Particle Filter Quality under Real World Conditions: DPF Quality in Off-Road Diesel Engines

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Content

- **Requirements on exhaust aftertreatment systems for off-highway applications**
  - Legislative requirements
  - Market and in use requirements
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  - Retrofit-DPF for Stage I, II & IIIA Engines
  - DPF Solution for Stage IIIB / Tier4i Engines
  - SCRFilter Solution for Stage V

Legislative requirements

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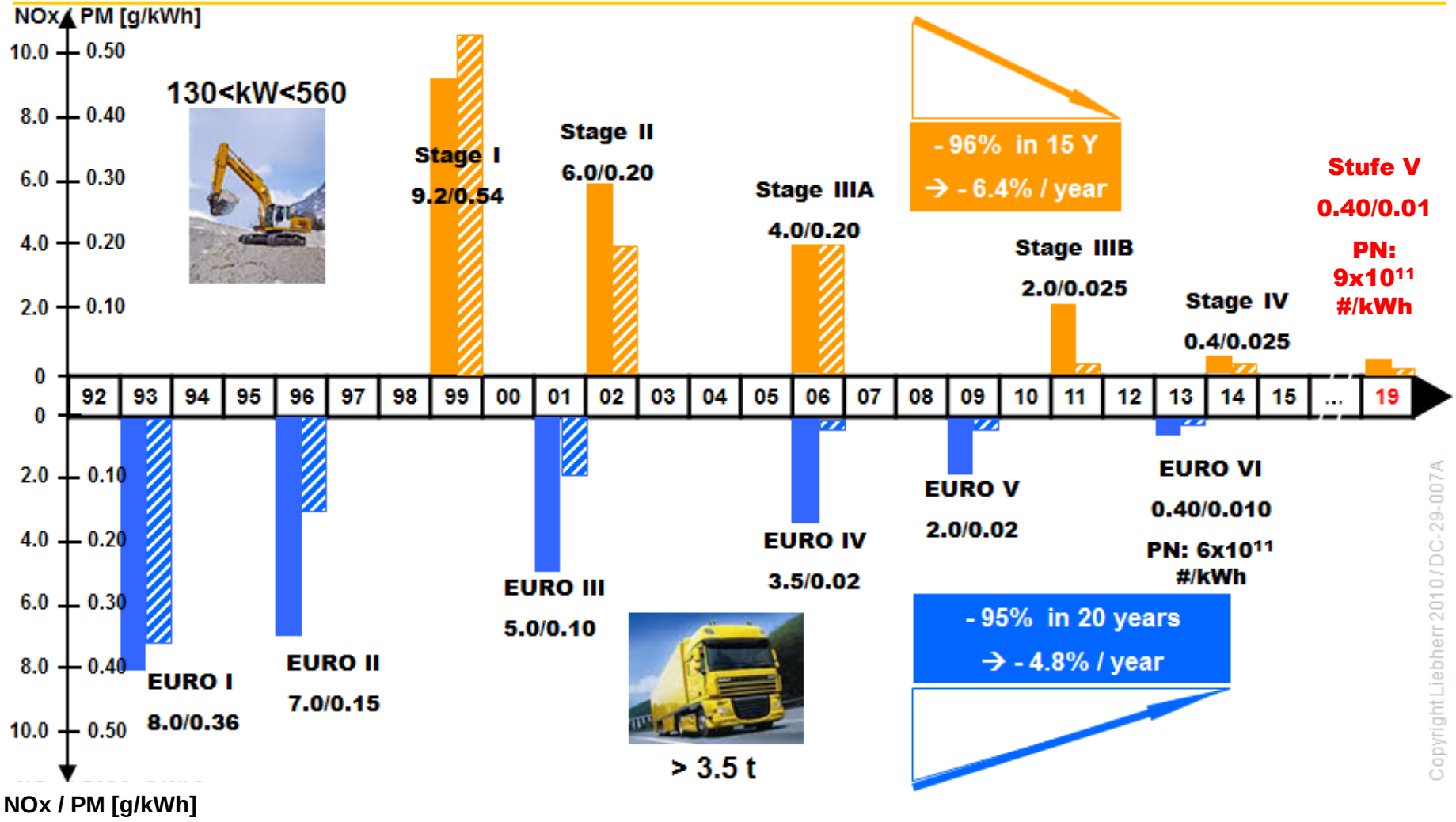
Chronology of exhaust legislation: on- vs. off-highway



