Physics of Particle Emission from Engines,

J. Czerwinski / AFHB

23th ETH-Conference on Combustion Generated Nanoparticles, Focus Event, June 20th, 2019

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- PM 10 vs. NP
- PM and PN from engines
- Nuclei mode
- Examples of PN emissions
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- What to do ? – exhaust gas filtration
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PM 10 Versus Nanoparticles

PM-10 Measurement EMPA

(Nabel Network)

WHAT IS FINE DUST?

PM_{10} **Particles with aerodynamic diameter of 10 µm and less.**
(PM = particulate matter)

Komplex mixture from natural and antropogenic sources:
- **primary, emitted,**
- **secondary, produced components.**

organic carbon, minerals, sulphates, nitrates, oxides, metals, HC & PAH.

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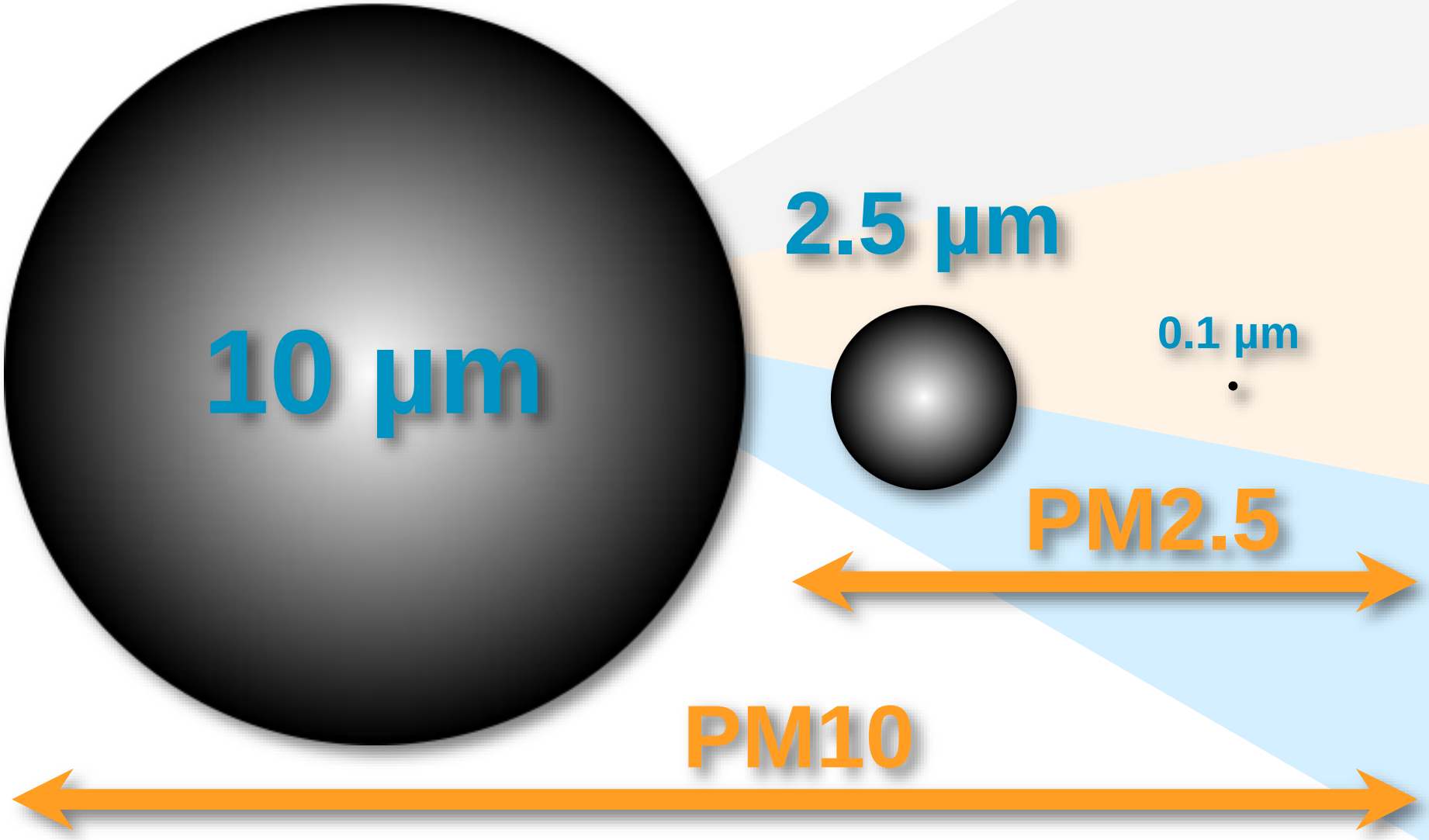
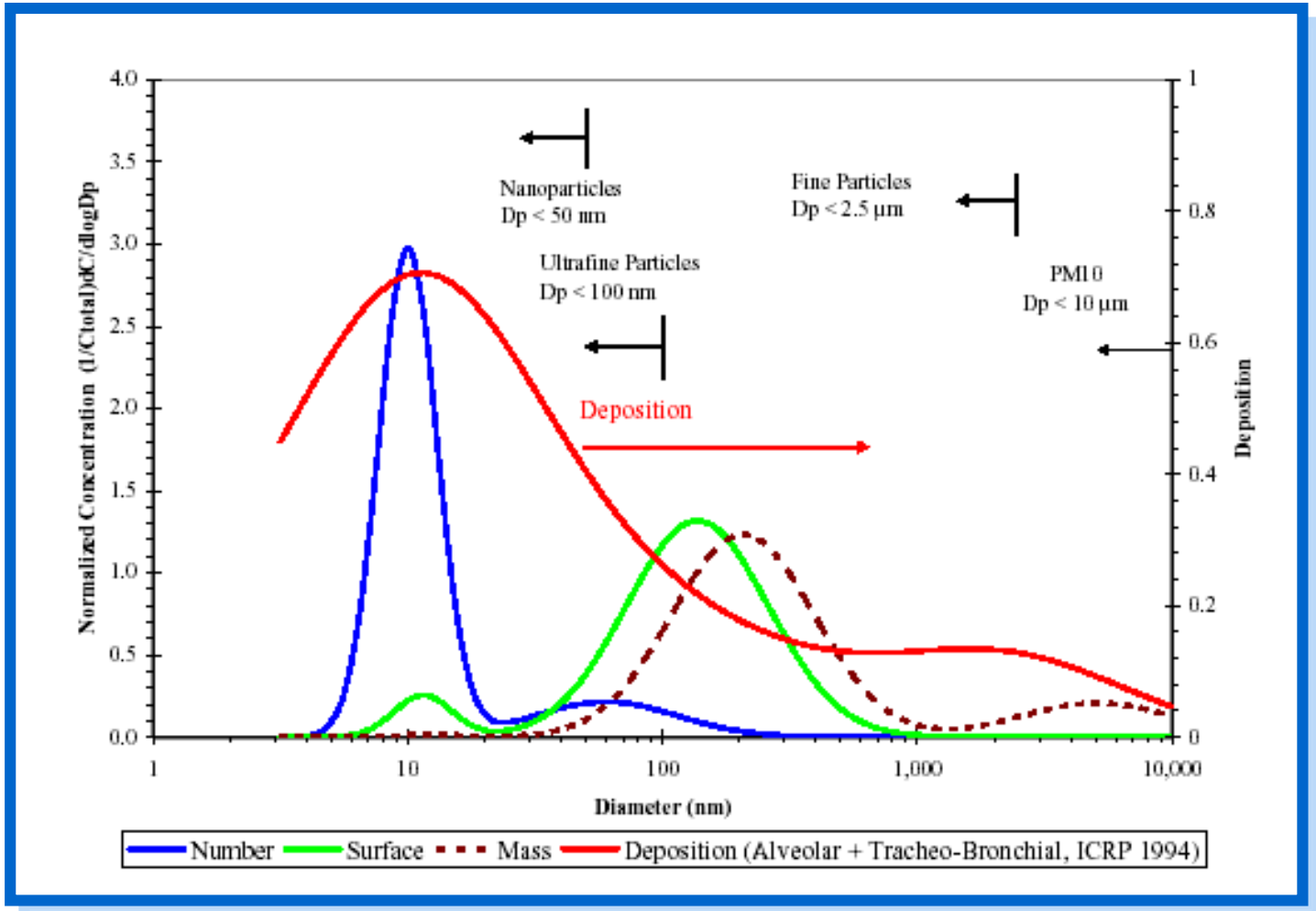
Particle Mass vs. Particle Number



Ultrafine particles are deposited on the deep lung regions more efficiently than fine particles



D.B. Kittelson - Ultrafine Particle Emission & Control Strategies - 2006

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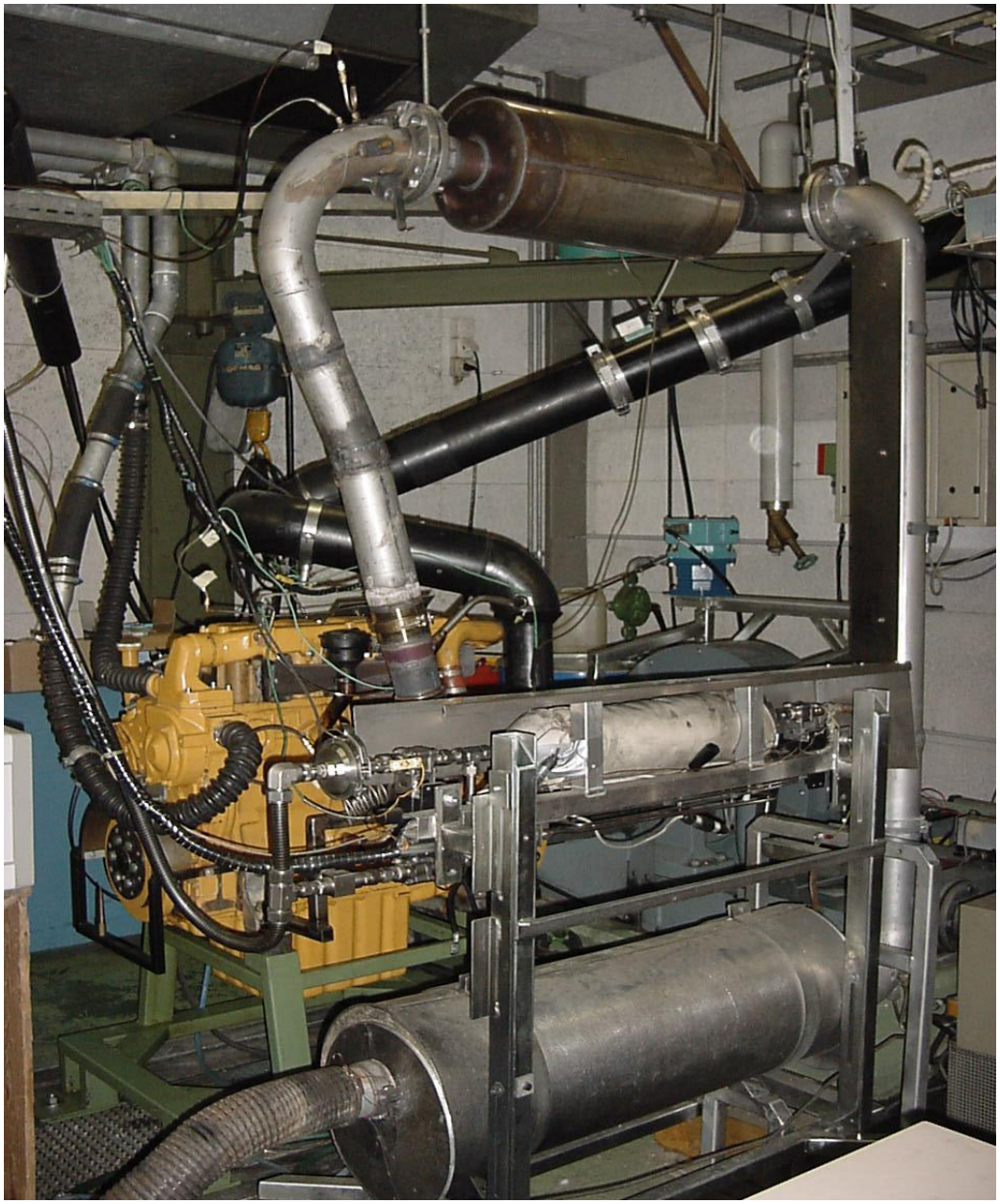
PM and PN from engines

