ENVIRONMENT

# The Diesel Engine and the Environment

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# The Diesel Engine and the Environment

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# The diesel engine and the environment

- rules and regulations

- emission reduction technologies

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# Typical composition of diesel engine exhaust gas

| | | | | |
|---|---|---|---|---|
| Together > 99.5% | Nitrogen | $N_2$: | 76% | |
| | Oxygen | $O_2$: | 13% | |
| | Carbon dioxide | $CO_2$: | 5% | Low due to high efficiency |
| | Water | $H_2O$: | 5% | |
| | Sulphur oxides | $SO_X$ | | Fuel choice related |
| | Carbon monoxide | $CO$ | | Low due to good combustion |
| | Hydrocarbons | $C_XH_y$ | | Low due to good combustion |
| | Particles | | | Low at steady state operation<br>Influenced by fuel ash and sulphur content |
| | Visible smoke | FSN | | Low load related (<25% load) |
| | Nitrogen oxides | $NO_X$ | | To be controlled |

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# Exhaust compounds and their environmental impact

**$NO_x$:**

– acid rain, acidification

– ozone/smog formation in the lower atmosphere (potential damage on vegetation and human health)

**Particulates:**

– some considered carcinogenic

– blackening with soot

**$SO_x$:**

– acid rain, acidification

– potential detrimental effect on human health

**CO:**

– ozone/smog formation in the lower atmosphere

**Hydrocarbons:**

– ozone/smog formation in the lower atmosphere

– some considered carcinogenic

– contribute to the greenhouse effect

**$CO_2$:**

– the major greenhouse gas

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# Annex VI to MARPOL 73/78

- Applies to: Ships of 400 GRT or above,Platforms and Drilling Rigs

- Enters into force: 12 month after the date on which not less than 15 states, constituting not less than 50% of the gross tonnage of the world's merchant fleet, have signed the protocol

- It is important to note that the NOx emission regulation is linked to the date, 1st of January 2000. Ships constructed after this date will be required retroactively to comply with these requirements when Annex VI enters into force.

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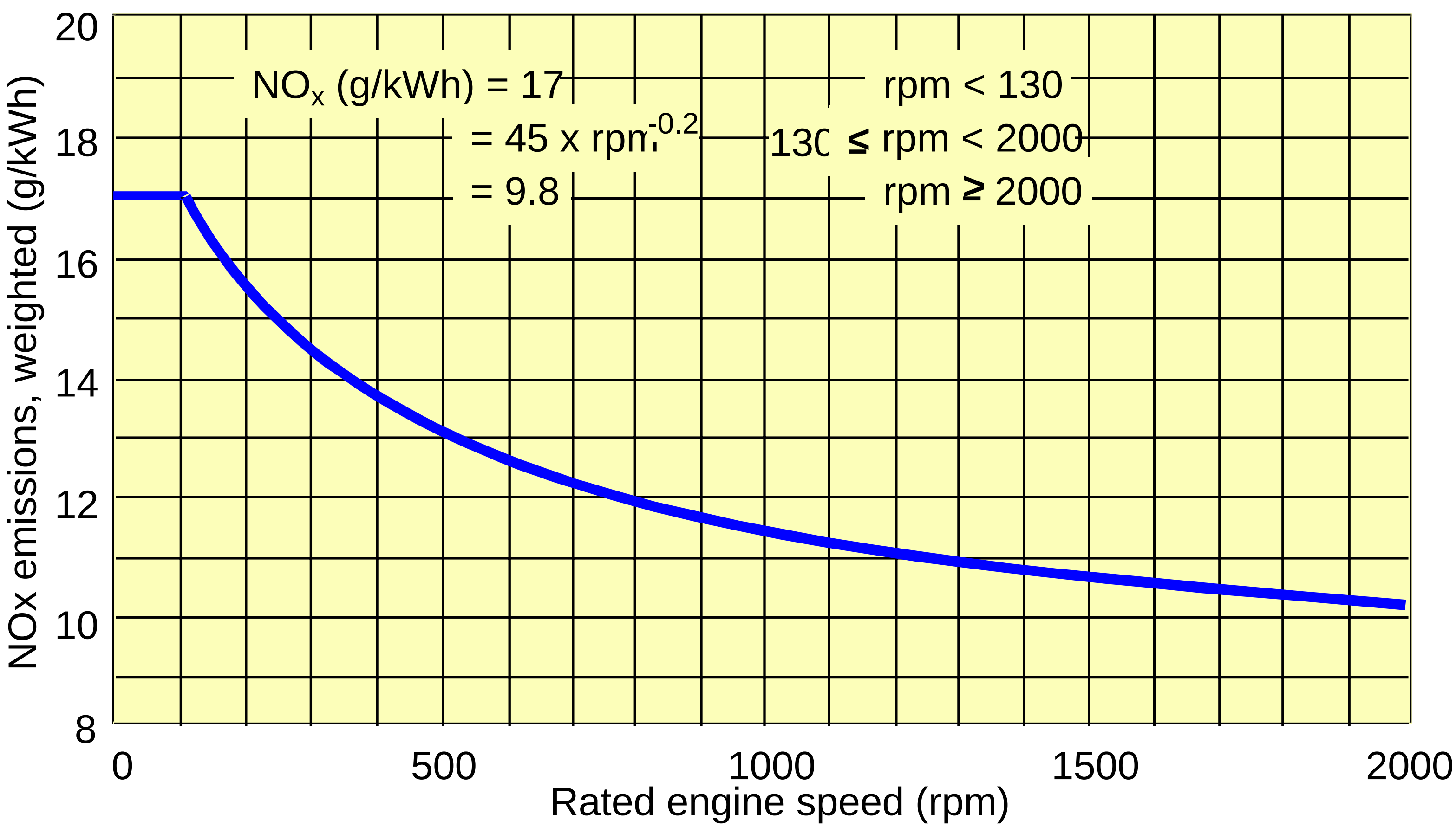
# IMO MEPC Proposal for Global Marine $NO_x$ Legislation