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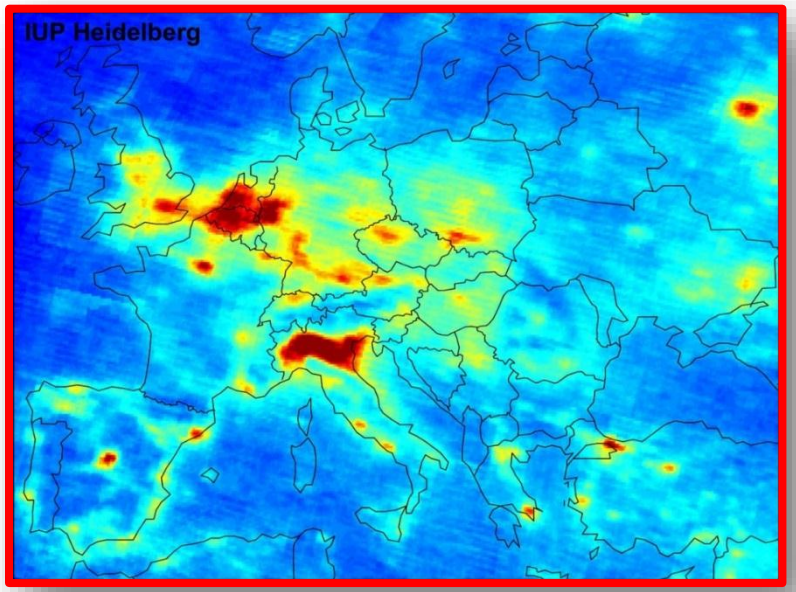
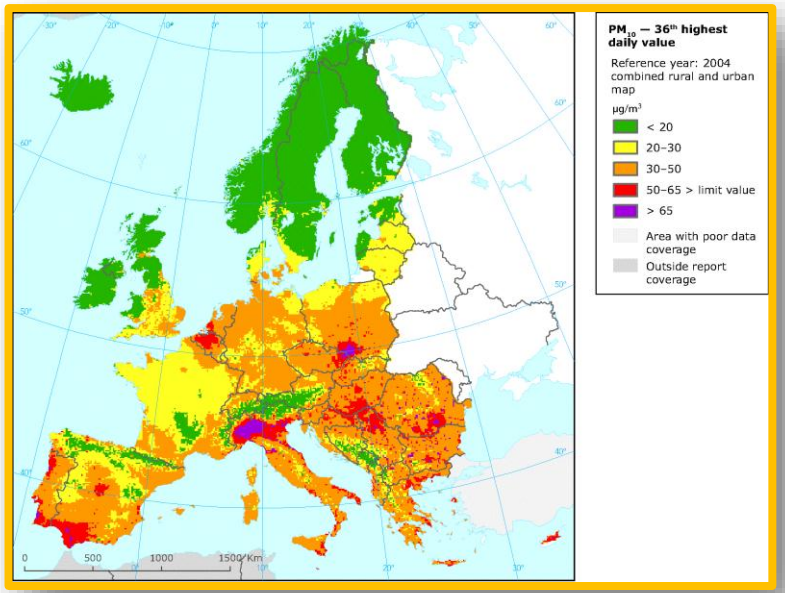
Local Emission - Directive 2008/50/EC

Relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air

- Requires that action plans be developed for zones within which concentrations of pollutants in ambient air exceed limit values
- LEZ (Low Emissions Zone)





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97/68/EC «Engine Emissions durability periods»

2. EMISSION DURABILITY PERIODS FOR STAGE IIIA, IIIB AND IV ENGINES.

2.1. Manufacturers shall use the EDP in Table 1 of this section.

Table 1: EDP categories for CI Stage IIIA, IIIB and IV Engines (hours)

Category (power band)	Useful life (hours) (PDE)
≤ 37 kW (constant speed engines)	3 000
≤ 37 kW (not constant speed engines)	5 000
> 37 kW	8 000
Engines for the use in inland waterway vessels	10 000
Railcar engines	10 000

- **Emission compliance: 8’000 hours**
- **Liebherr durability target: 15’000 hours (B10)**

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US-CFR 40, §1039-125: Emission-related maintenance

- **For engines below 130 kW:**

  For the following components, including associated sensors and actuators, **the minimum interval is 3000 hours**: fuel injectors, turbochargers, **catalytic converters**, electronic control units, **particulate traps, trap oxidizers, components related to particulate traps and trap oxidizers**, EGR systems (including related components, but excluding filters and coolers), and other add-on components. **For particulate traps, trap oxidizers, and components related to either of these, maintenance is limited to cleaning and repair only.**

- **For engines at or above 130 kW:**

  For the following components, including associated sensors and actuators, **the minimum interval is 4500 hours**: fuel injectors, turbochargers, **catalytic converters**, electronic control units, **particulate traps, trap oxidizers, components related to particulate traps and trap oxidizers**, EGR systems (including related components, but excluding filters and coolers), and other add-on components. **For particulate traps, trap oxidizers, and components related to either of these, maintenance is limited to cleaning and repair only.**

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Market and in use requirements

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Applications with Liebherr diesel engines


Crawler excavators 20-100 t


Crawler tractors 12-60 t


Duty cycle excavators


Wheeled excavators 20-200t


Mobile construction cranes


Harbour mobile cranes


Mining excavators 100-150 t


Pipelaying machines


Mobile cranes <1200t


Crawler cranes <3000t


Reachstackers


Wheel loaders


Articulated Trucks


Material handling excavators


Ship & offshore cranes


Snow blower


Pipe Bending Machine


Shredder


Special vehicles


Agriculture


Generator set

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Same emission target, different conditions

Water

Dust

Inclined position

Heat

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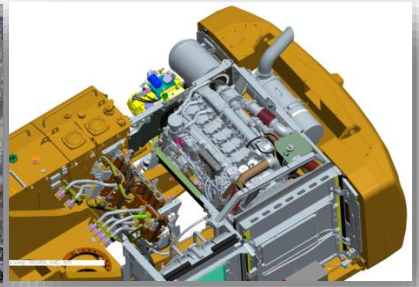
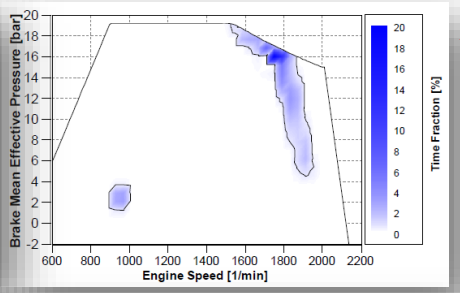
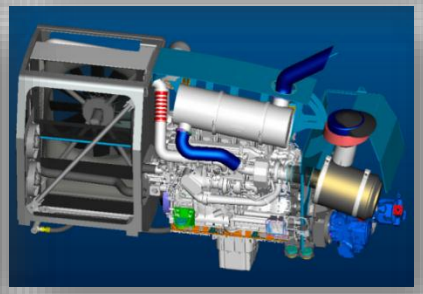
Diversity of variants: machine-specific application

