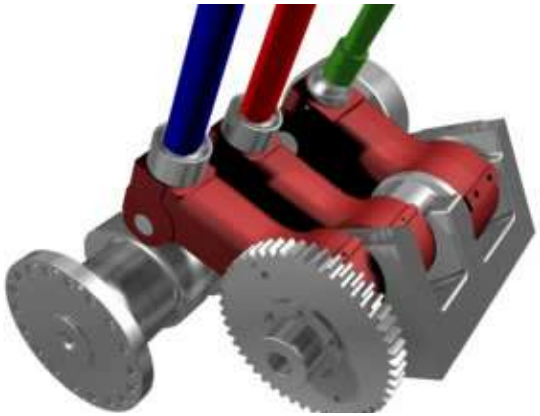
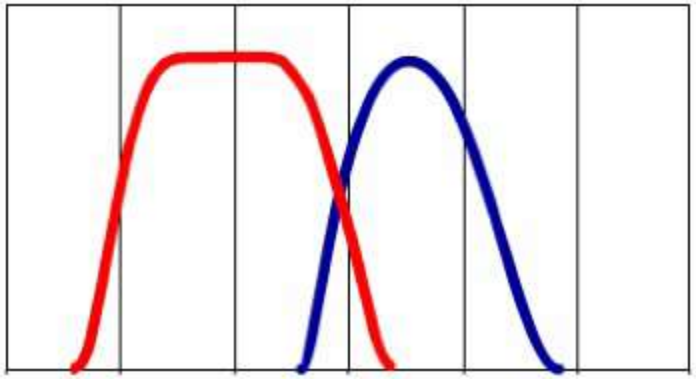
VM 43 with Flexible Camshaft Technology