Emissions of solid particles from Diesel engines

1995

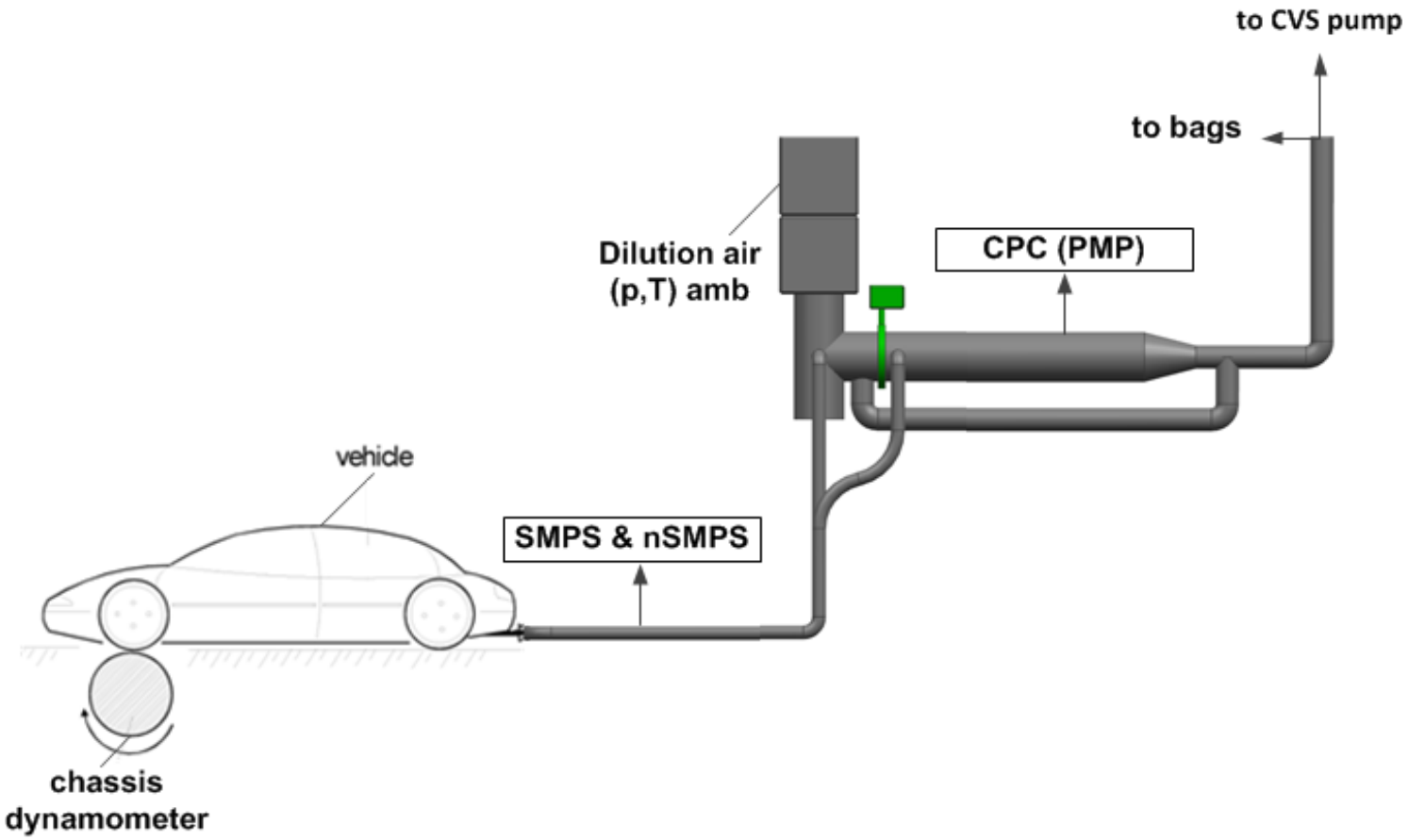
gravimetry	counts
PM …particulate matter	PN …particle number
actual Legislation	new component



GRAVIMETRY

GRAVIMETRY

Sampling of Exhaust Gas for Analysis of Particles



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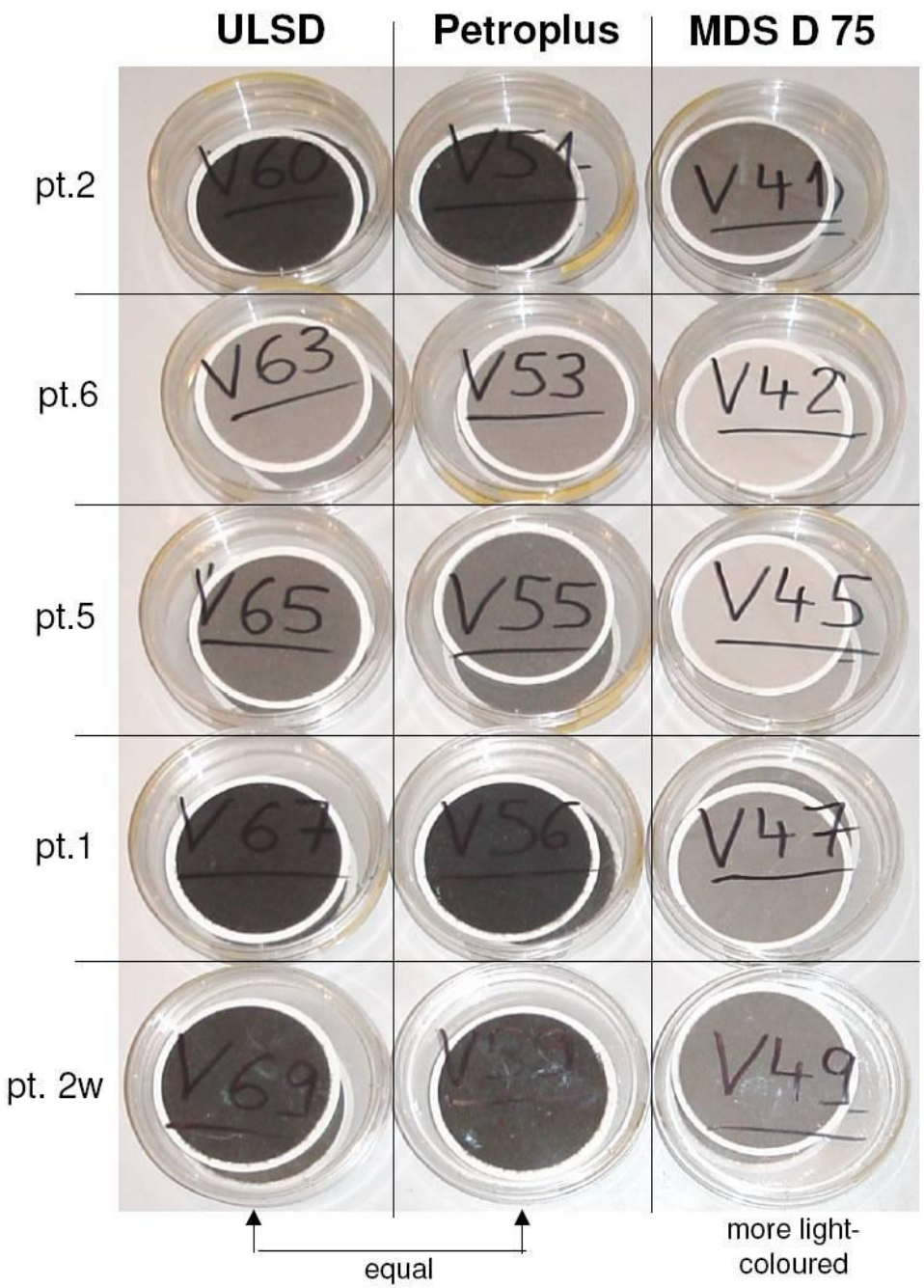
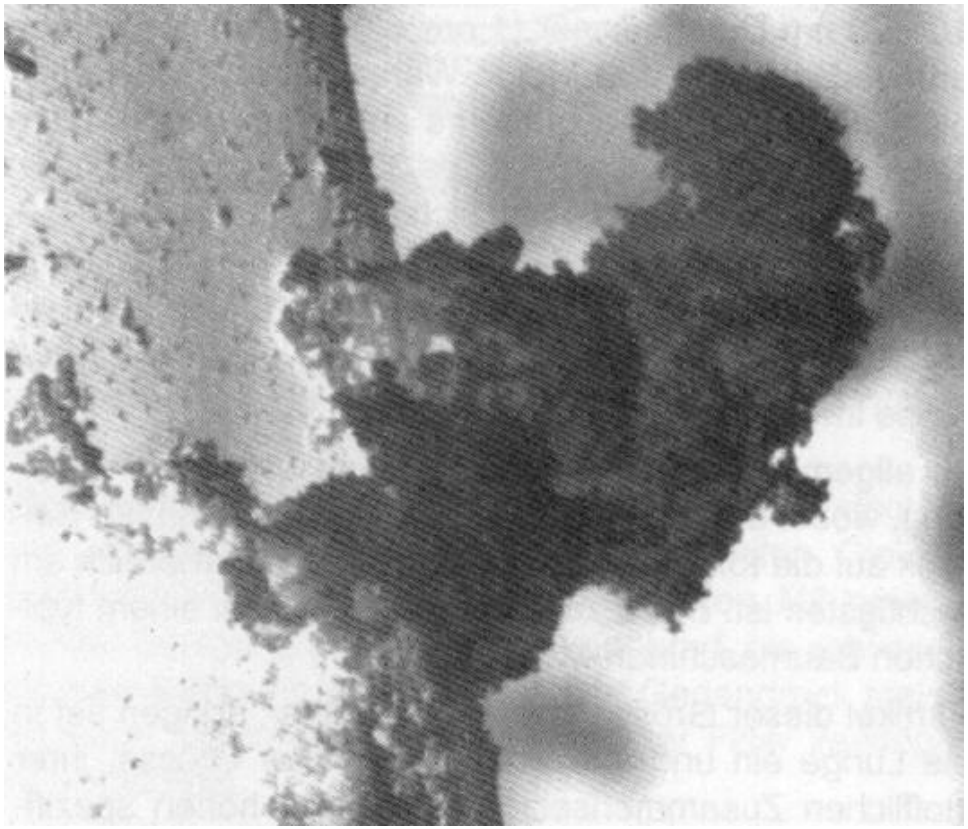
GRAVIMETRY WITHOUT DPF