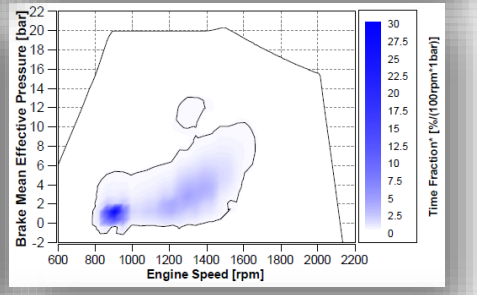
Base engine → Application → EAT integration → Duty cycle

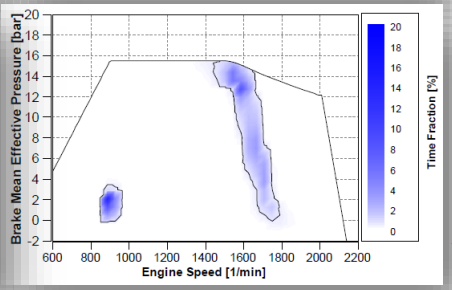
D936 A7 DPF
230 kW @ 2000 min-1











Goal: Common DPF regeneration strategy

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Retrofit-DPF for Stage I, II & IIIA Engines

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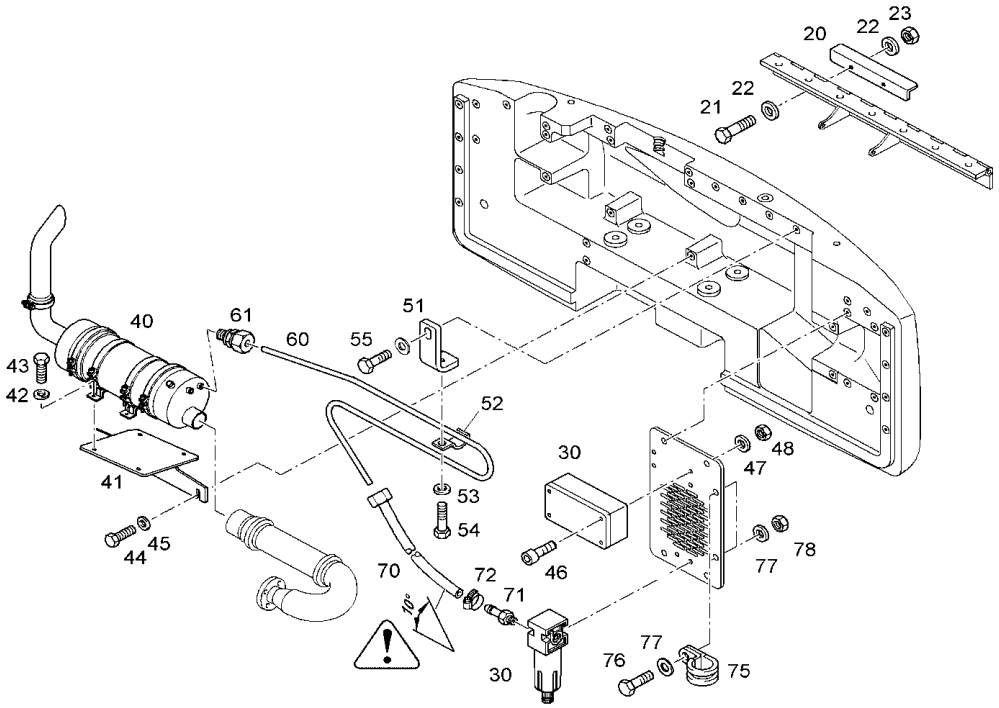
DPF kit – options for construction machinery

PFS assembly kit for hydraulic excavator A/R 900 C Li (Stage II Liebherr diesel engine)



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Field experience: operation and service life

Filter cleaning

- In a workshop
- Every 1,000 to 2,000 operation hours

Lifetime

- 6,000 to 8,000 operating hours – provided regular maintenance

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DPF Solution for Stage IIIB / Tier4i Engines