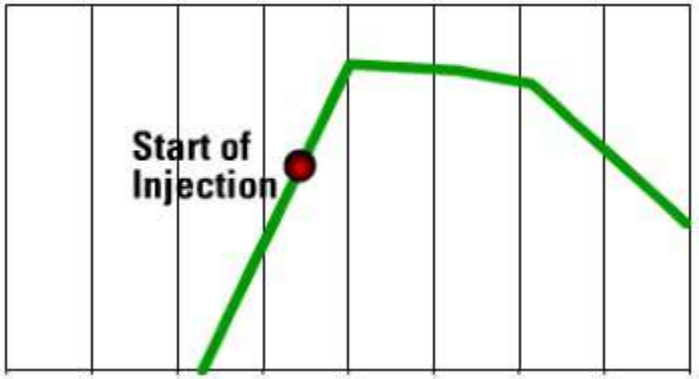




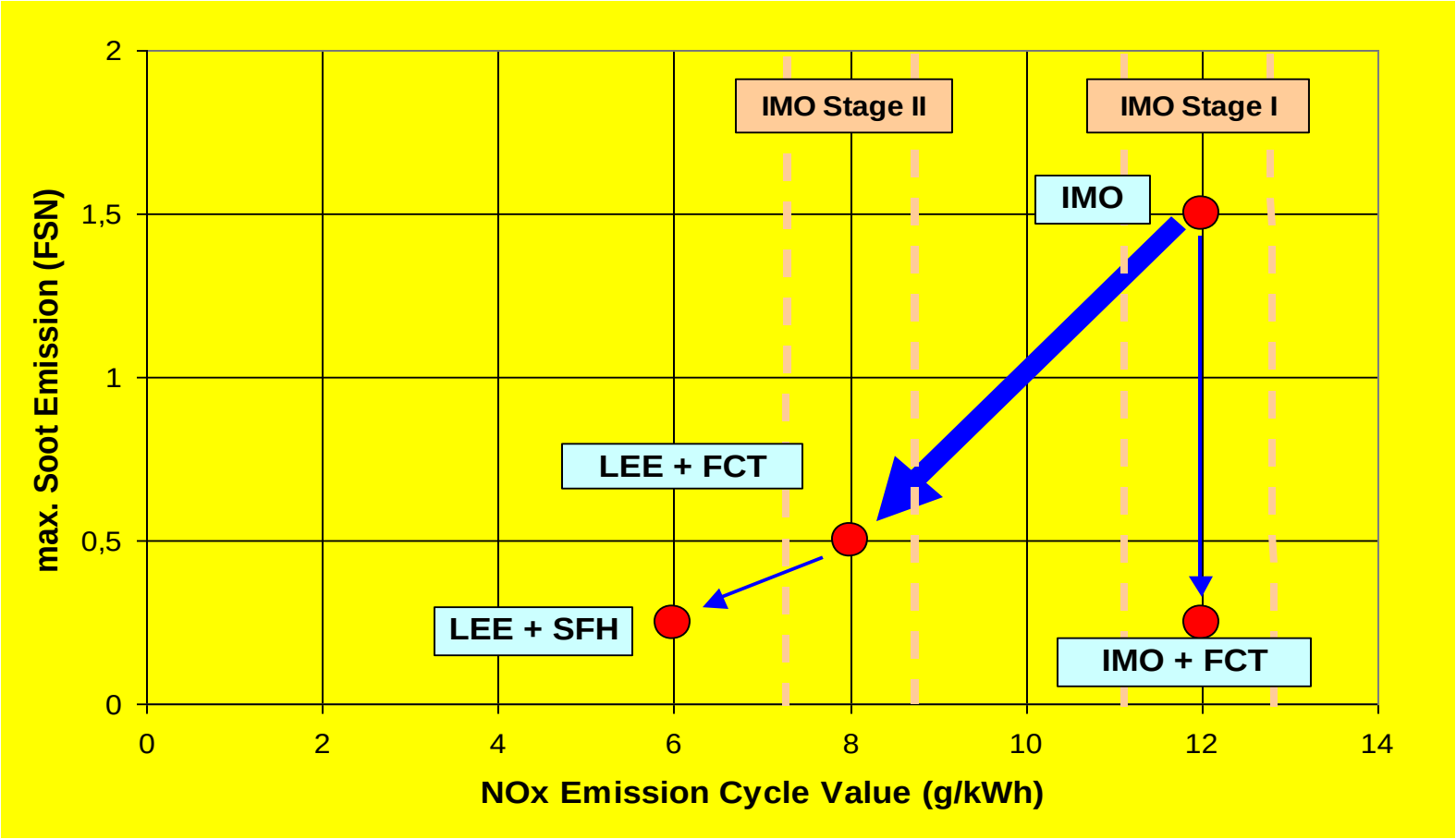
VM 43 with Flexible Camshaft Technology