ISO 8178 Test Procedure
Reference Fuel: Marine Diesel Oil

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# Diesel $NO_X$ Formation

- Thermal $NO_X$ formation (65-75%)
- Nitrogen source: combustion air
- Formation process: extremely complex including hundreds of different reactions
- Strong temperature influence (exponential)

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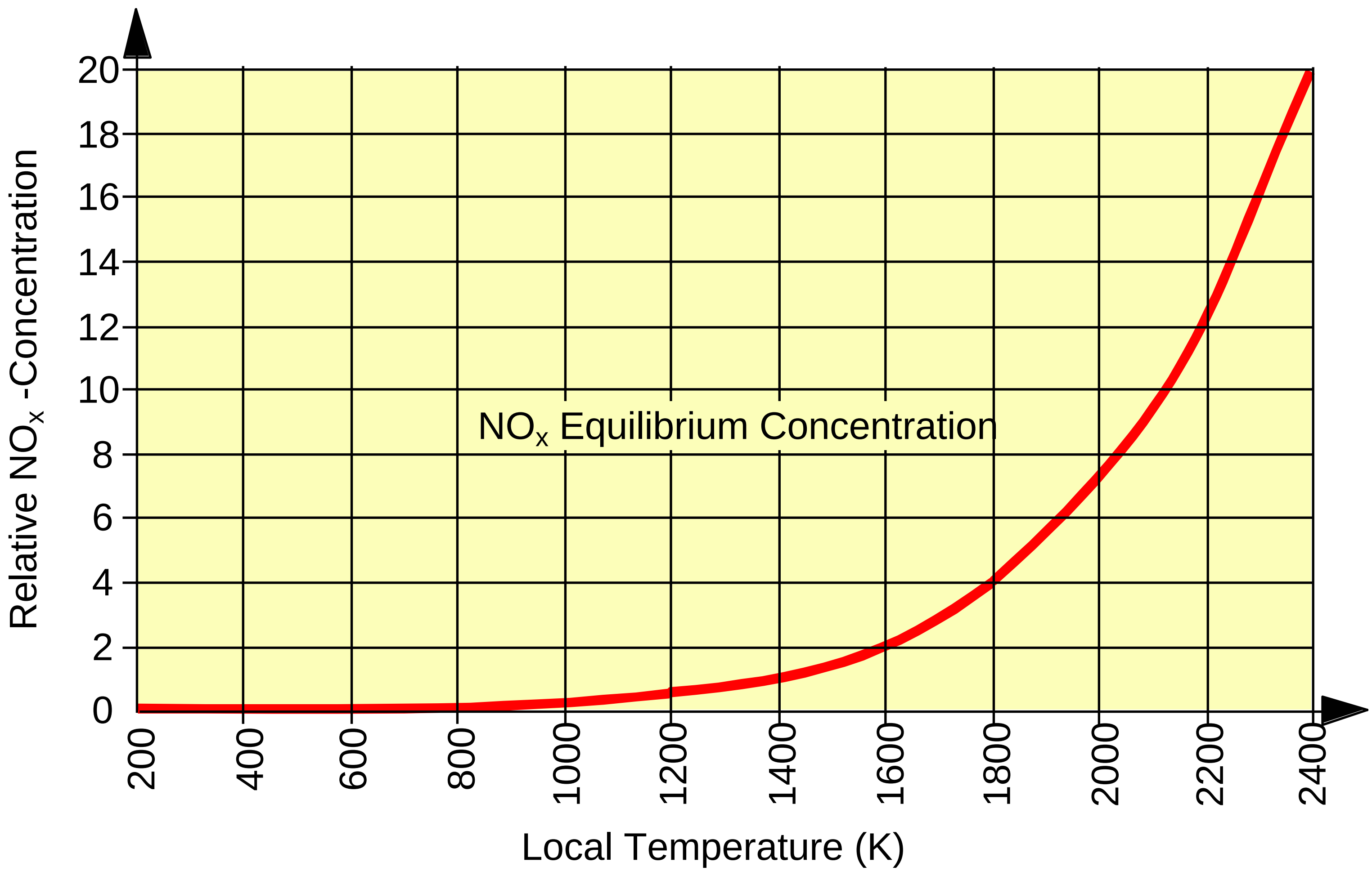
# Thermal $NO_x$ Formation