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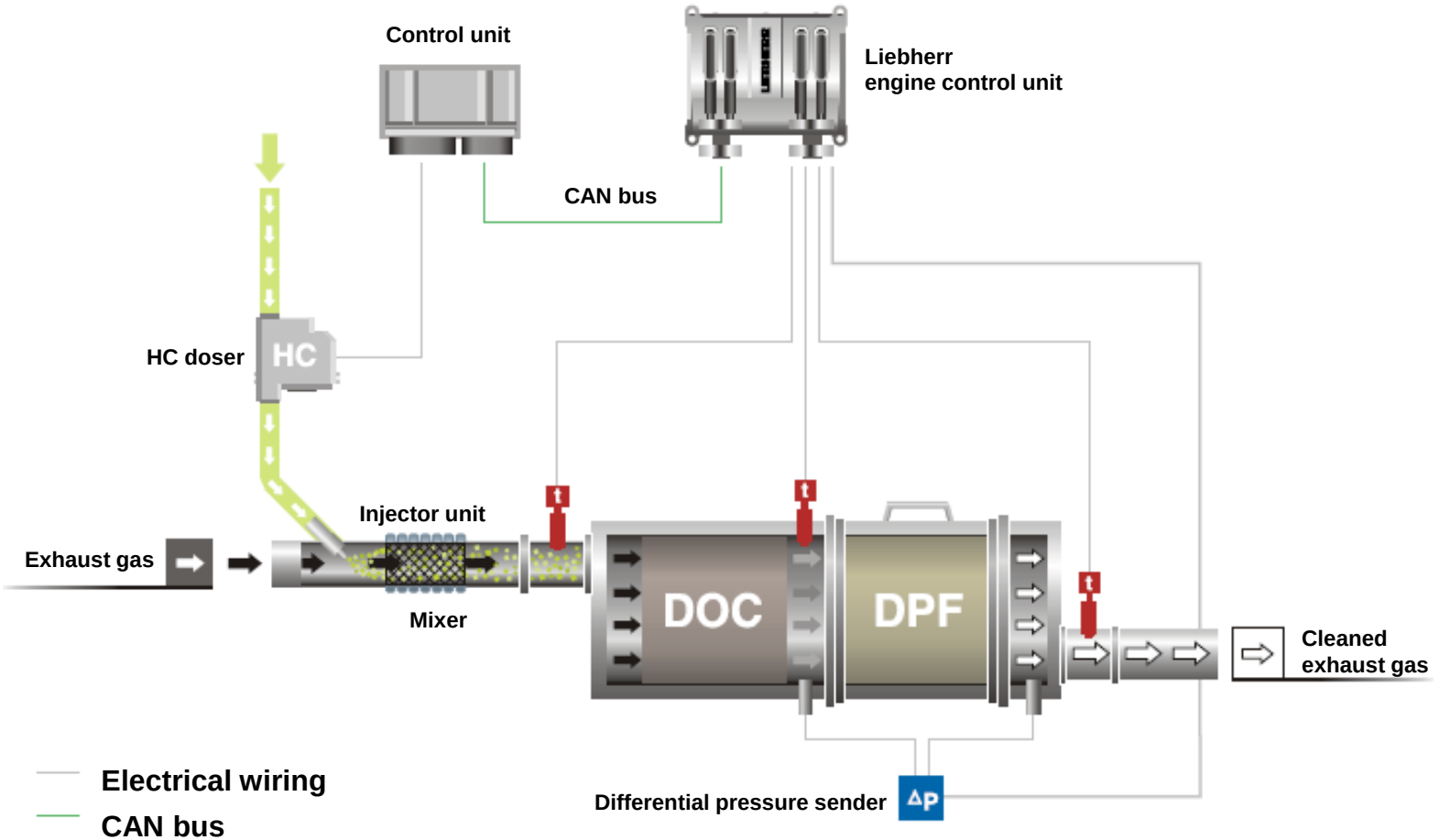
EGR / DPF system for stage IIIB / Tier 4i