NANOPARTICLES

- negligible mass
- astronomically high numbers
- penetration like gases

$(PN)_{max}$



Diesel:

$$10^6 - 10^7 \left[\frac{1}{cm^3}\right]$$

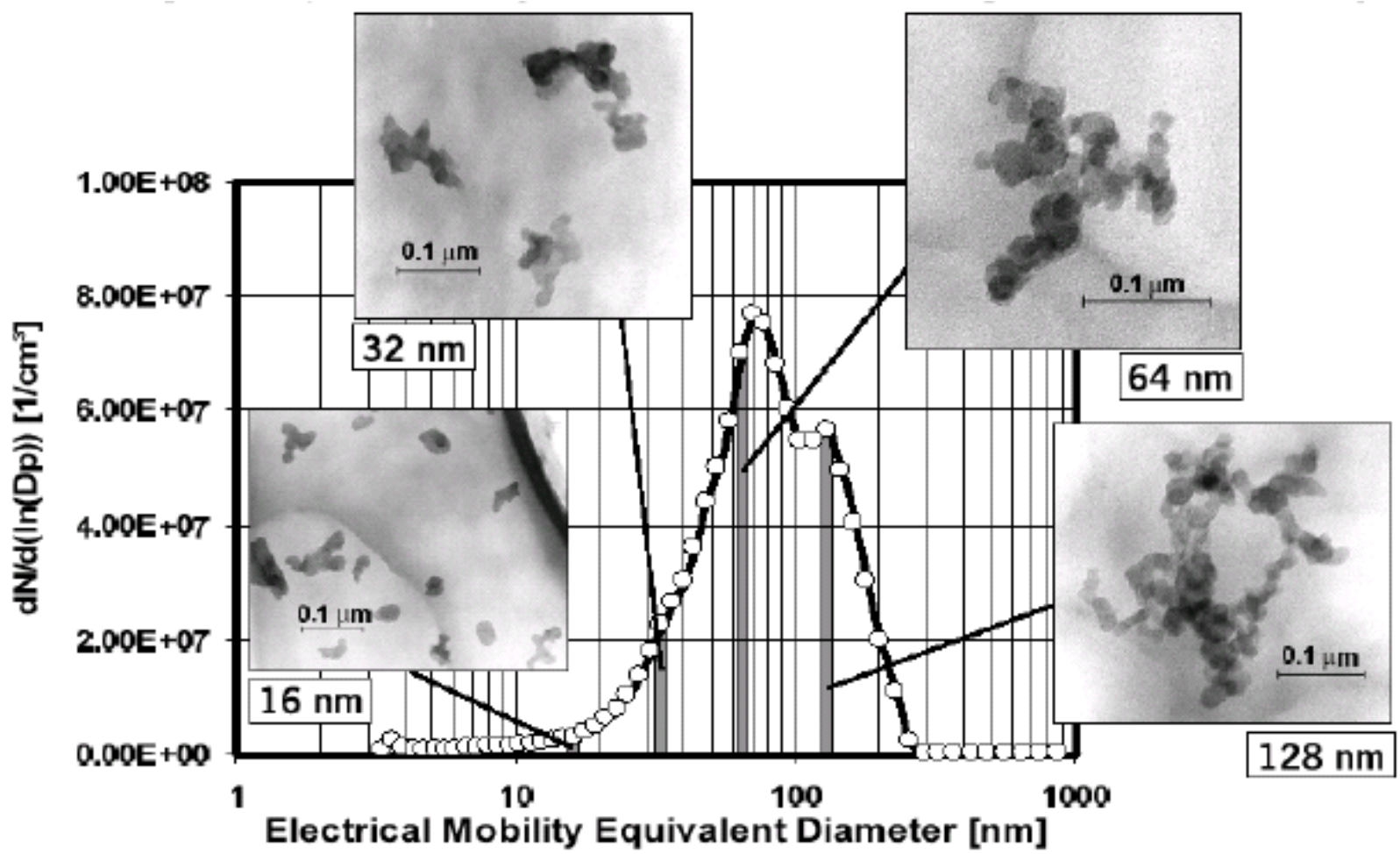
Ambient air:

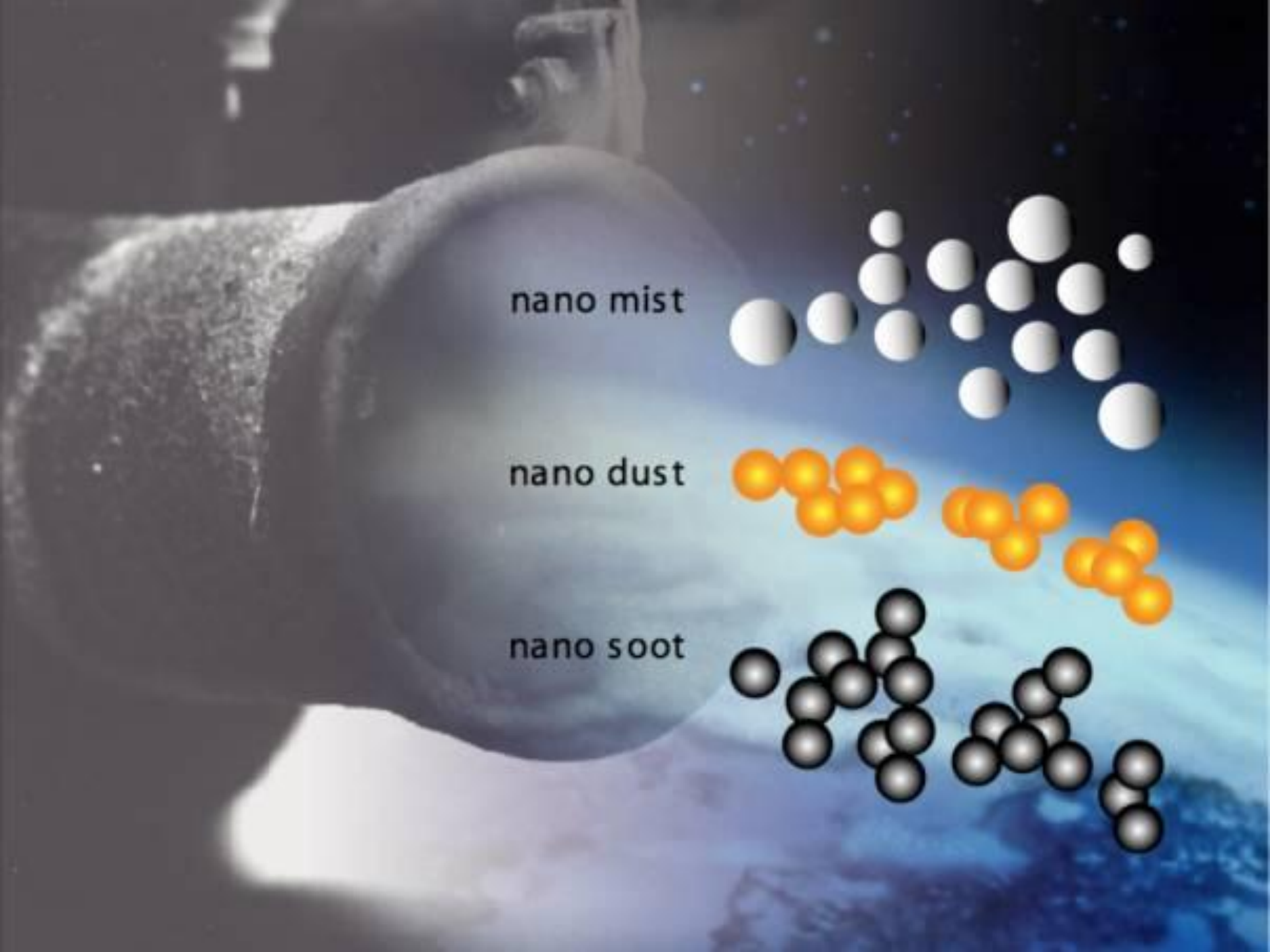
$$\sim 2{,}5 \times 10^4 \left[\frac{1}{cm^3}\right]$$

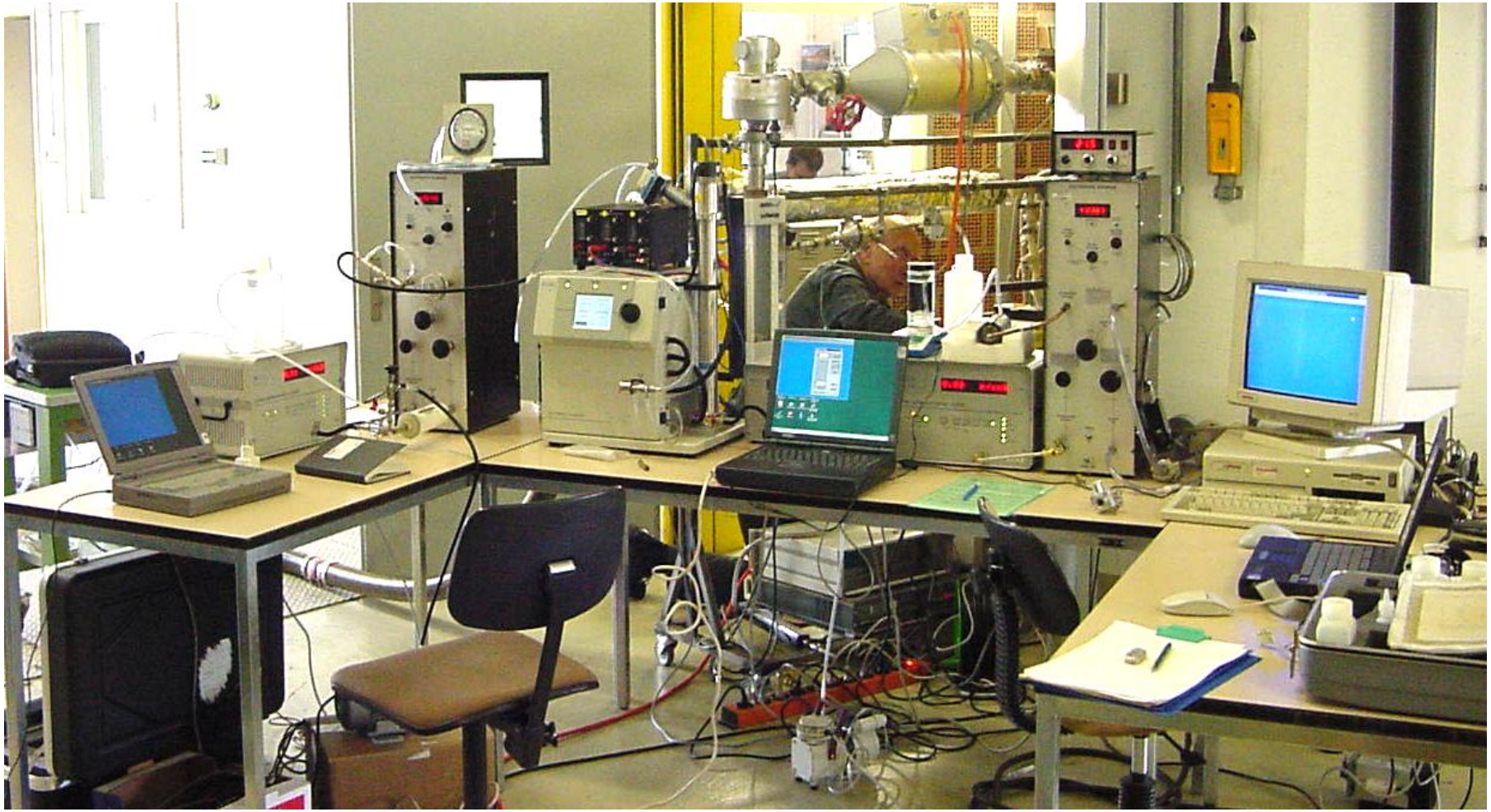
$$\sim 2{,}5 \times 10^{13} \text{ Molecules}$$