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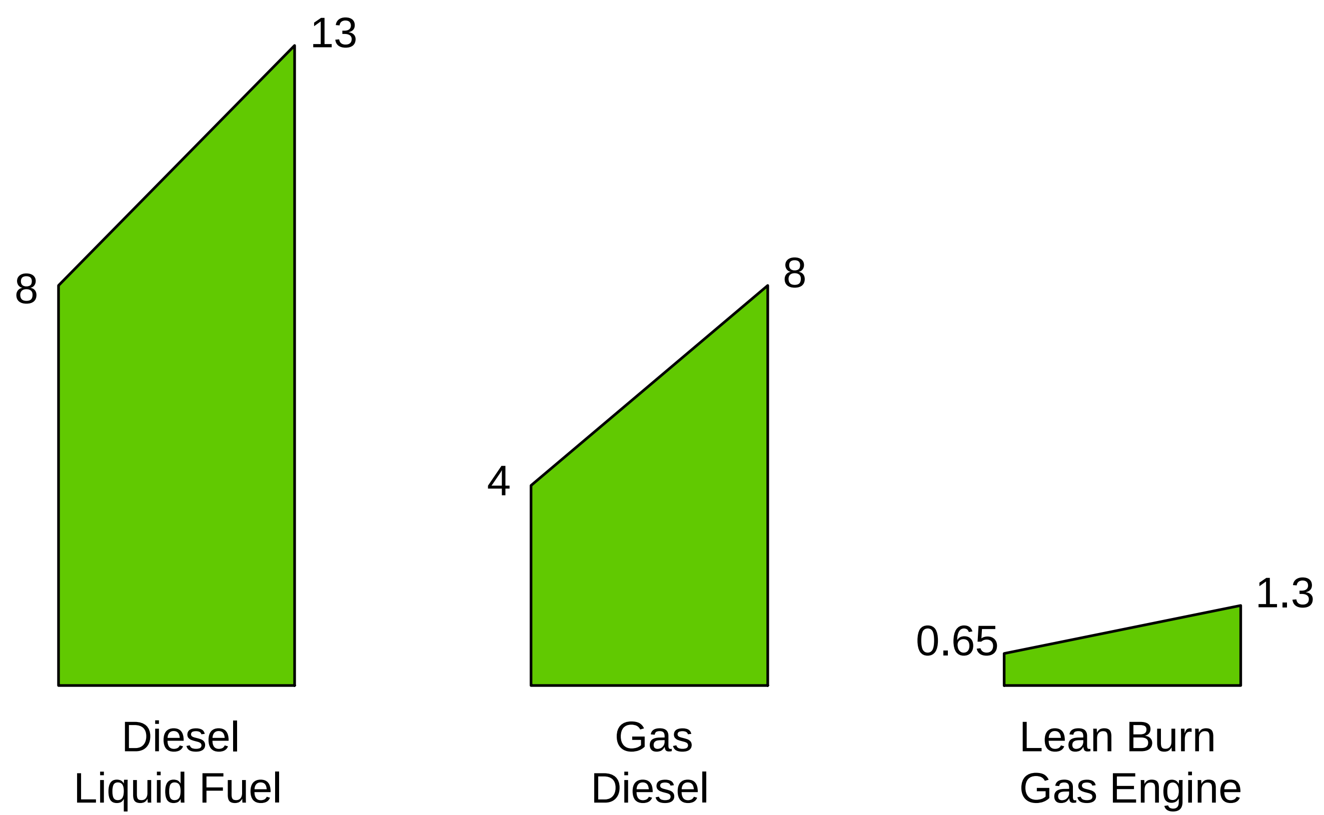
# Typical $NO_x$-Emissions for Different Types of Engines

Typical $NO_x$ Emissions in g/kWh:

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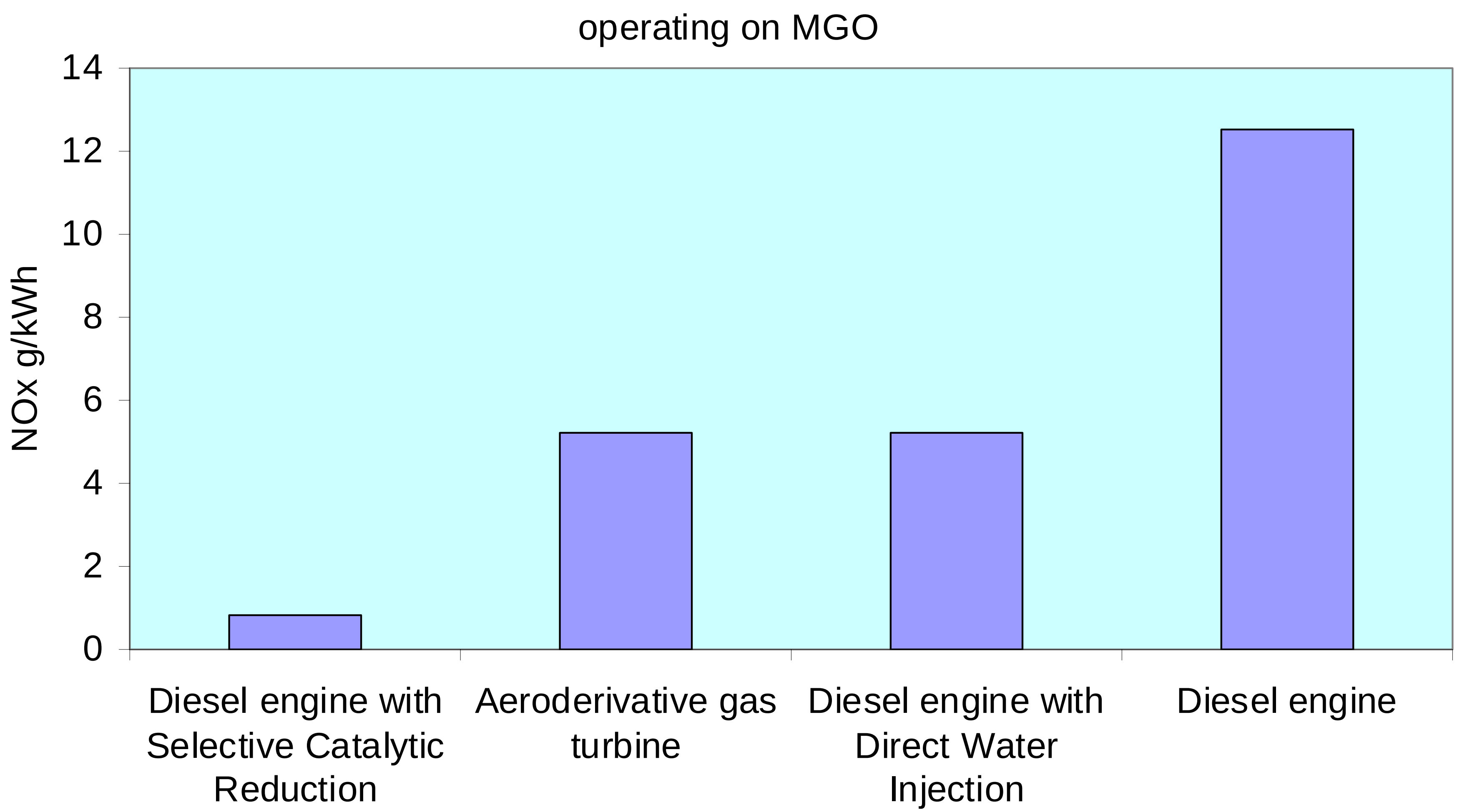
# NOx emissions of different prime movers