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Ashes accumulation

L = 13“ = 330mm
D =12“ = 305 mm
A = 7,3 dm²
ash load = 929g

V= 24,1l
OFA= 34,5 %

eff. V = 8,3145l

„clean lenght“ = 175mm

„clean“ Volume = 4,06
Volume ash = 3,91

ash density = 238 g/l

Ash filing rate: 47%

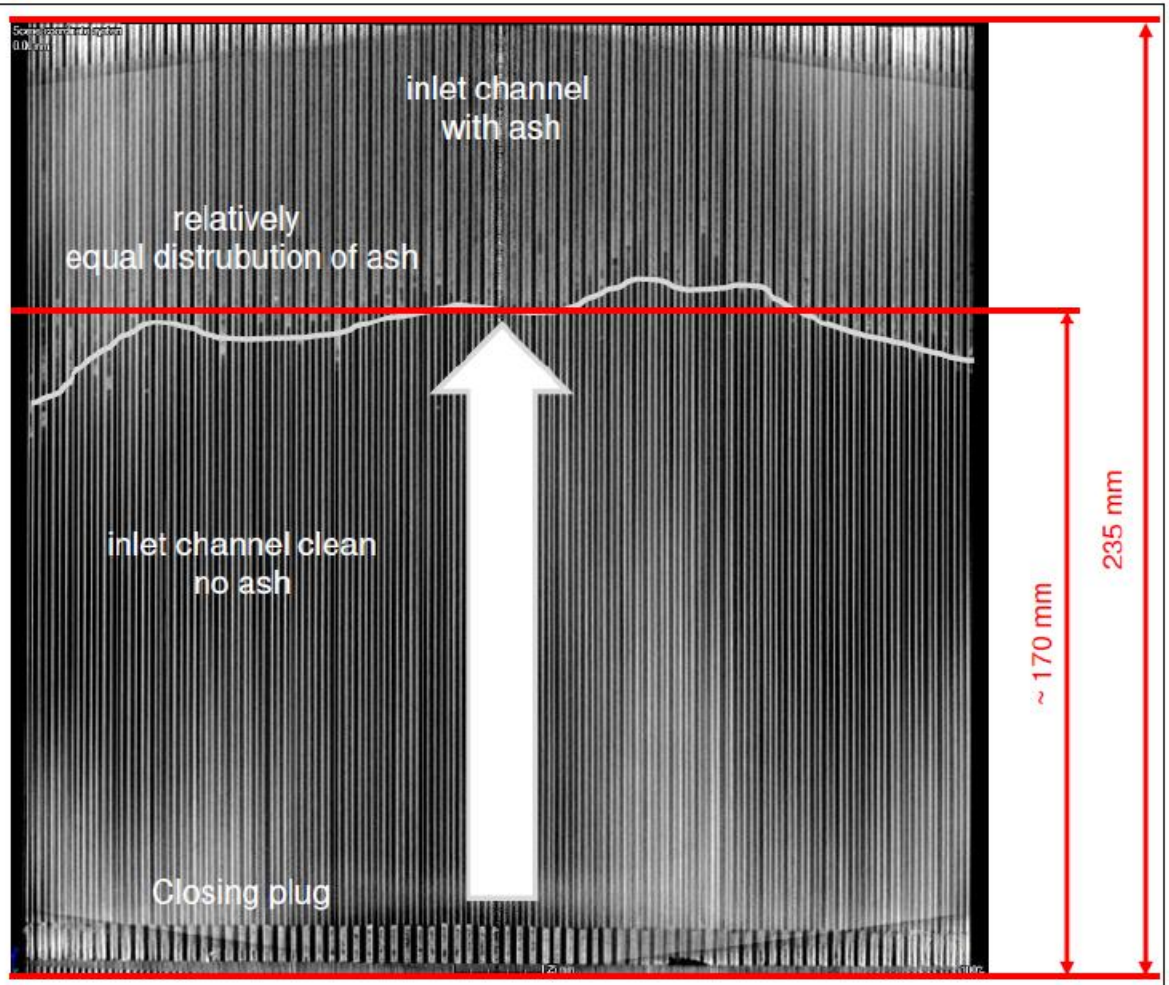

Figure 7-2 CT Analysis at 4500h

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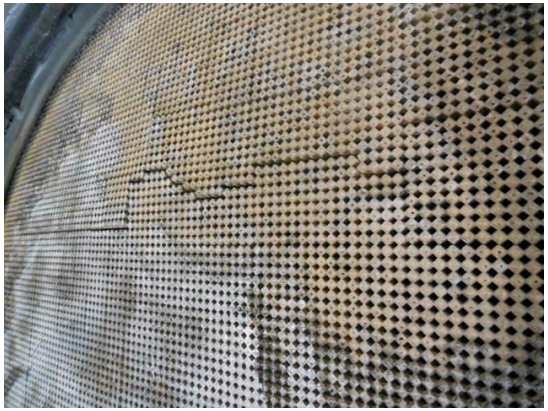
DPF cracks due to too high temperature

INLET Face

OUTLET Face

OUTLET Face cracks



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Field Experience with Stage IIIB DPF

- **5’386 4 and 6 cylinder engines**
- **~ 30% of the machines with more than 8’000 Bh**

- **Failure rate:**
  - DPF: 0.1 %
  - HC Doser: 0.4 %

- **DPF cleaning interval : 4’500 Bh ~ 6’000 Bh**

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SCRFilter Solution for Stage V

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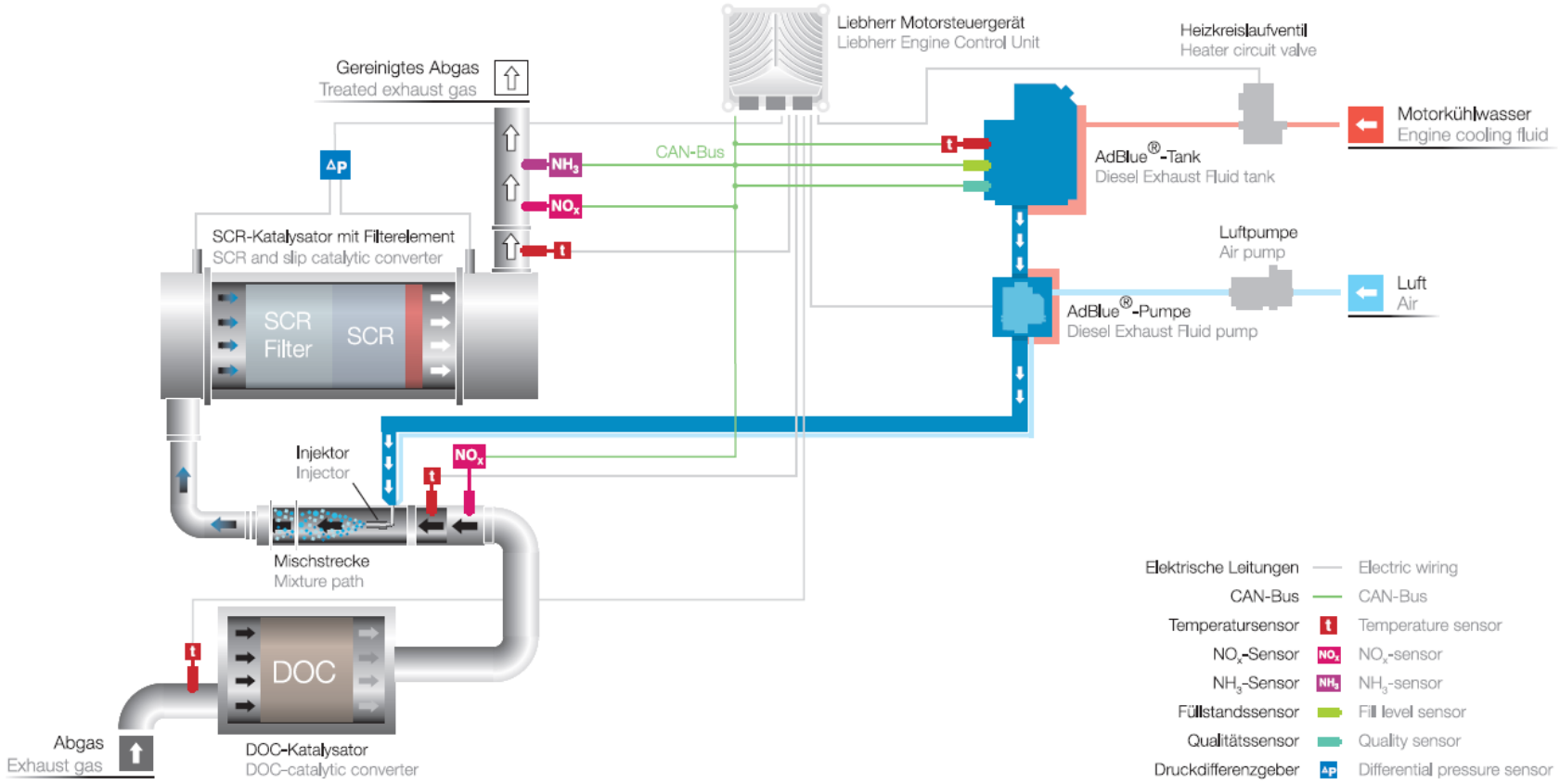
SCRFilter system