Soot deposition on a 10 um filter fiber;
a large agglomerate, formed on the fiber and
many ultrafine particles in the size range of 100 nm

MORPHOLOGY OF NANOPARTICLES



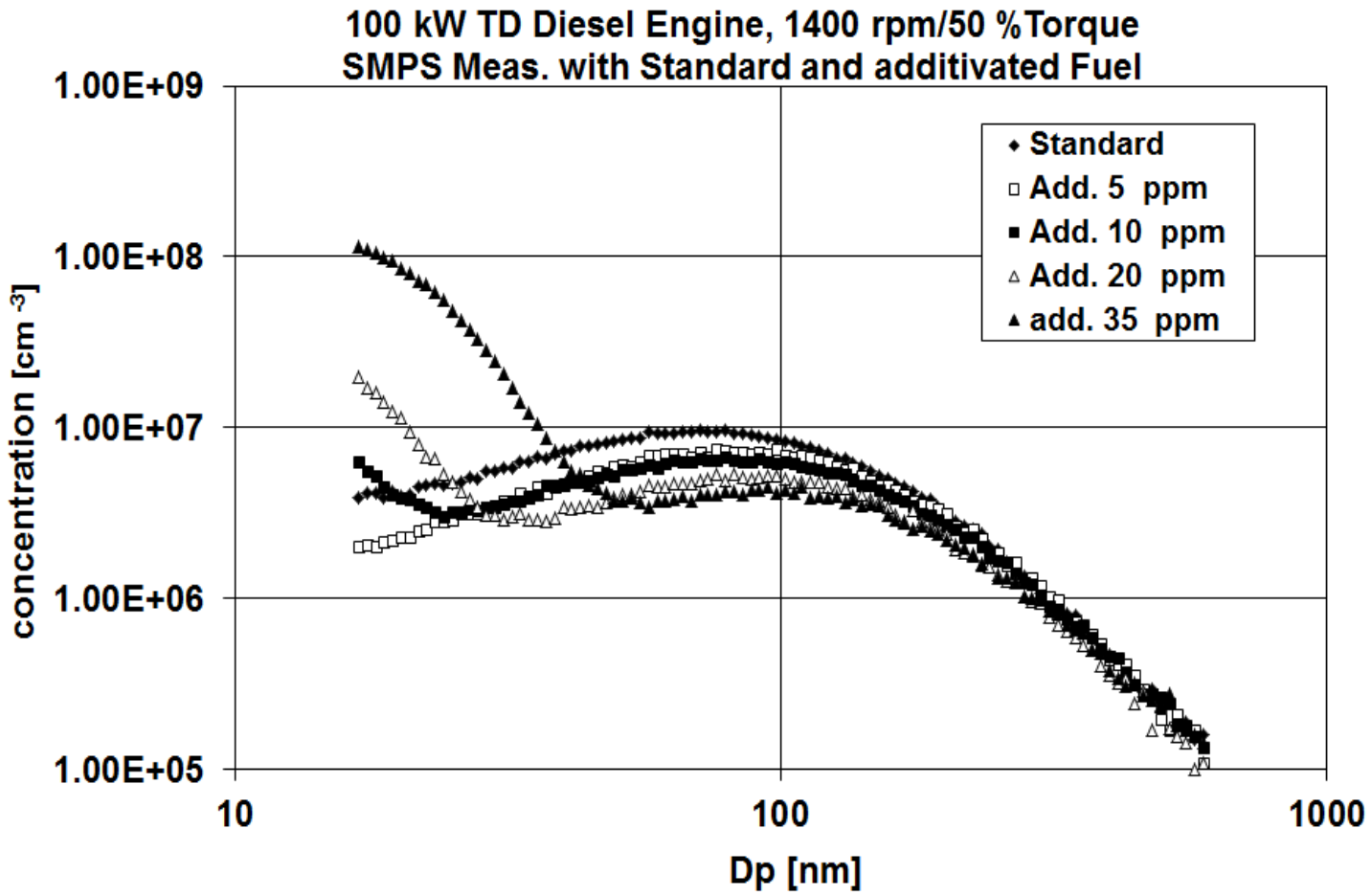

nano mist
nano dust
nano soot



Nuclei mode – what composition ?

Additive ash particle formation depending on concentration

[Kasper et al. SAE 2000-01-1998]

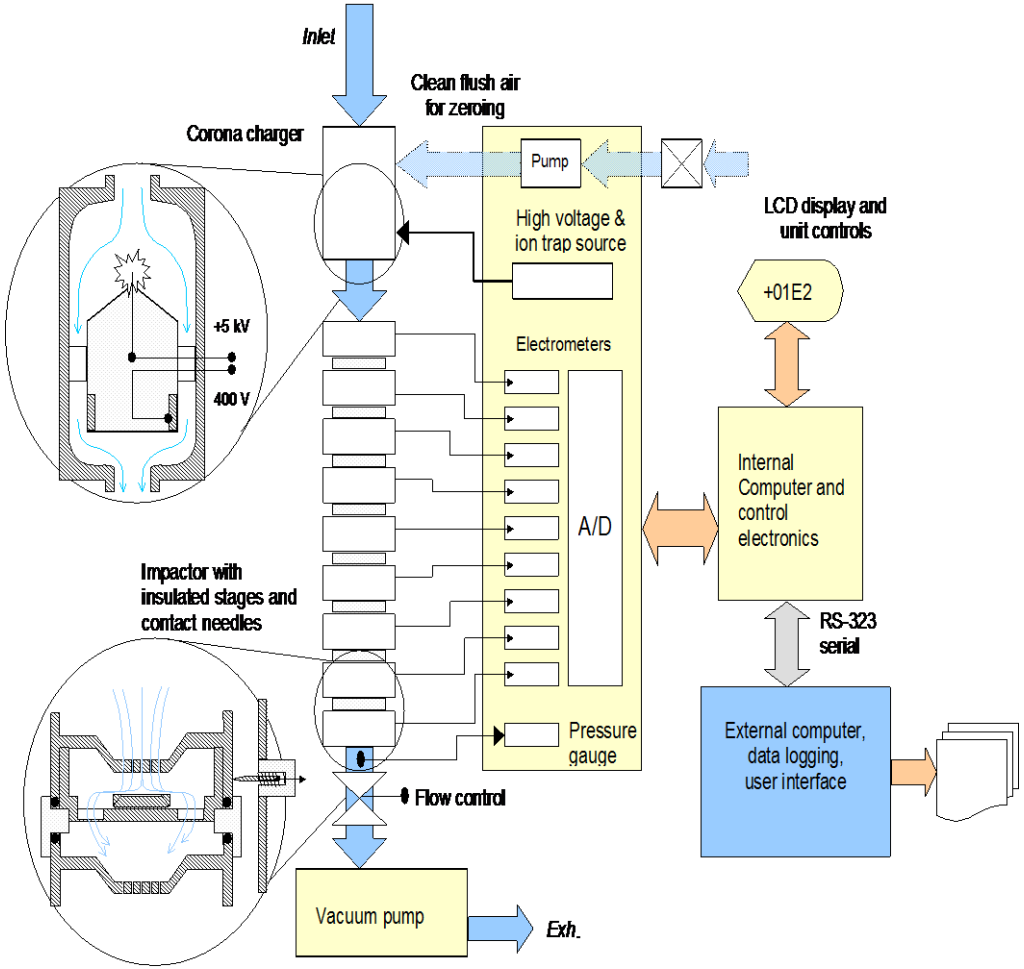


Fokused Study:

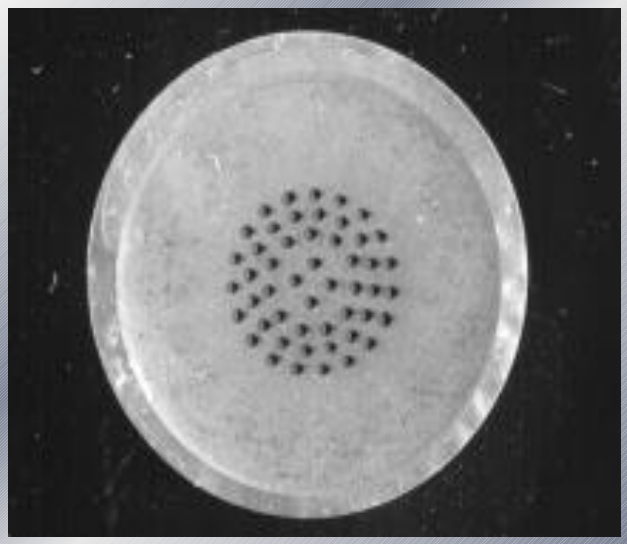
Elements used as tracer indicators in the tested lube oils

		Addition to the fuel		
	Engine lube oil	Motorex	DEA	FBC
Ca [ppm]	2630	3680	-	-
Zn [ppm]	1200	1010	-	-
Fe [ppm]	-	-	-	40