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# Emission reduction

**Technologies to reduce emissions:**

- Primary Methods - During Combustion
- Secondary Methods - After Combustion

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# Primary $NO_x$ control - diesel engines

## Available today - Combustion Modification

- Emission rating
  - – Adjustment of fuel injection timing/TC specification
  - – $NO_x$ reduction potential: 10 - 20 %
  - – Simple and cheap
  - – Increased fuel consumption and thermal load
- Low $NO_x$ combustion
  - – Rearranged diesel cycle
  - – $NO_x$ reduction typically: 25 - 35 %
  - – $NO_x$ well below the IMO limit
  - – Unchanged or improved fuel consumption

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# Primary $NO_x$ control - diesel engines

## Available today - Water Injection

- Water-in-fuel emulsions
  - Humidification of the combustion process
  - $NO_x$ reduction potential typically: 20 %
  - Limitations
    - emulsion stability
    - fuel injection system capacity
    - poor engine performance in “non-water” operational mode
    - cavitation risk in injection system

- Direct water injection
  - Humidification of the combustion process
  - $NO_x$ reduction typically: 50 - 60 %
  - Improved thermal load and engine cleanliness

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# Low $NO_X$ Combustion Engine Design

- Rearranged diesel cycle
  - – Very late fuel injection start
  - – Higher compression ratio
  - – Early inlet valve closing (4-stroke)
  - – Late exhaust closing (2-stroke)
  - – Optimized combustion chamber
  - – Optimized fuel injection pressure
- Results
  - – Lower combustion temperatures
  - – Shorter duration at high temperatures
- Conclusions
  - – $NO_X$ reduction typically 25-35%
  - – Unaffected fuel consumption

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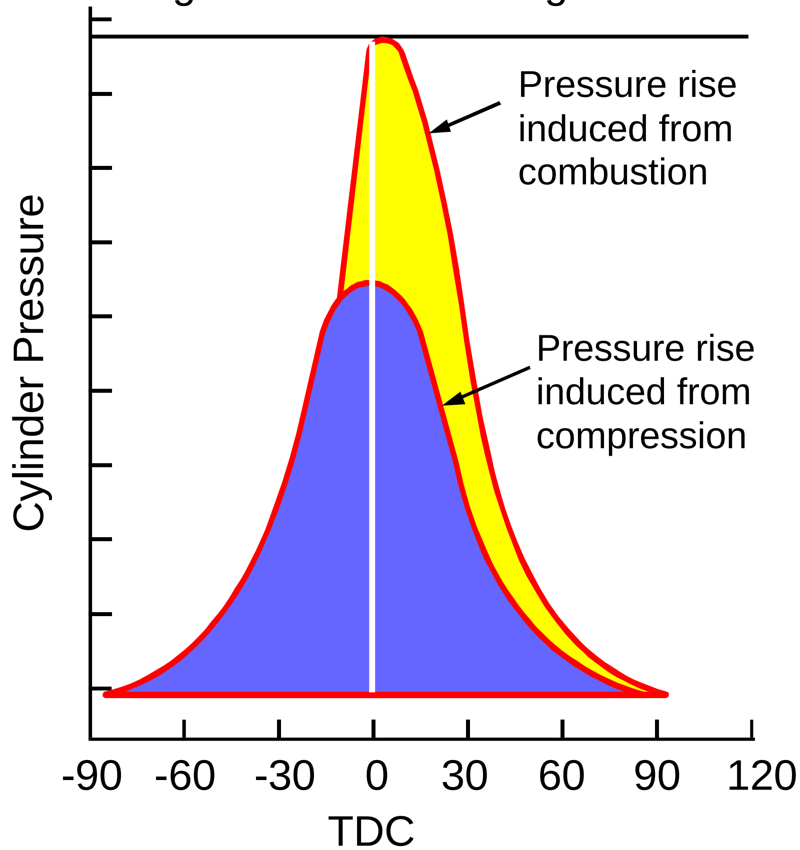
# Low $NO_x$ Combustion