SCRFilter

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System Performance

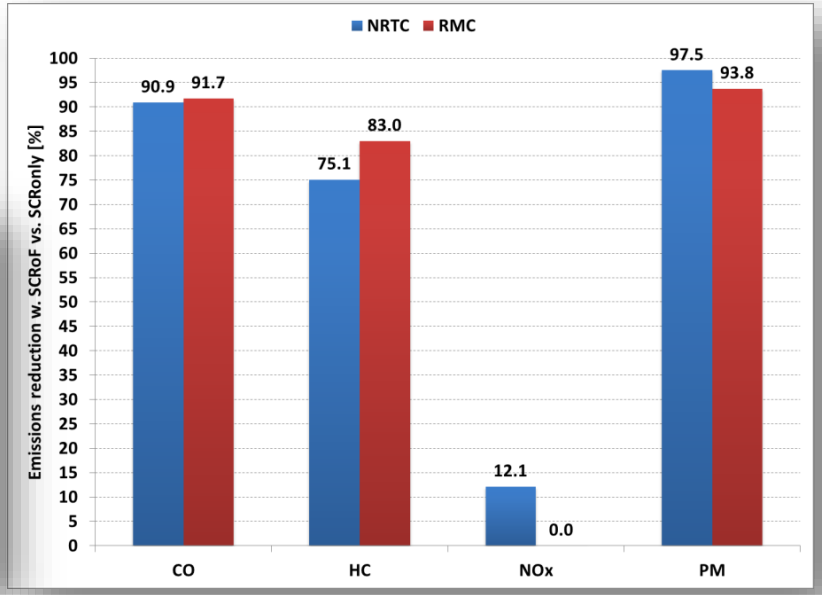
SCR only - Tier4F

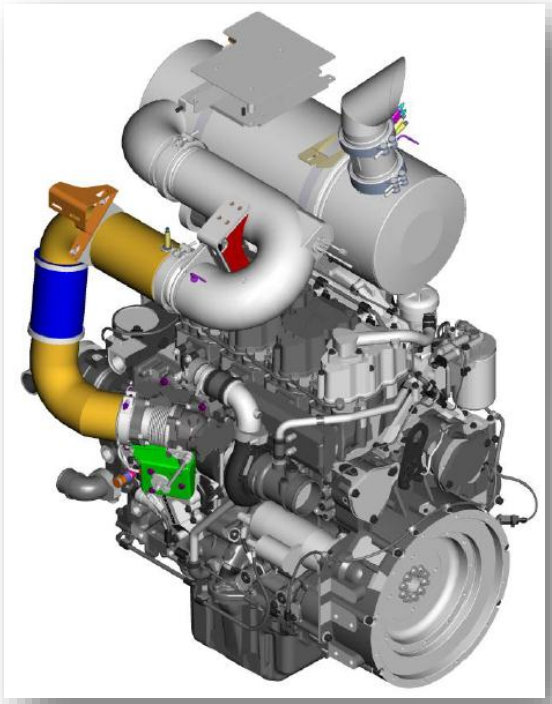
		CO	HC	NOx	PM
		g/kWh	g/kWh	g/kWh	g/kWh
230kW	NRTC	0.4899	0.0225	0.3376	0.02
	RMC	0.1778	0.0106	0.3182	0.0128
200kW	NRTC	0.4338	0.0213	0.3275	0.0172
	RMC	0.1639	0.0089	0.3338	0.0066

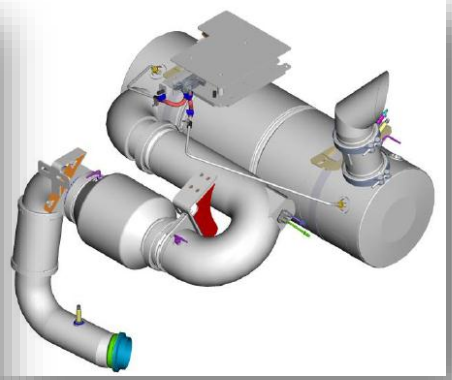
SCRFilter - Tier4F + LRV

CO	HC	NOx	PM	PN
g/kWh	g/kWh	g/kWh	g/kWh	#/kWh
0.0445	0.0056	0.2967	0.0005	6.97E+10
0.0147	0.0018	0.3197	0.0008	1.87E+11
0.0513	0.0058	0.2774	0.0007	5.04E+10
0.0144	0.0017	0.2016	0.0006	9.03E+11

SCRFilter vs. SCR only







Compared to the SCRonly,

- He SCRFilter is able to reduce the CO_2 of about 90%, the HC of about 75% and the PM of about 95%.
- The SCRFilter length is about 20% longer