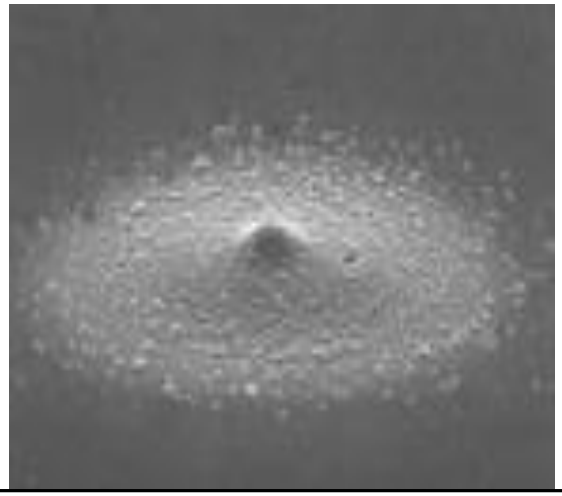
ELPI block diagram (DEKATI)



Typical appearance of particles deposits on ELPI filter plates



ELPI Filter



SEM/EDX

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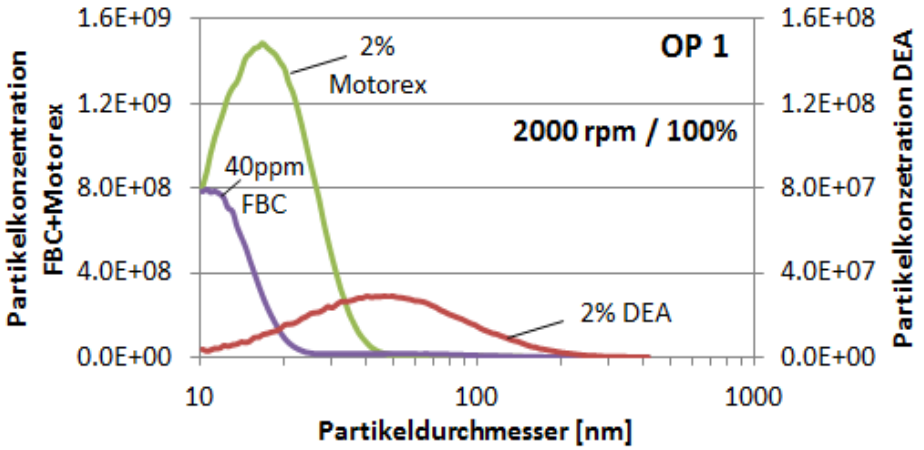
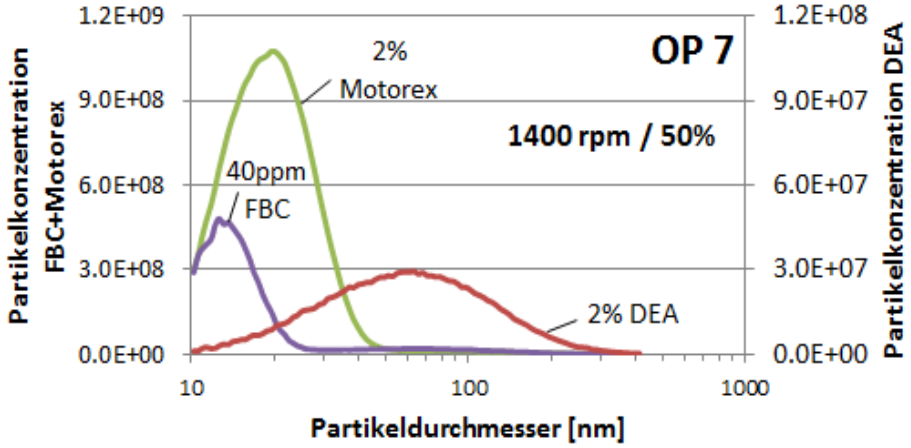
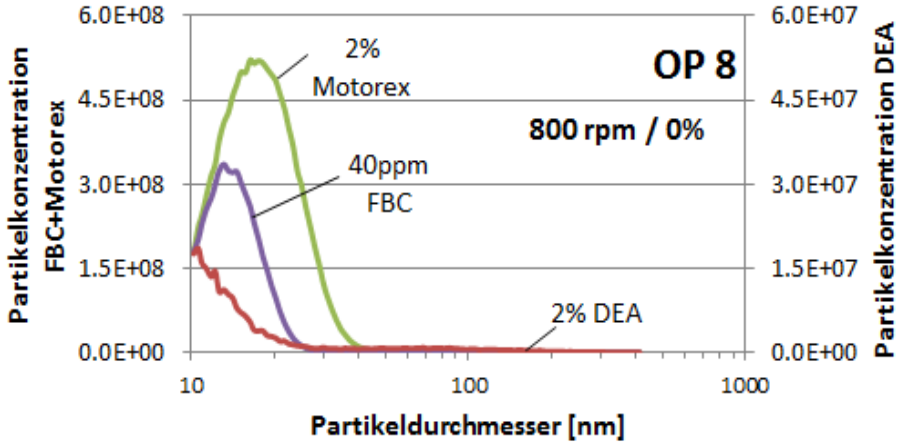
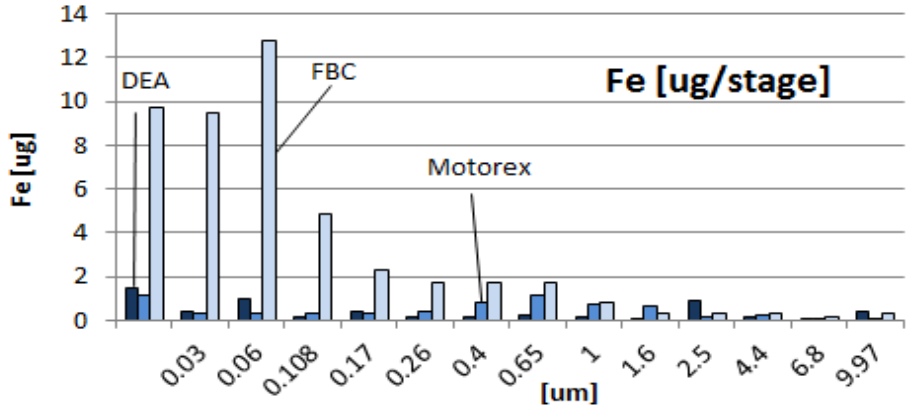
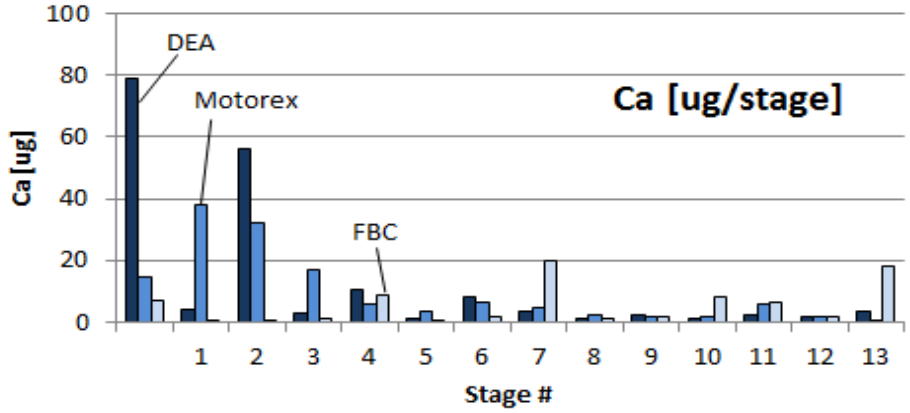


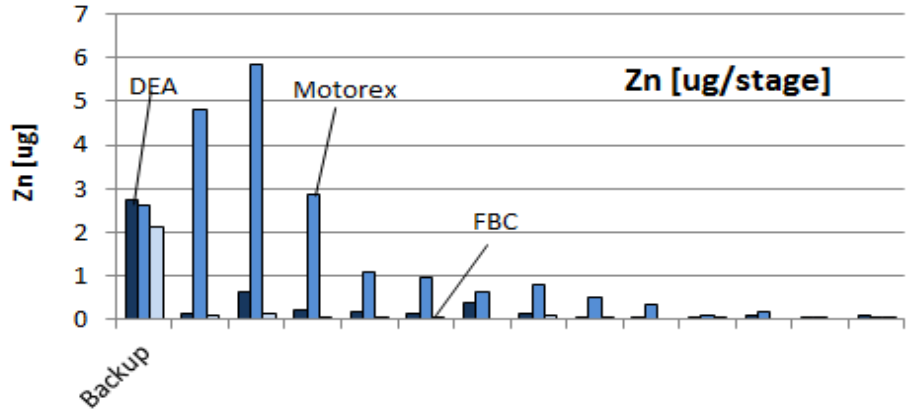




SMPS size distriubtions OP's 1, 7, 8







Size-selective emissions in 8 pts-test

CONCLUSIONS

Market lube oil
→ highest nuclei mode < 30 nm
→ combined effects of metal oxides & SOF

In the size range < 100 nm were found:
→ 79% Fe mass & 77% Zn mass
→ Ca inappropriate tracer; comes also from lube oil

From dosed elements summary masses were found:
43.5% Fe; 36.6 Zn & 65.5% Ca

It was confirmed that:
→ the dosed metals are emitted mostly below 100nm
→ 1/2 to 2/3 of the the dosed metals stay in the system.

Czerwinski Jan et al., PTNSS Comb. Engines, No1/2015(160)