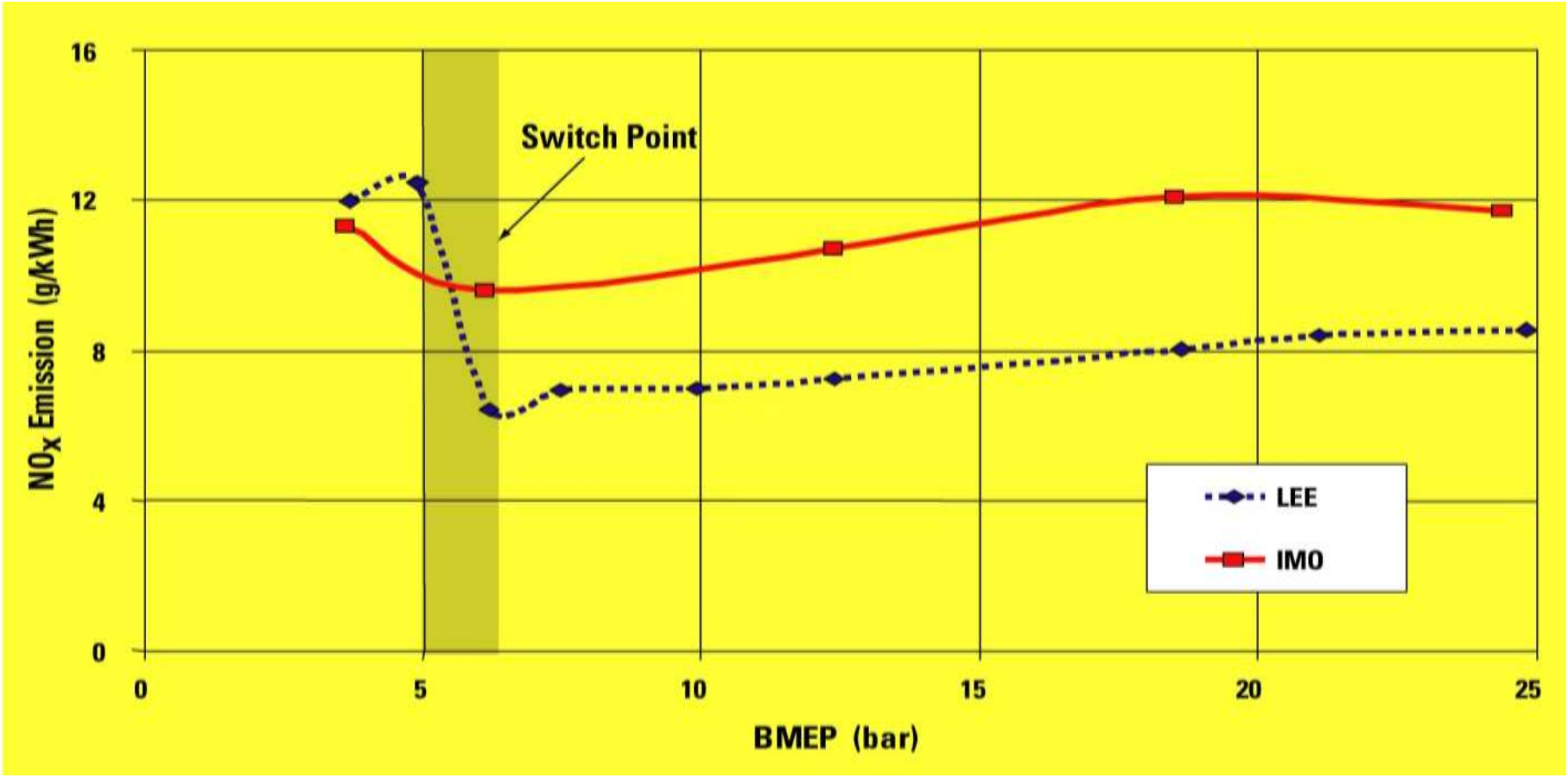




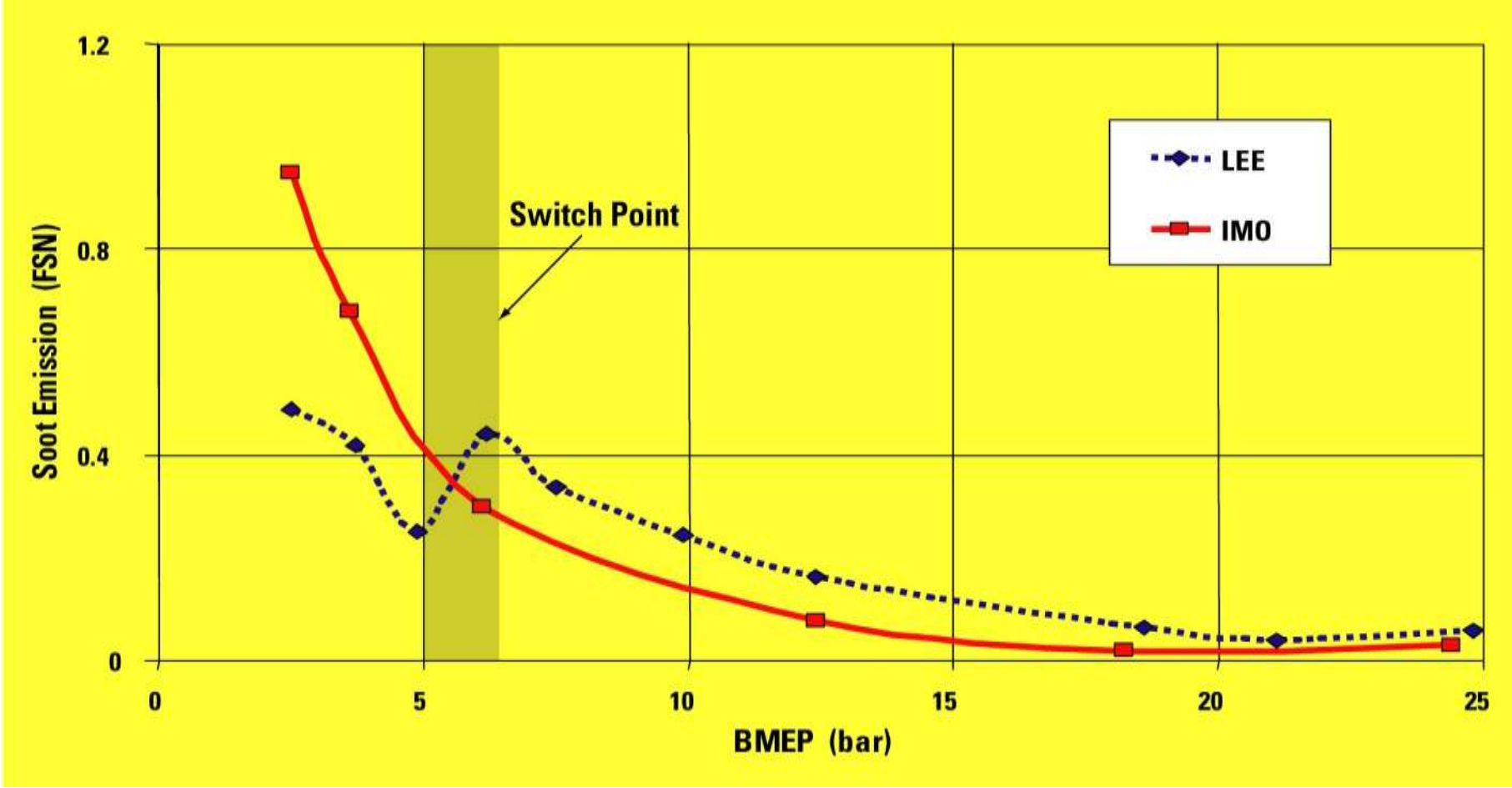