Application: All Fuel Types

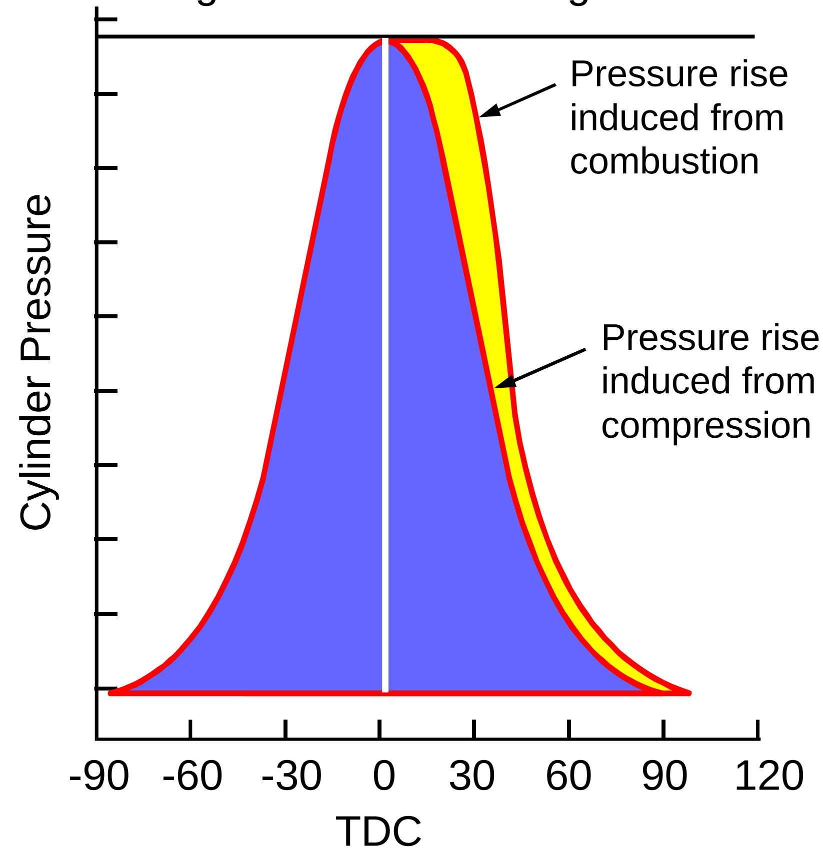
## Conventional Design

Engine Maximum Firing Pressure




## Low $NO_x$ Design

Engine Maximum Firing Pressure

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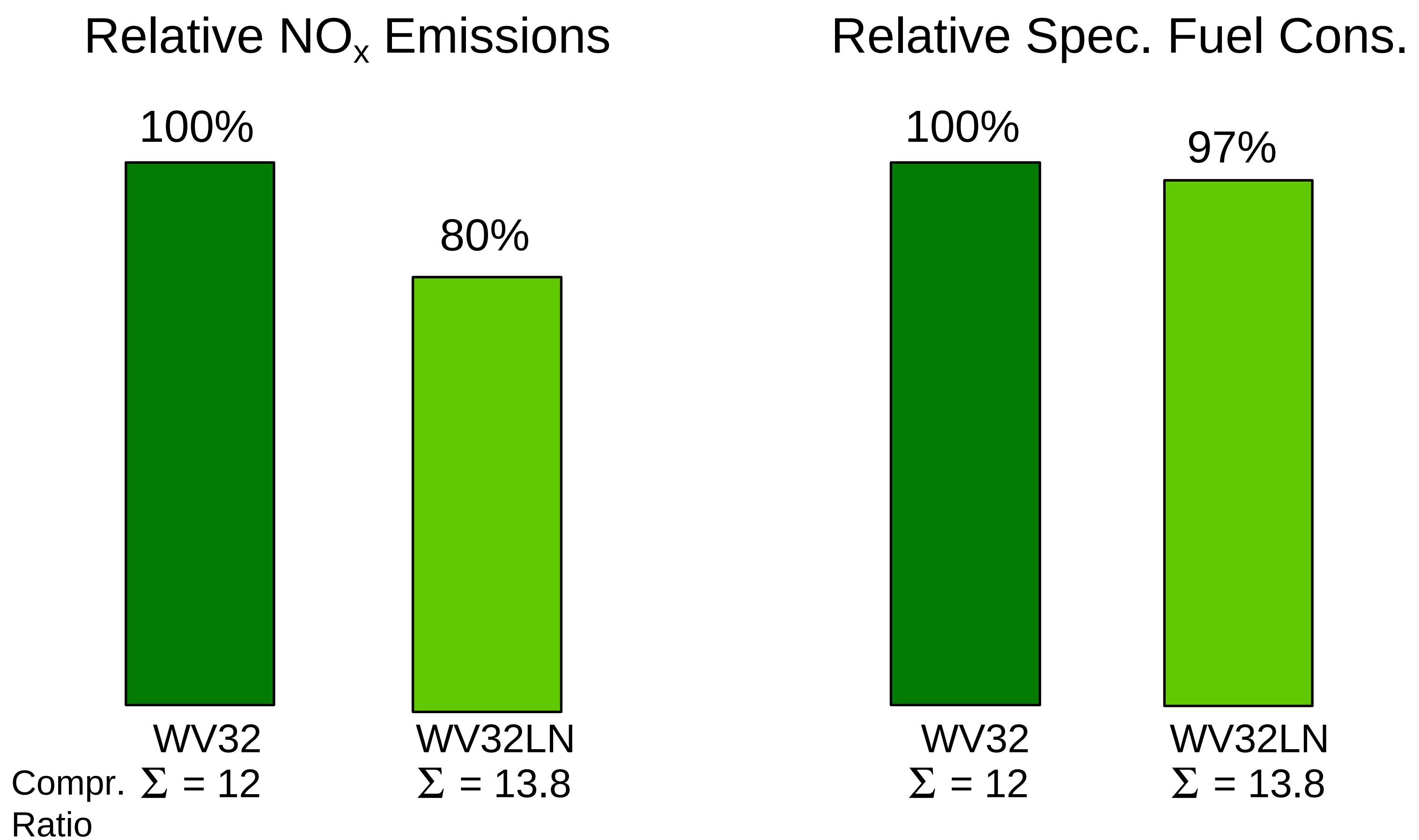
# Implementation of Low $NO_x$ Combustion on Wärtsilä Vasa 32b