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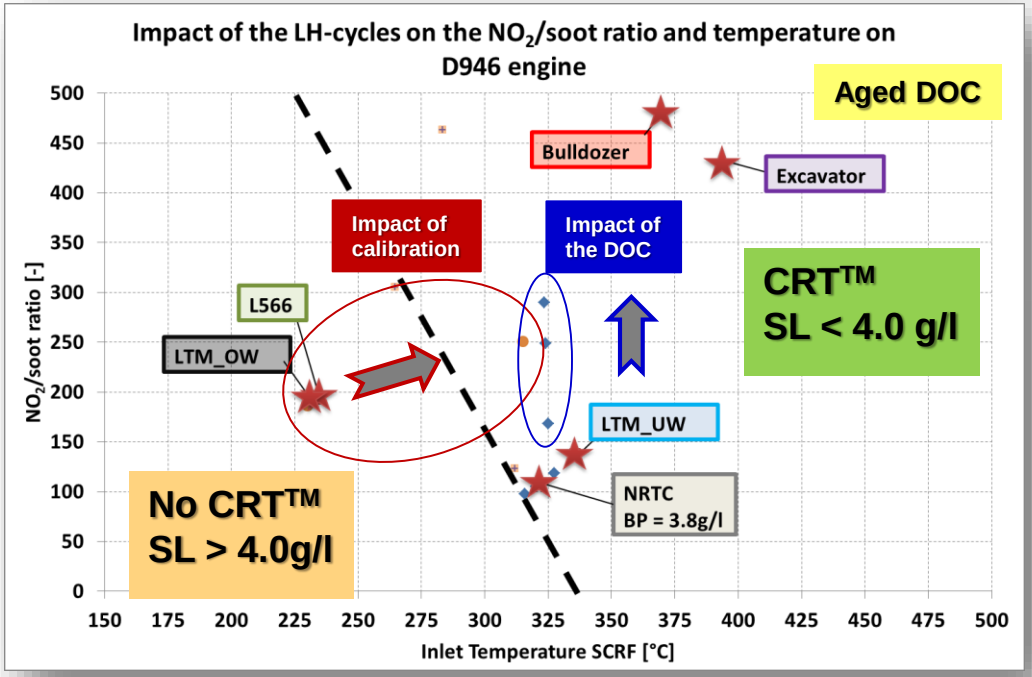
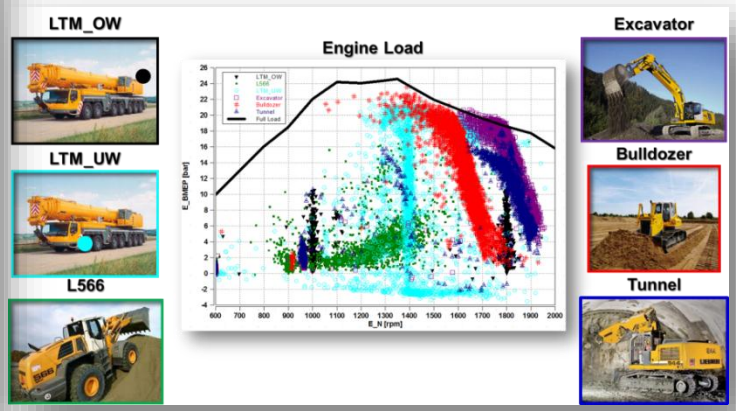
Passive regeneration





- Using the same calibration and the same Hardware, the NO_2/soot ratio depends on the application cycles
- Using the same calibration, and changing the DOC, it is possible to improve the NO_2/soot ratio (test done on NRTC cycle)
- It is possible to influence positively the NO_2/soot ratio with the engine calibration (test done on L566 cycle)

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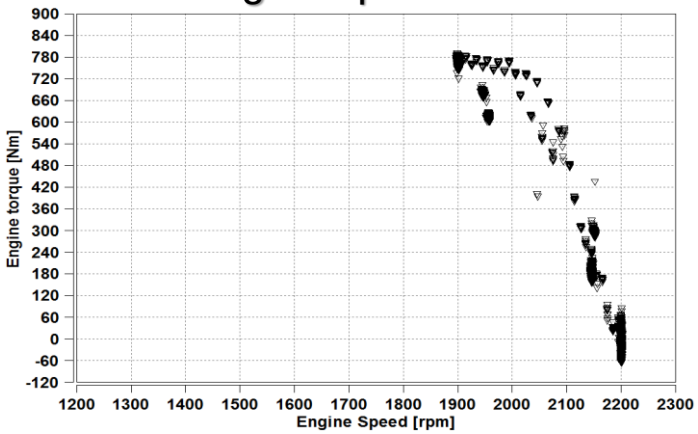
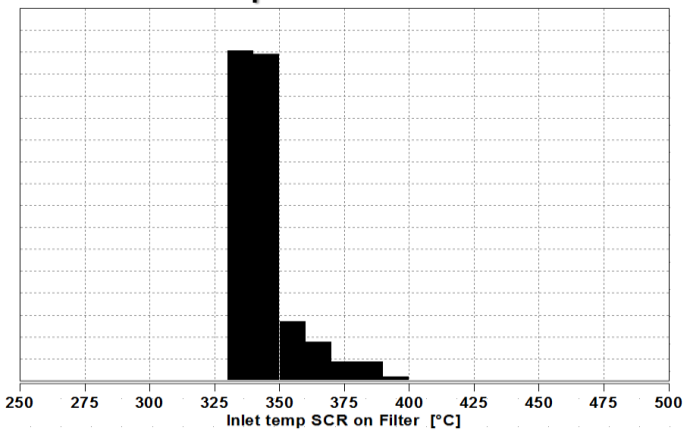
Durability (1/2)

Engine operation



Temp. SCRFilter



- The “Grenzlast” cycle was run during 4,000 hours
- During the endurance, all the performance of the EAS components were characterized 4 times
- The characterization @ 4,000 hours (M4000) is on going

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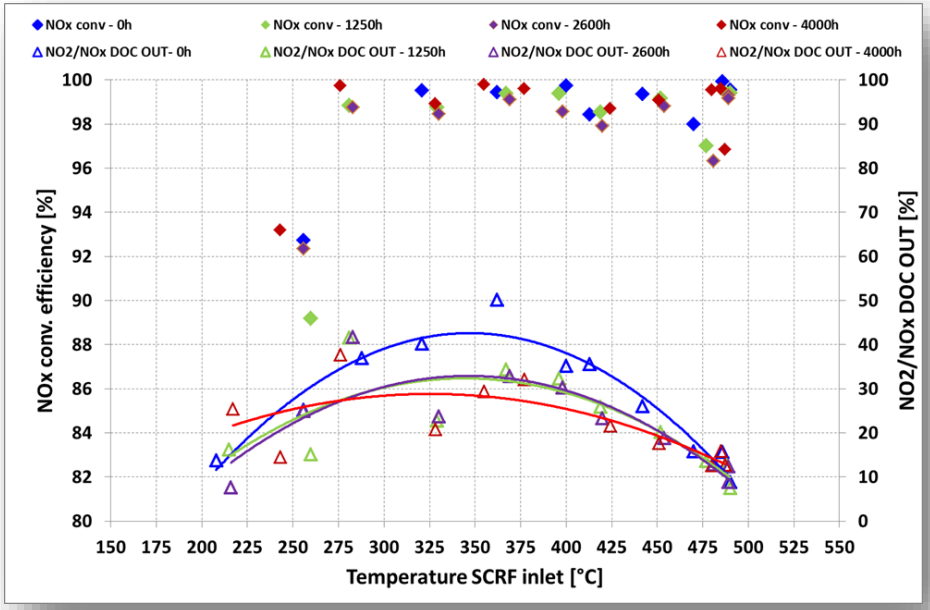
Durability (2/2)