Emission Targets of Caterpillar Motoren



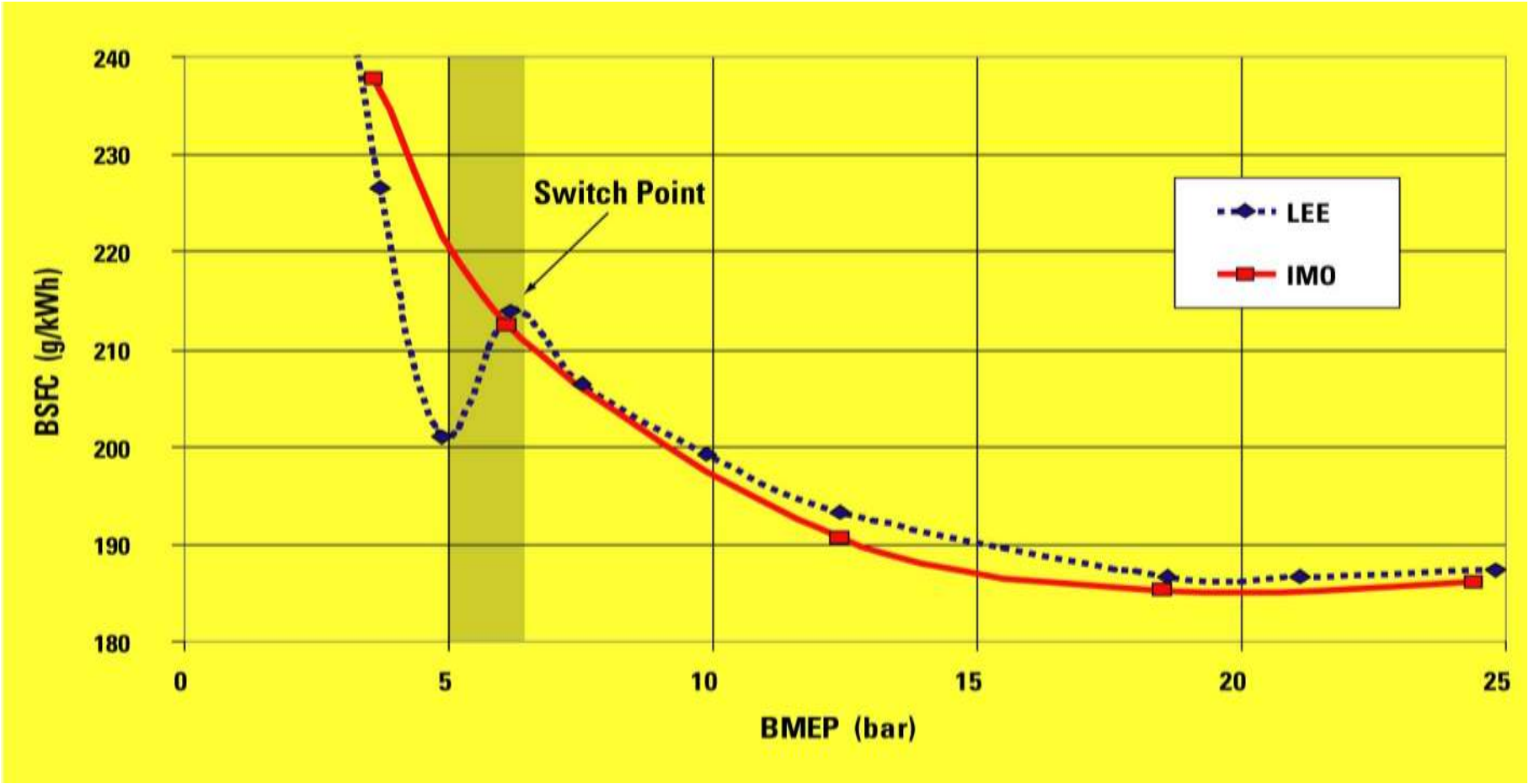
NO_x Emission Measurements @ 12 M 43 with FCT