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# Features of fuel-water emulsions

**Disadvantages**

- **Increased camshaft torque and cam load.**
- **Full load of engine not possible at high water ratios due to limitations in the fuel injection equipment.**
- **Same nozzles not optimal for operation with and without emulsion.**
- **Negative impact on injection equipment reliability and lifetime.**
- **Increased fuel viscosity, higher preheating temperatures needed.**

**Advantages**

- **Improved low load smoke.**
- **Lower NOx. The NOx limitation is limited to about 20%, because unlimited water amounts cannot be kept in a stable emulsion.**

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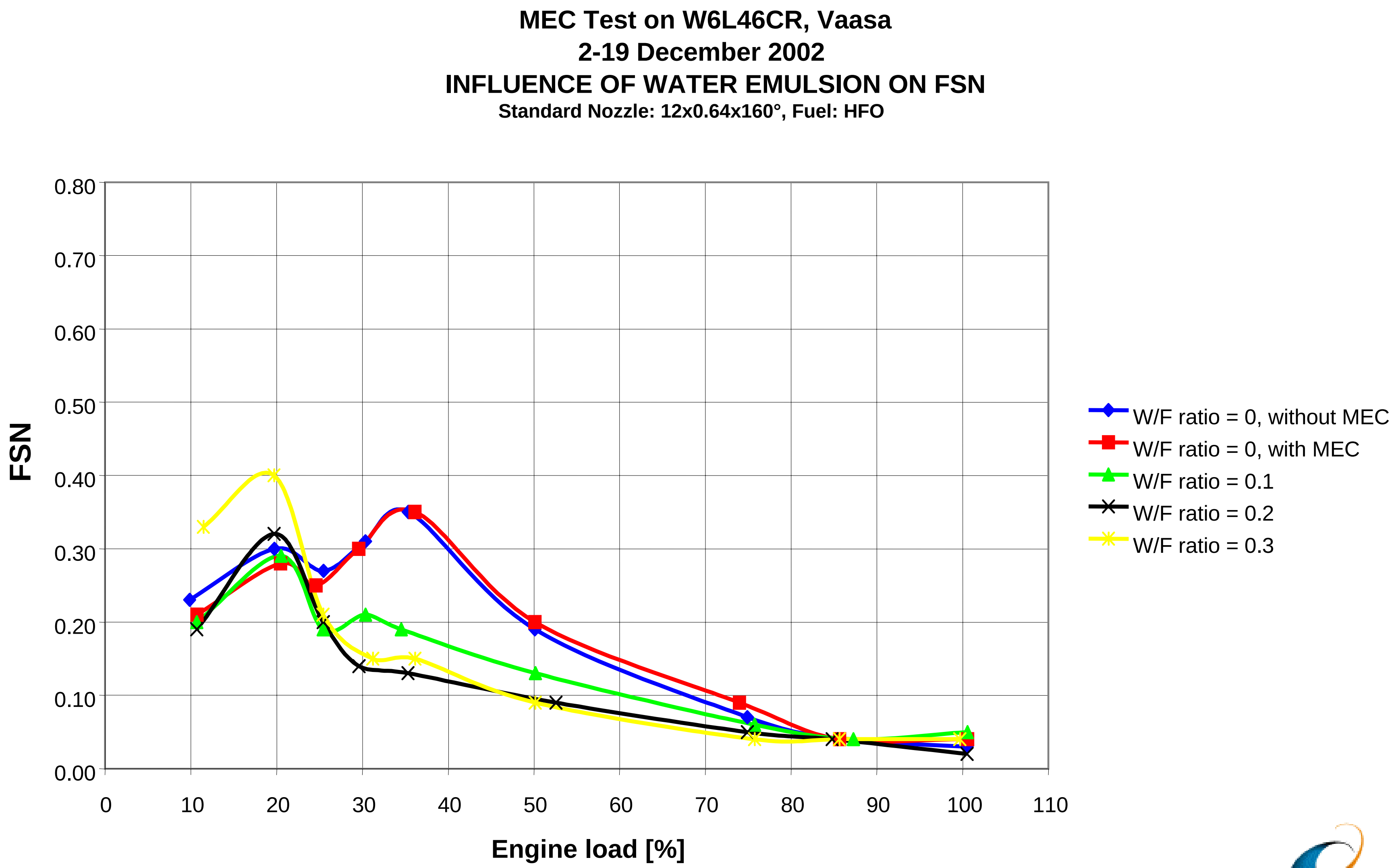
# FSN