Examples of PN emissions

Diesel Engine

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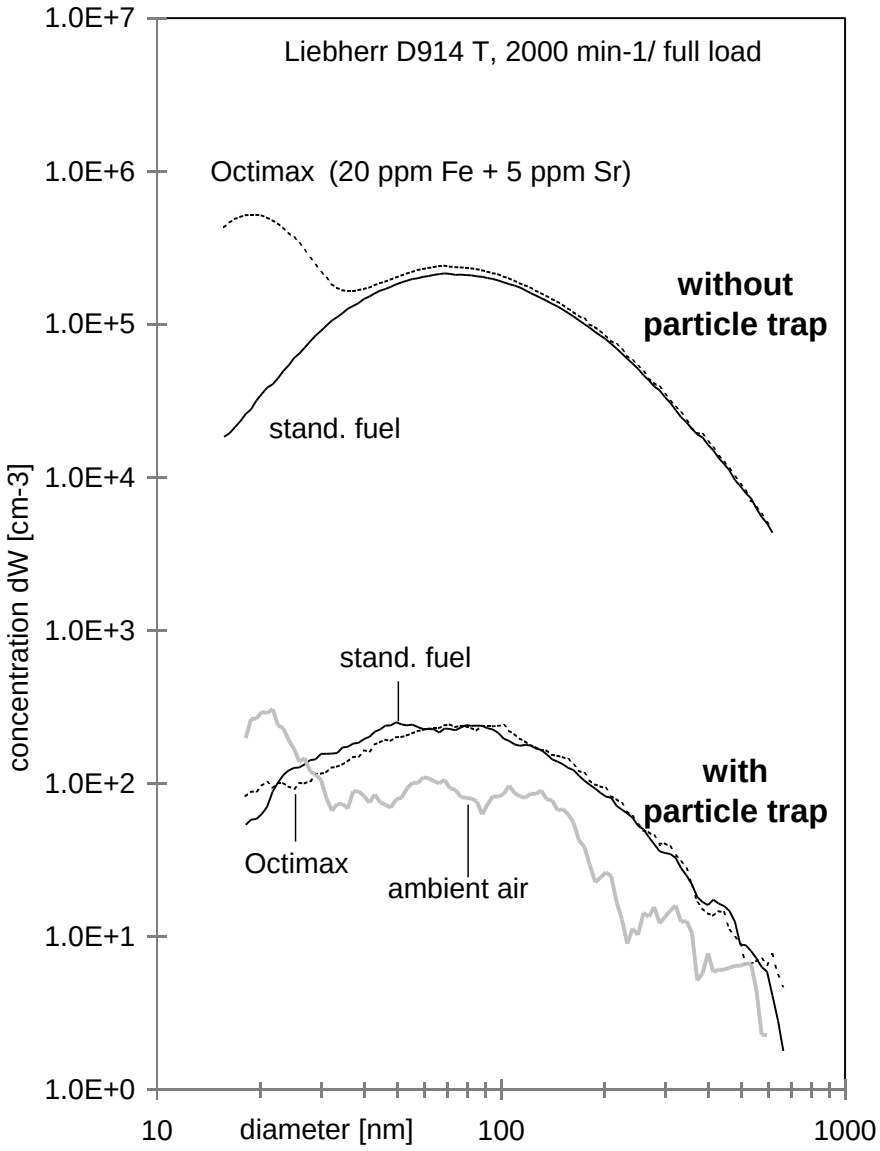
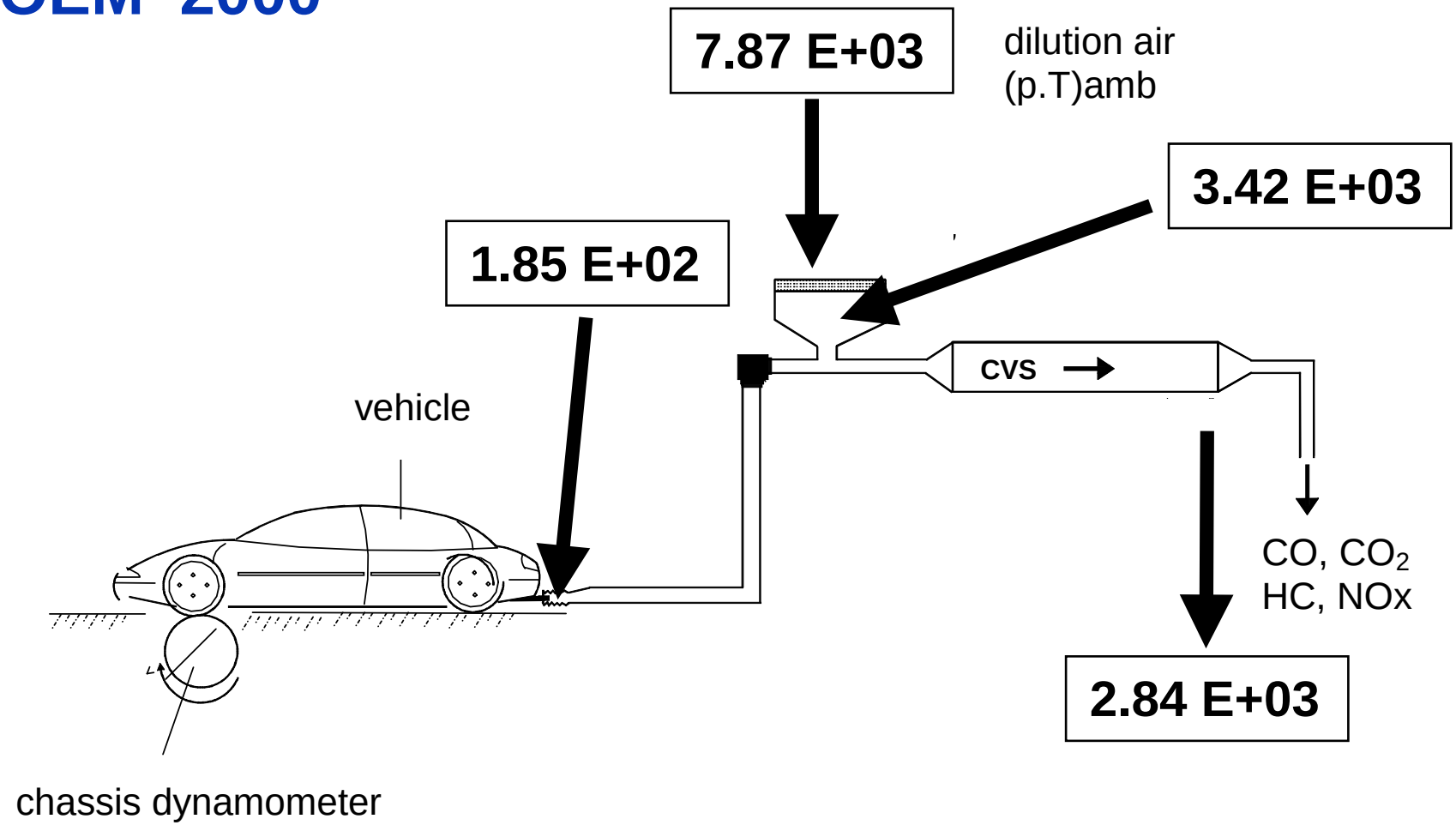


Particle size spectra with/without particle trap CORNING, with/without additive Octimax

1995

SUMMARY
OEM 2000



Example at 80 km/h

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YOKE MOVER

SIMPLE SI 4S-ENGINE

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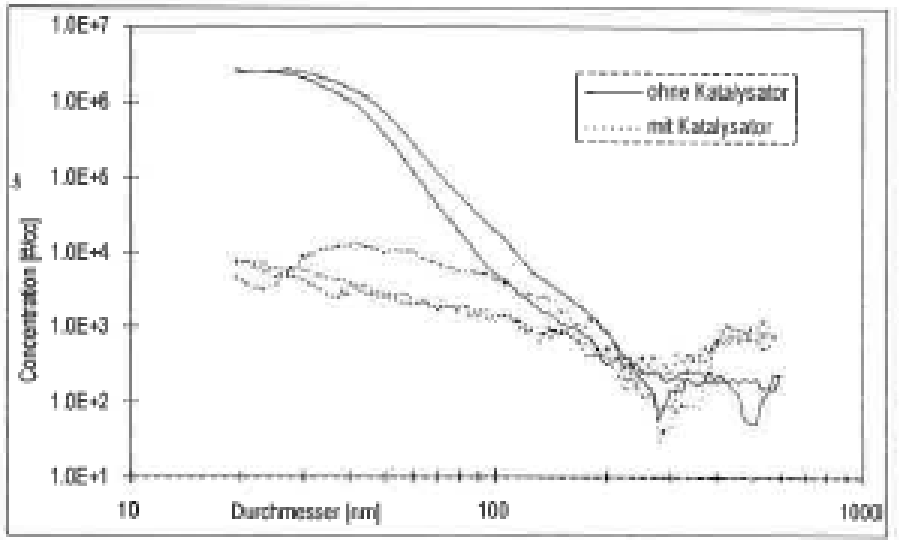
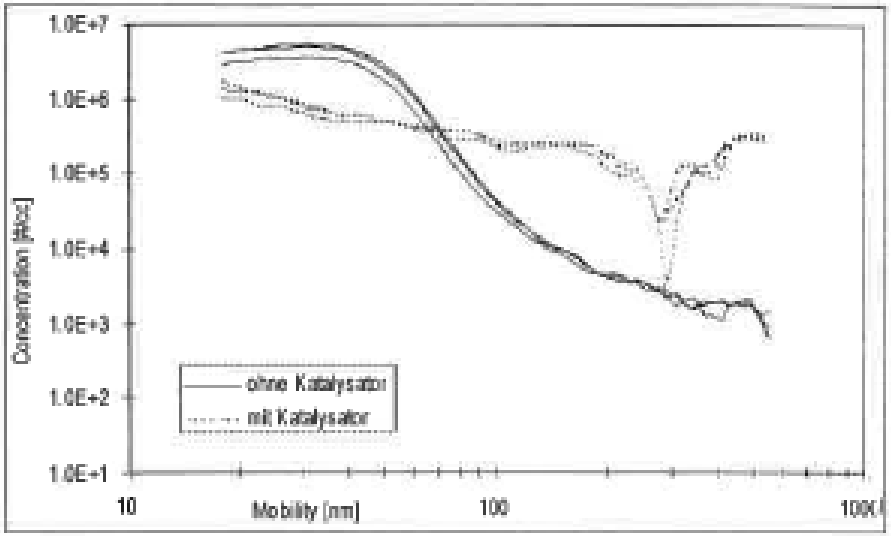
Number count as a function of the mobility diameter (SMPS method) for both engines at full load with/without catalytic converter