Soot Emission Measurements of 12 M 43 with FCT



BSFC Measurements of 12 M 43 with FCT



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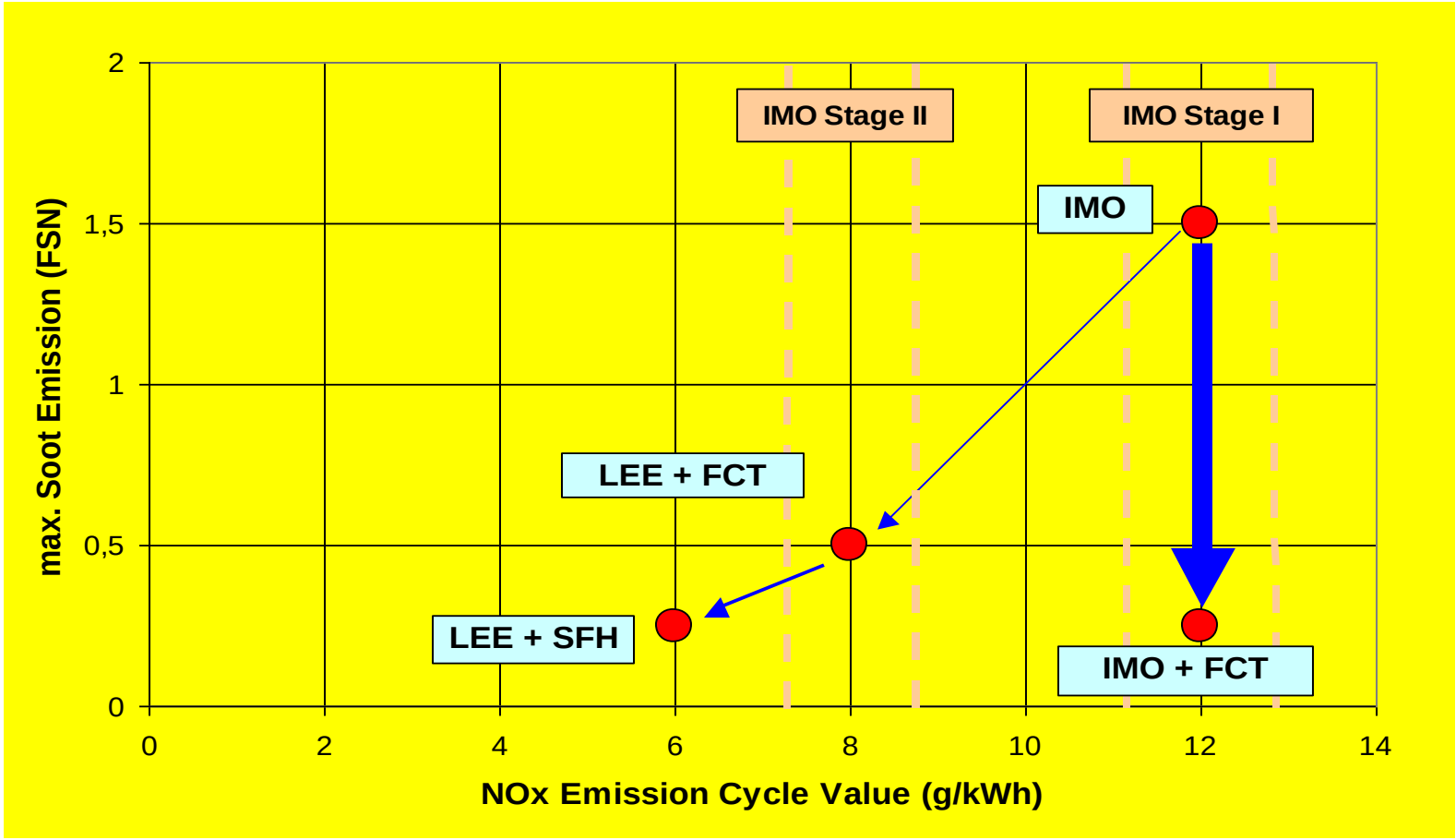
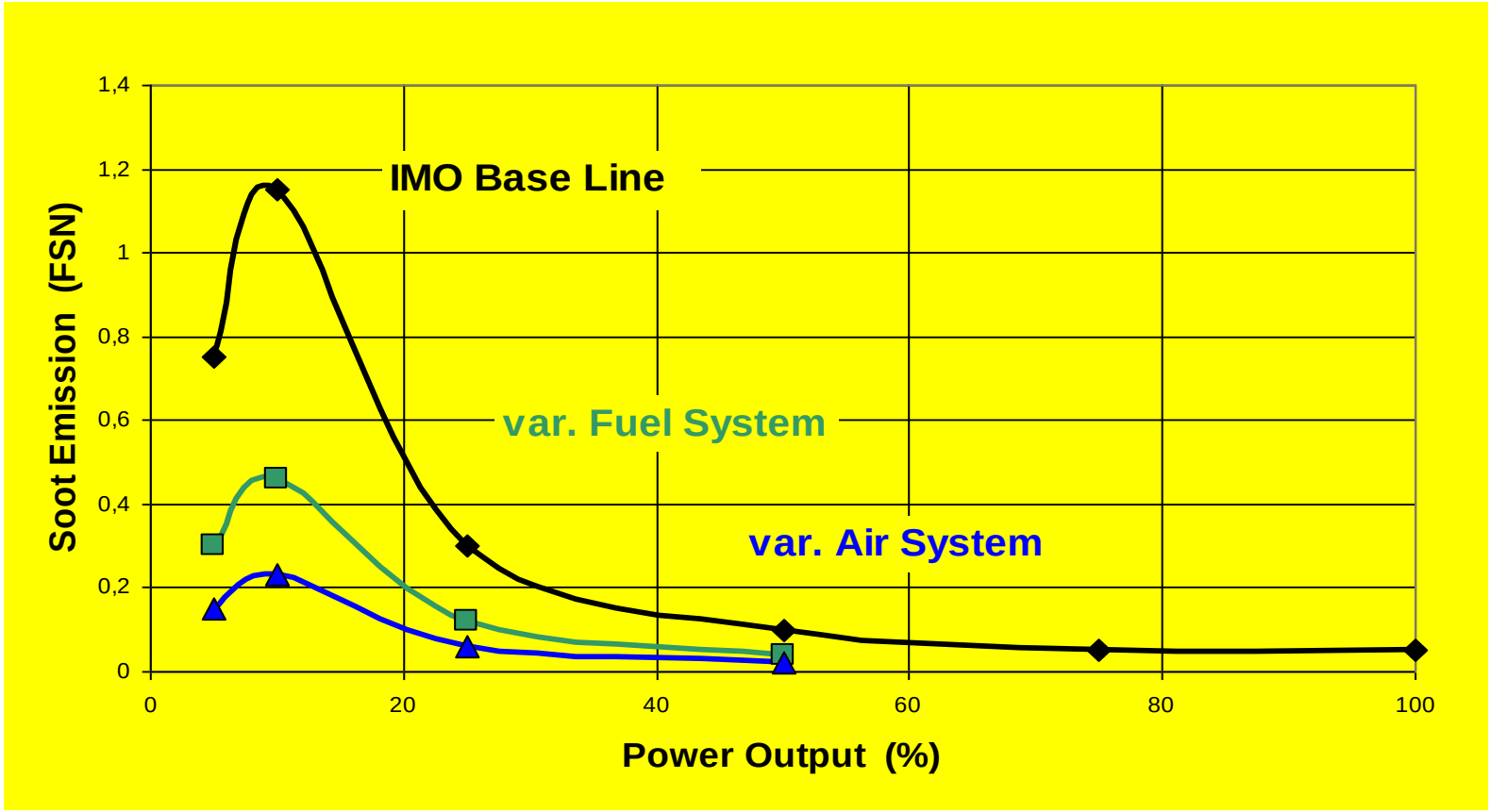
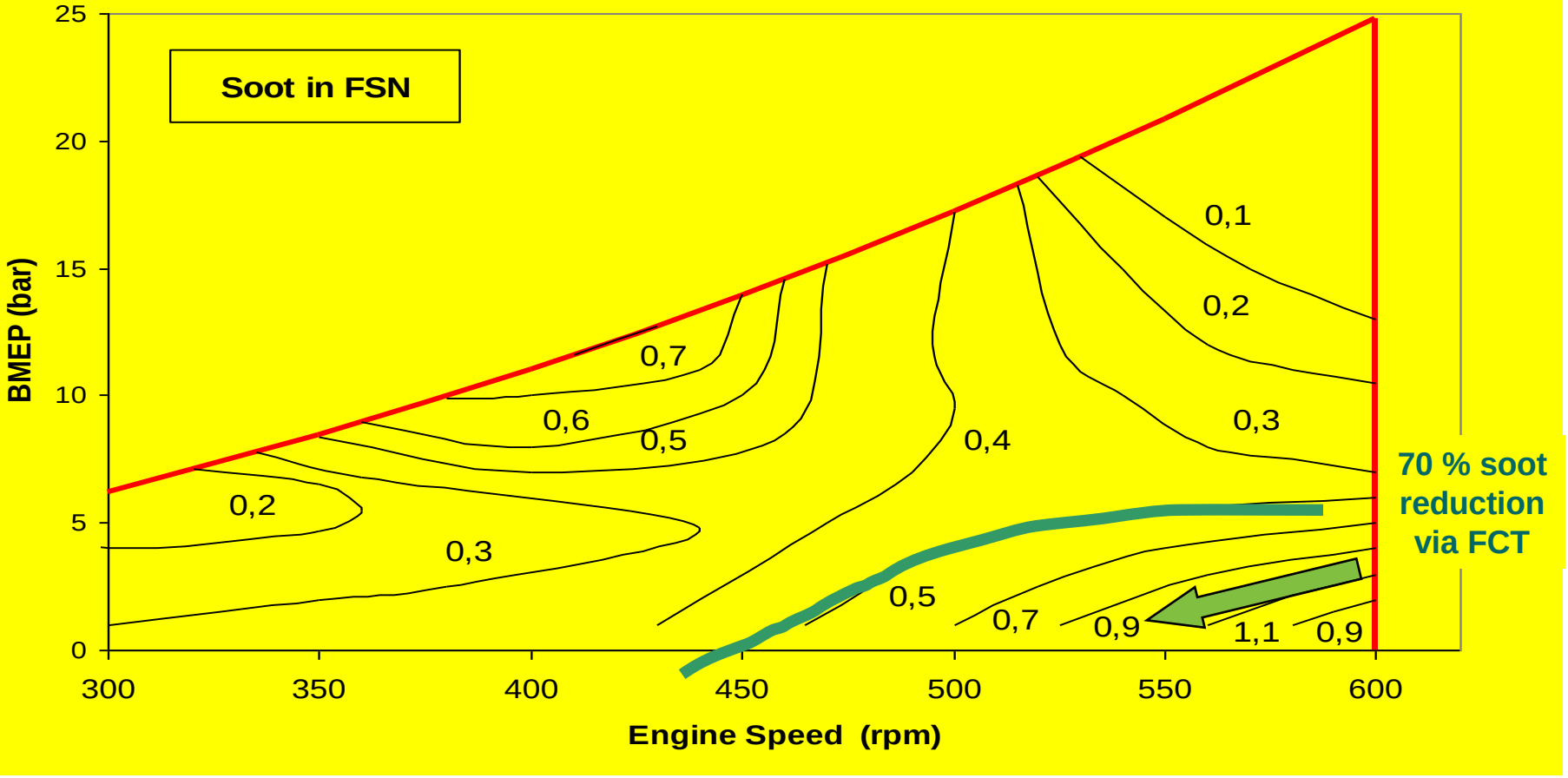