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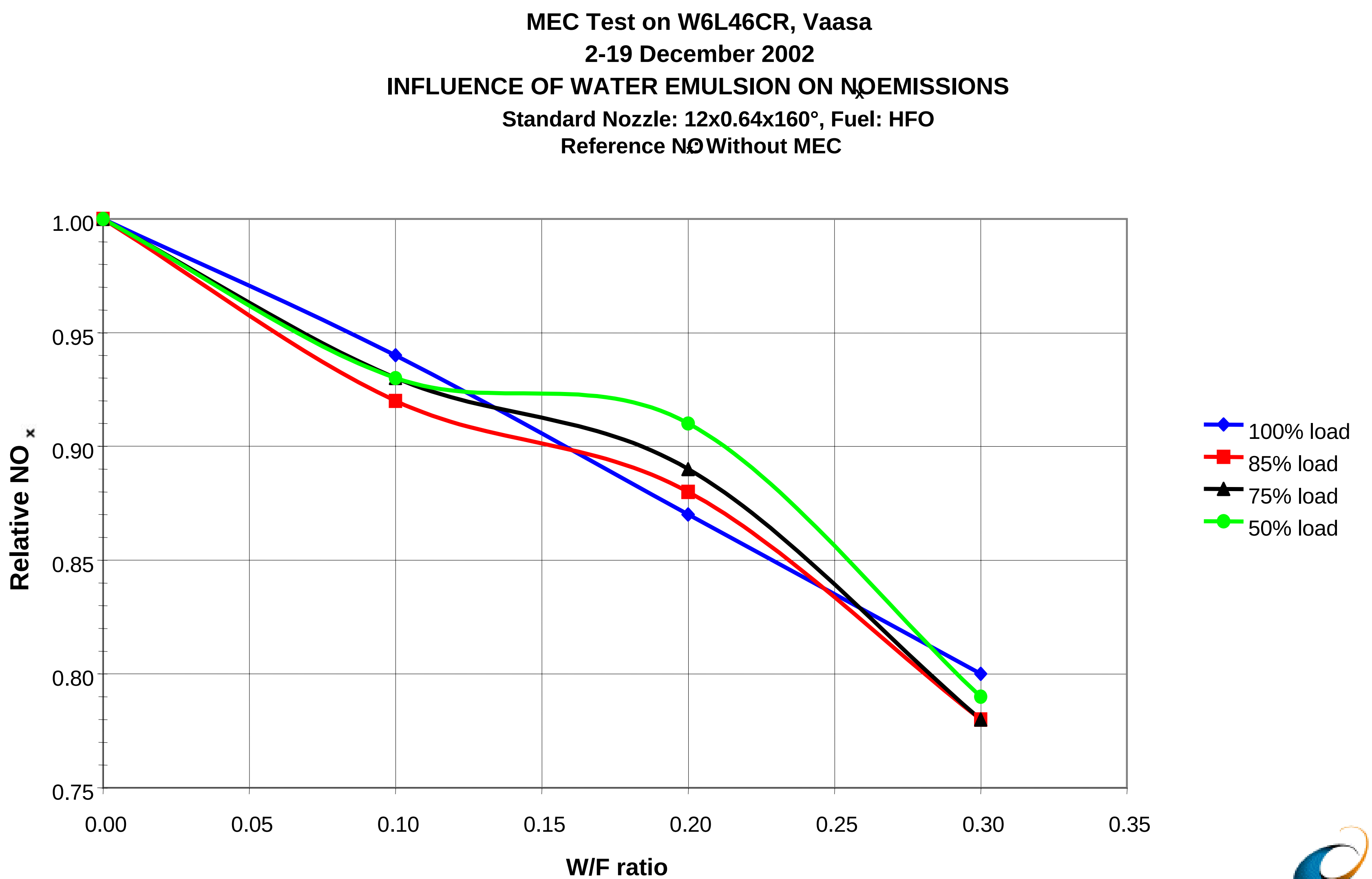
# $NO_x$ emissions

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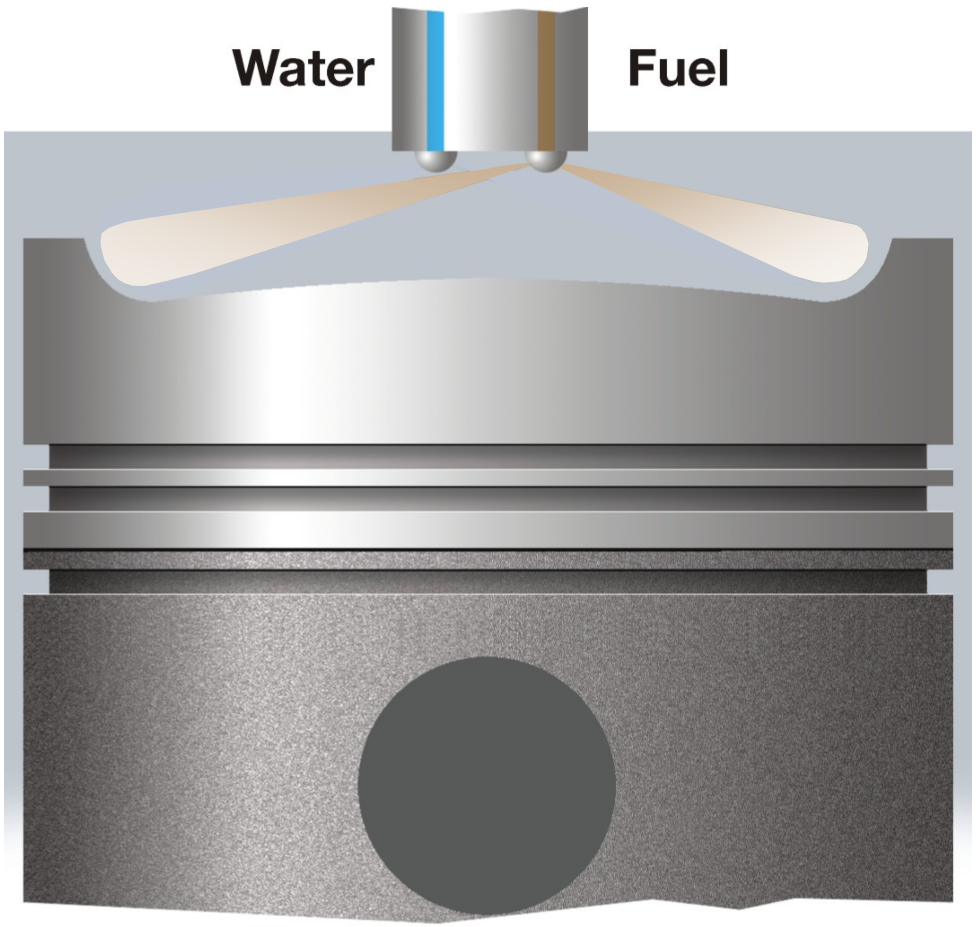
# The principle of Direct Water Injection