- During the 4,000 hrs, the complete SCRFilter system was characterized on the P&E test bench
- The last check done @ 2600 hours showed no decrease on the NO_X conversion efficiency.
- A strong DOC aging impact was observed after the 1st check (1,250hrs) but after, the DOC performance was stable
- Limited impact of the ashes on the DeNOx was observed

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Field test

R950 Tunnel
2500hrs

L556
1500hrs

L586
3800hrs

PR746
500hrs

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In use monitoring up to 1025 (TBC)

Karsten Mathies
TÜV Hessen Automotive

PEMS beim TÜV Hessen,
Anforderungen für mobile Ma

TÜV Hessen PEMS Applikation

Tests mit System : AVL M.O.V.E. GAS PEMS 493 (PM PEMS 494)
System Control und Stromversorgung, Heavy-Duty-Cases
Abgasmassenstromsensor SEMTECH EFM 4"

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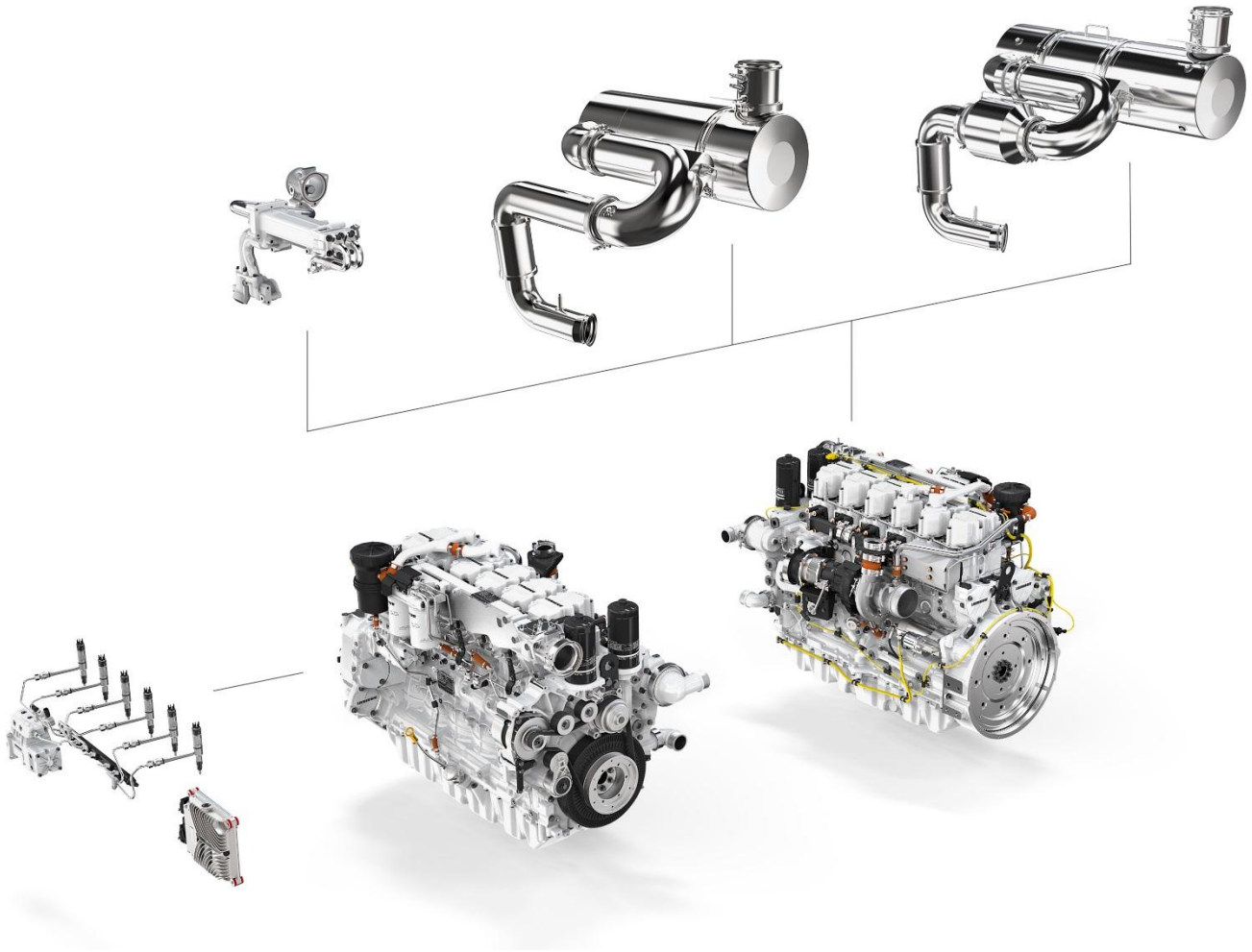
New generation of LIEBHERR Diesel Engines (P<560kW) → 1 single basis for 4 emission levels



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Thank you for your attention!

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