Predicted M 32 C with FCT @ 600 rpm

NOx = 12 g/kWh, acc. MARPOL 73/78, Annex VI, Cycle D2



Soot Emission of 6 M 32 C



Retrofit Kit for Low Emissions

Soot Killer

NOx Killer

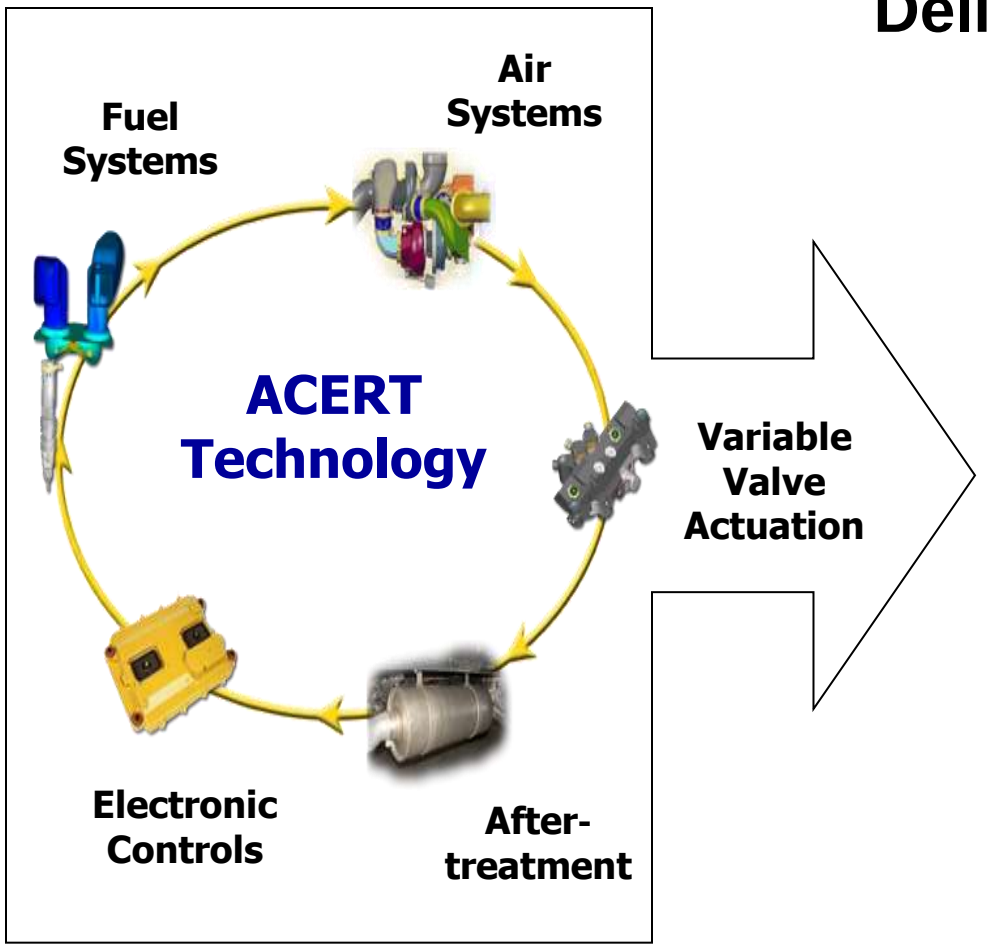
References?