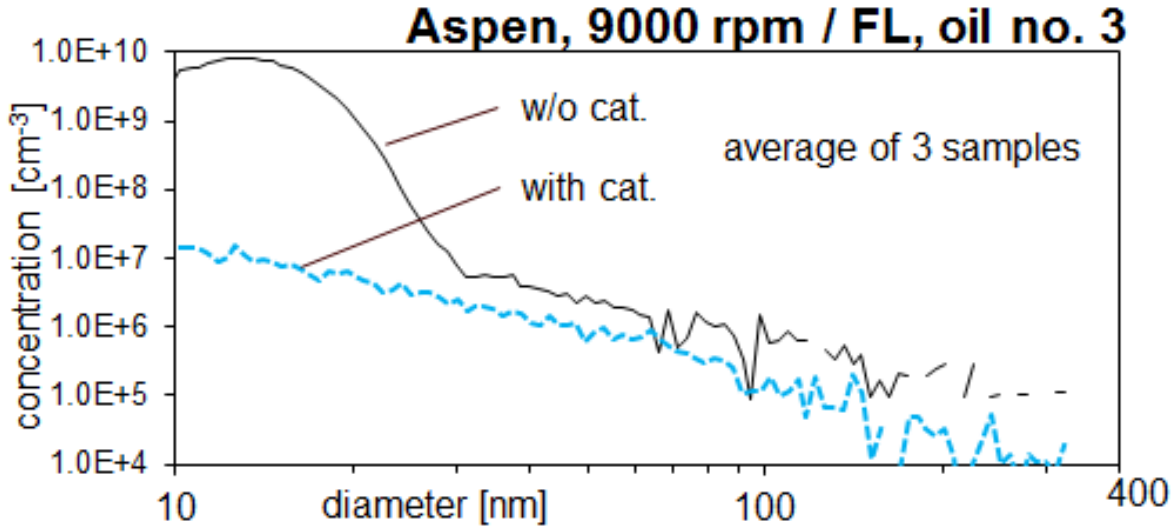
SAE Paper 1999-01-3338

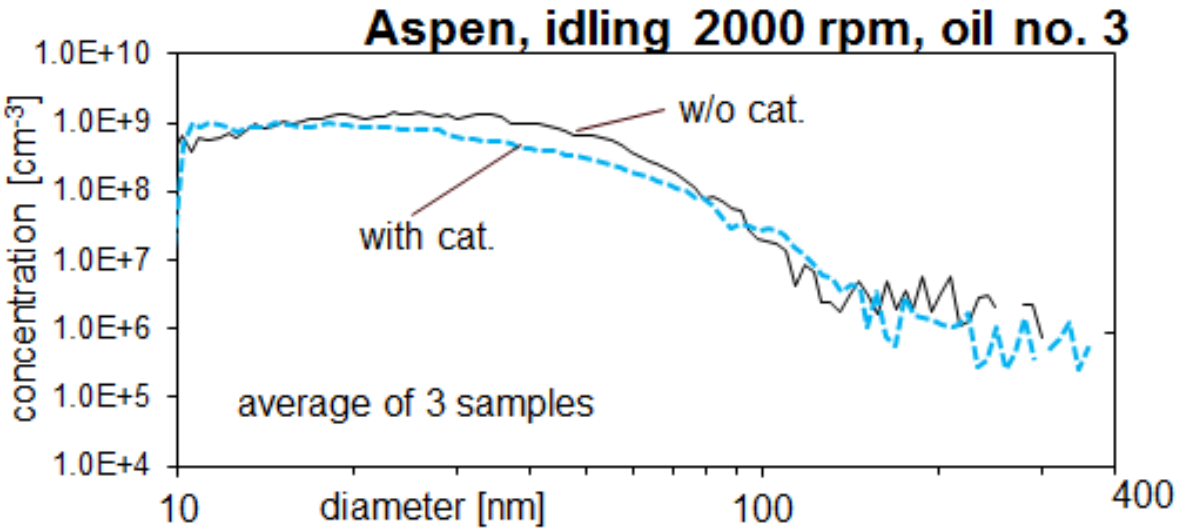
1998

CHAIN SAW

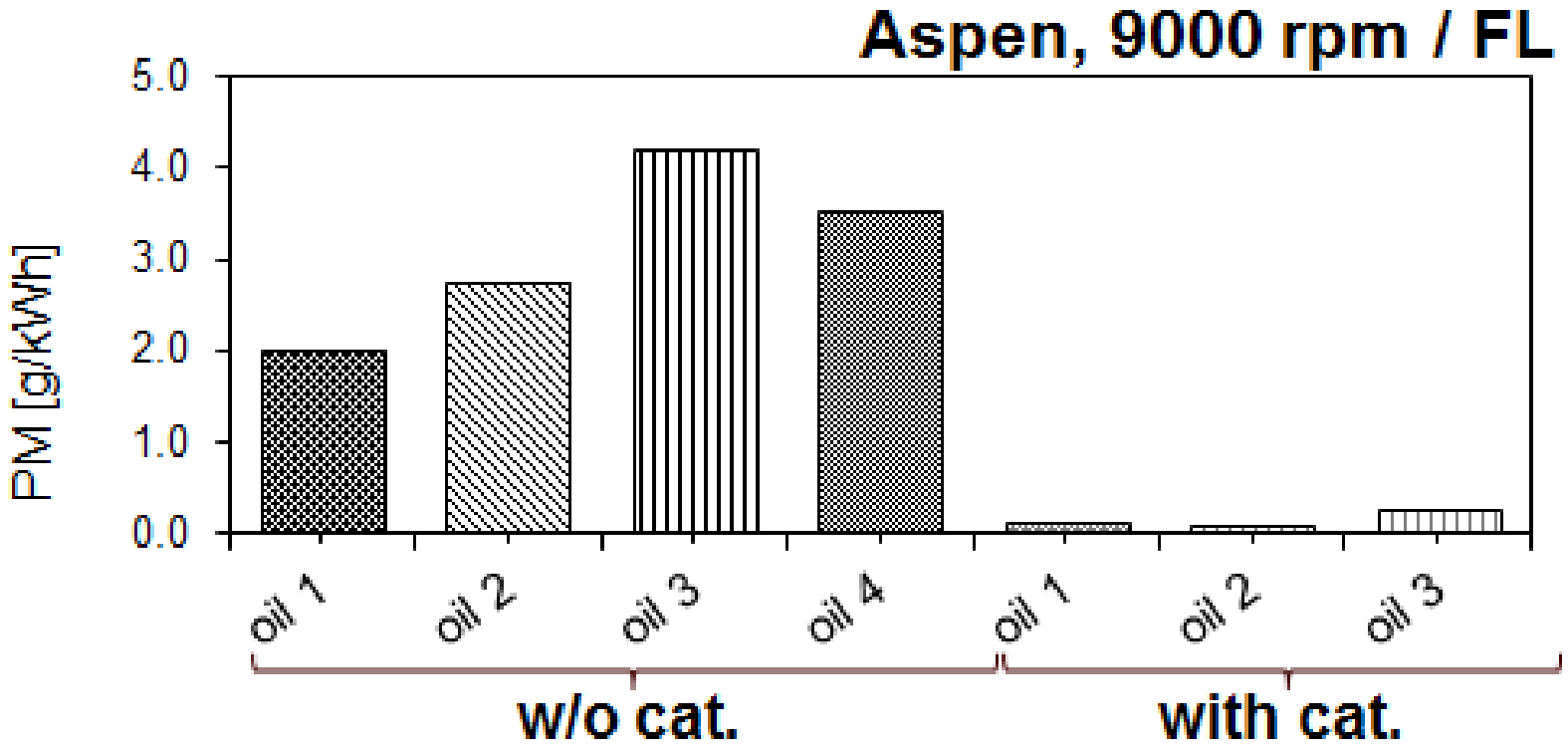
1999/2014

INFLUENCES OF OXIDATION CATALYST ON PARTICLE SIZE DISTRIBUTIONS (PSD) AT FULL LOAD & IDLING





PARTICLE MASS (PM) WITH DIFFERENT LUBE OILS AT FULL LOAD

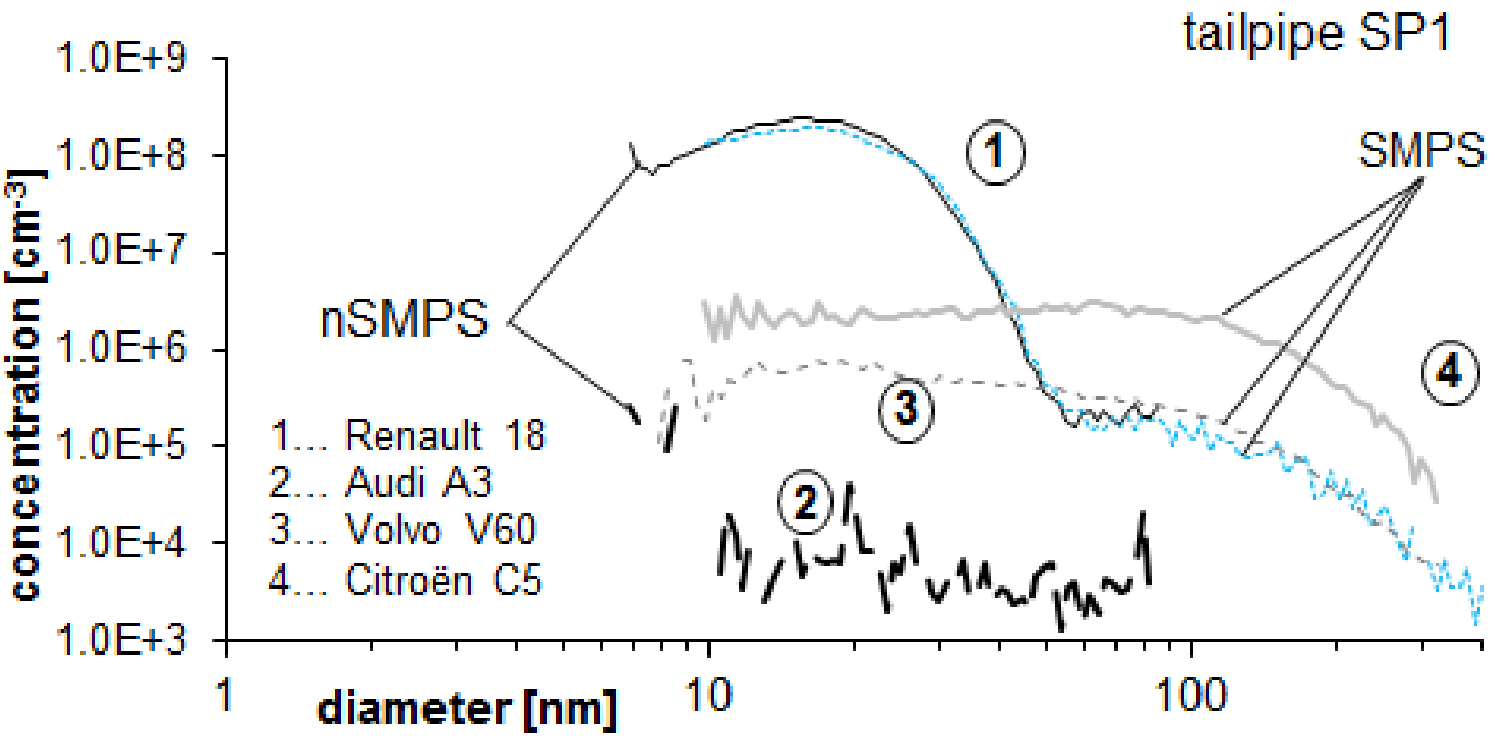


GASOLINE CARS

GDI & MPI

Since 2013