- Water needle and fuel needle in the same injector

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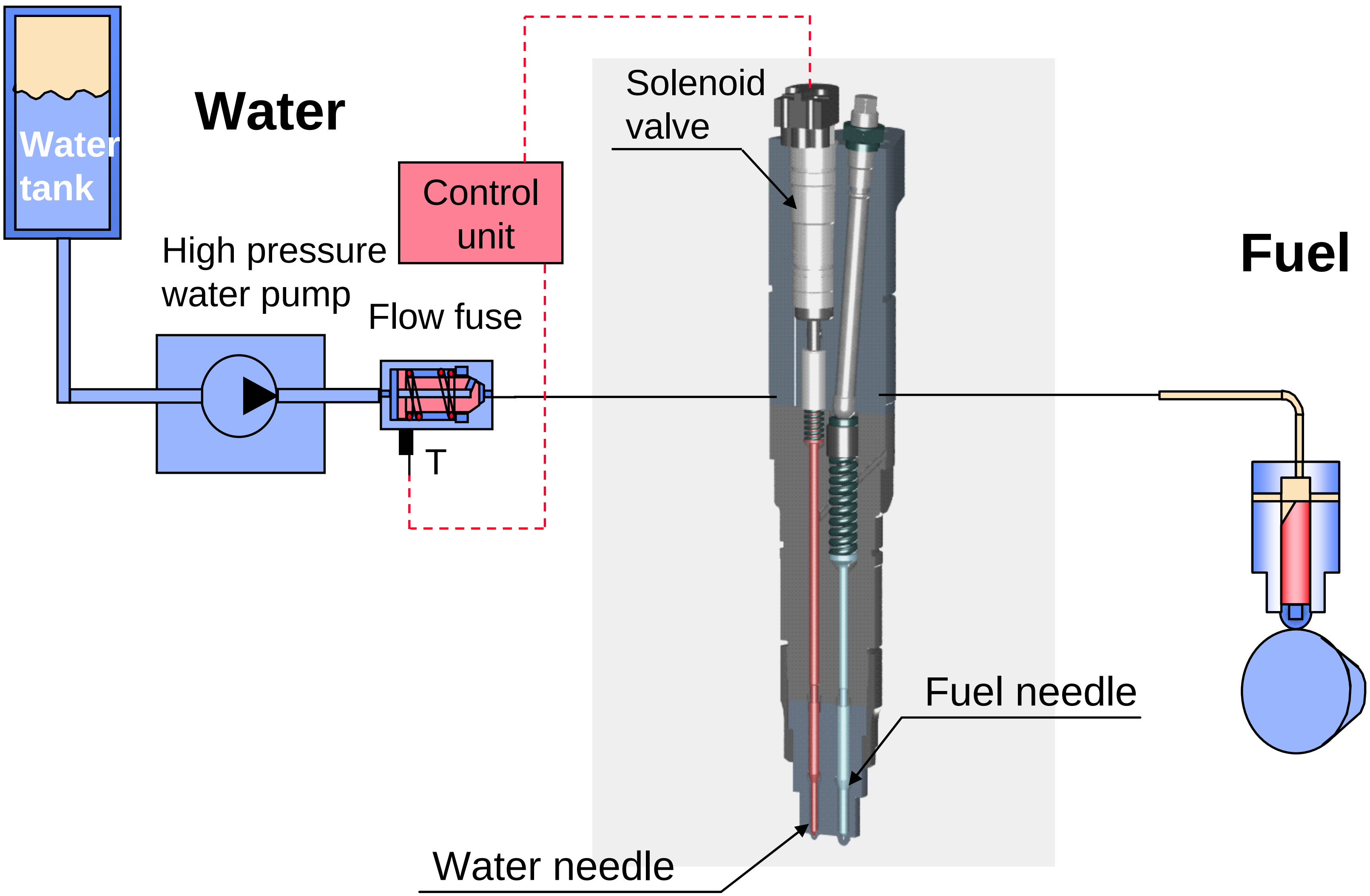
# Direct Water Injection

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