LEE + FCT

- ✓Highly Effective
- ✓Simple
- ✓Cost Effective
- ✓Reliable
- ✓Fuel Efficient
- ✓Lub oil Efficient

ACERT and ongoing R&D

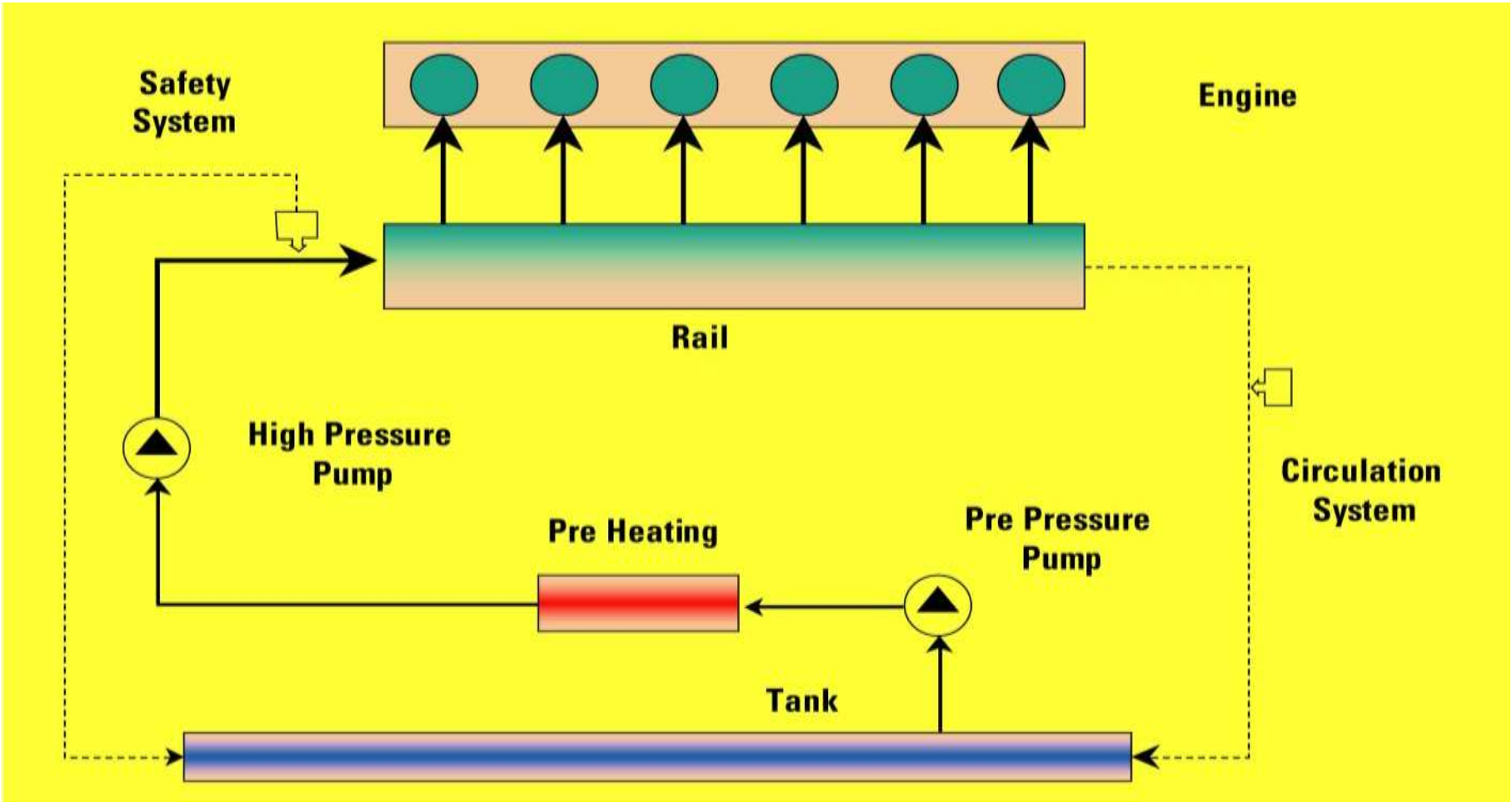
ACERT® – Suite of Technologies



Delivering Customer Value

- Reliability
- Durability
- Performance
- Fuel Efficiency
- Emissions Reduction
- Noise Reduction
- Operating Costs

Single Fluid HEUI



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M 20 LEE with Single Fluid HEUI

Rail Pump

Rail + Valves

Injector

Electronic

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Global Marine Power Supplied and Supported Locally