PARTICLE SIZE DISTRIBUTIONS OF DIFFERENT VEHICLES AT TAILPIPE & 40 KM/H



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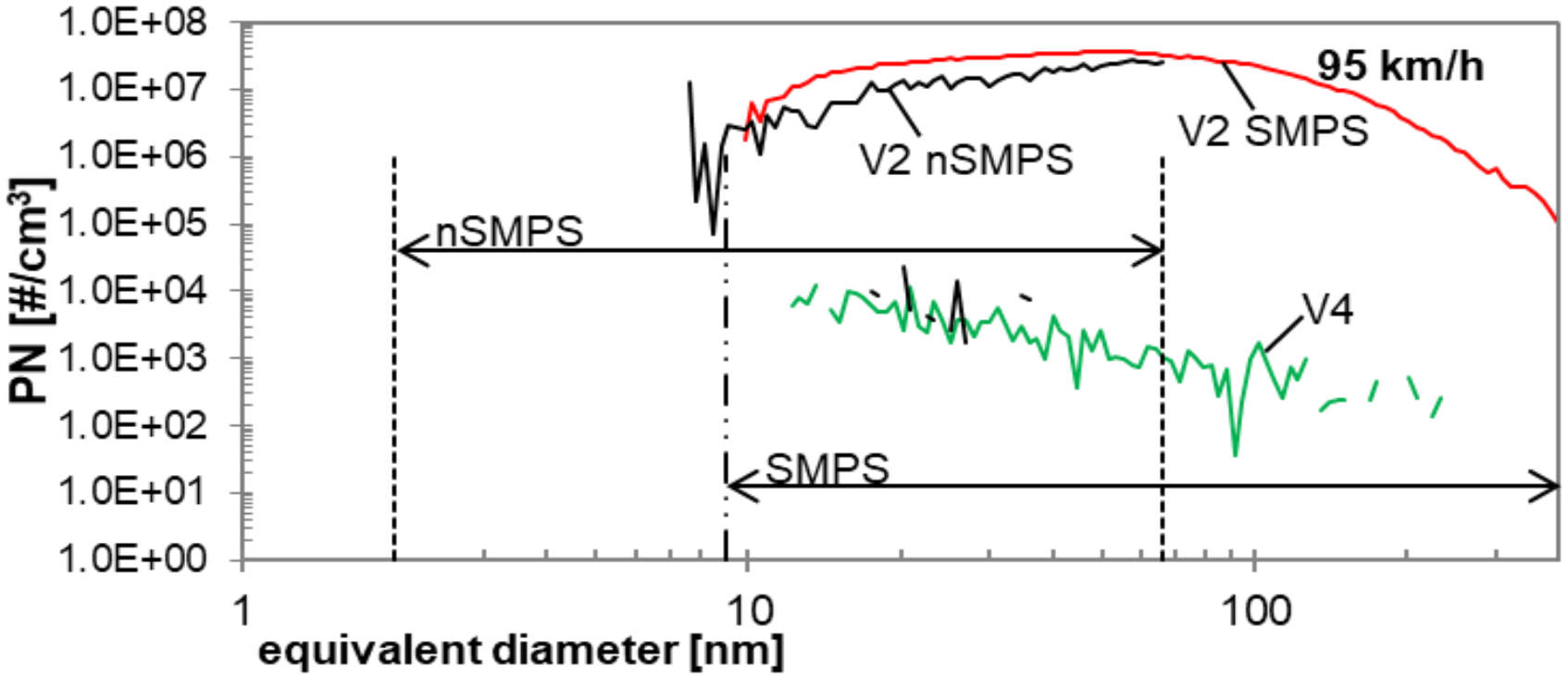
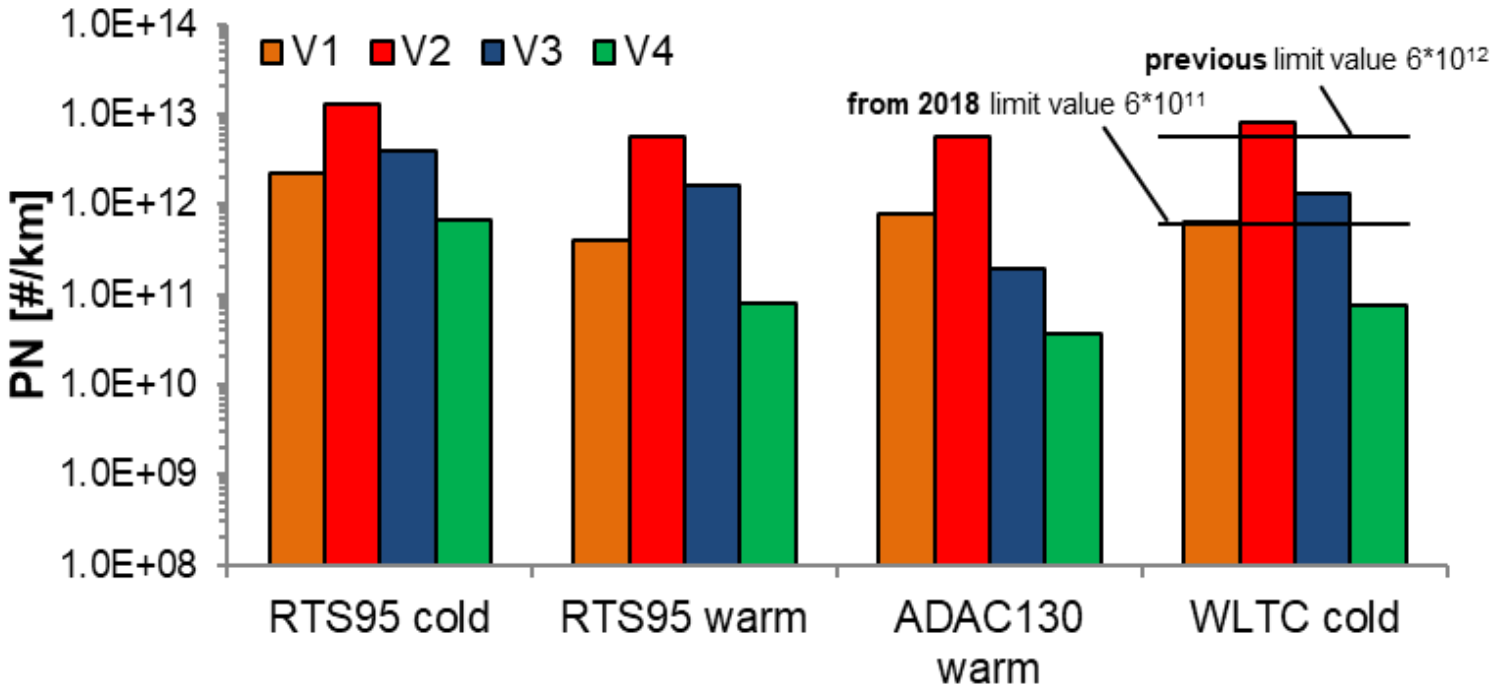
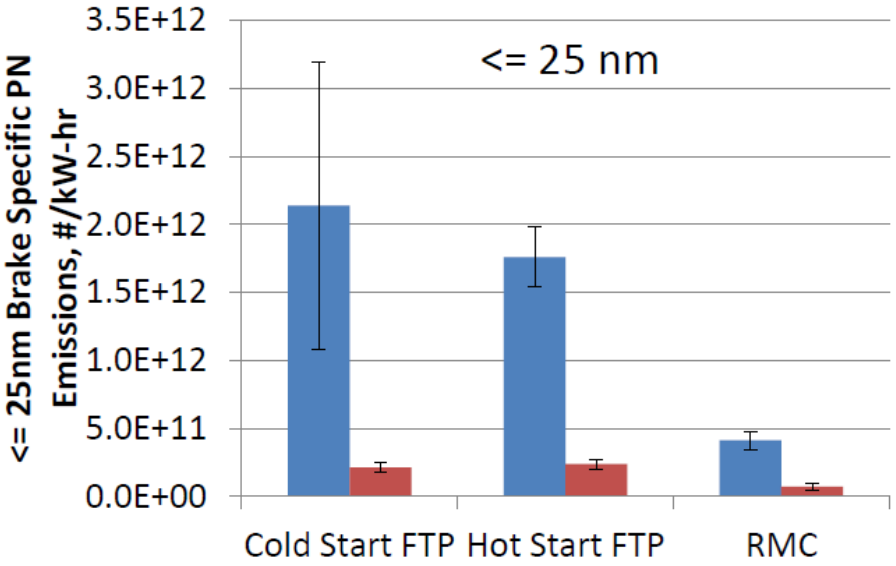
Particle size distribution of MPI vehicles (min/max emissions) at 95 km/h.

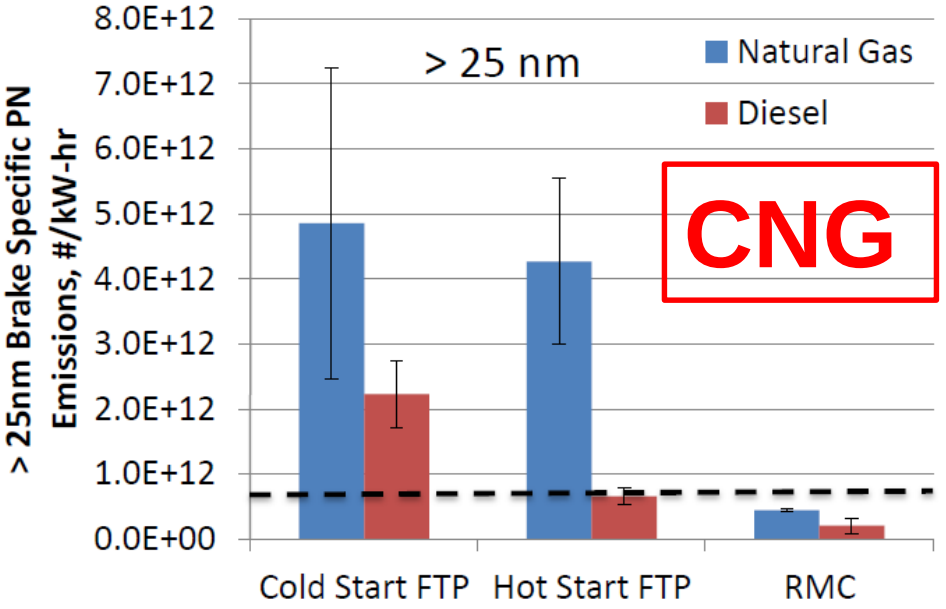


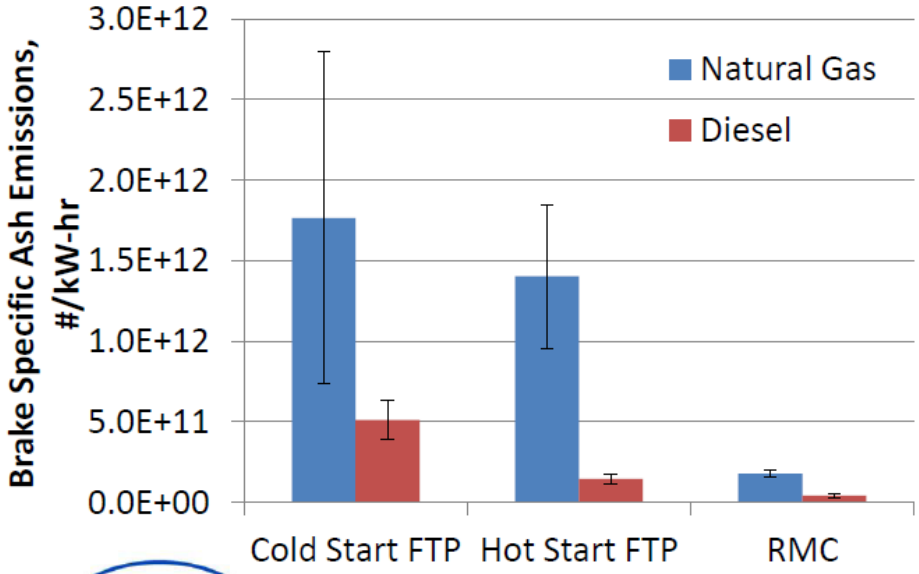
PN RESULTS IN ALL DRIVING CYCLES

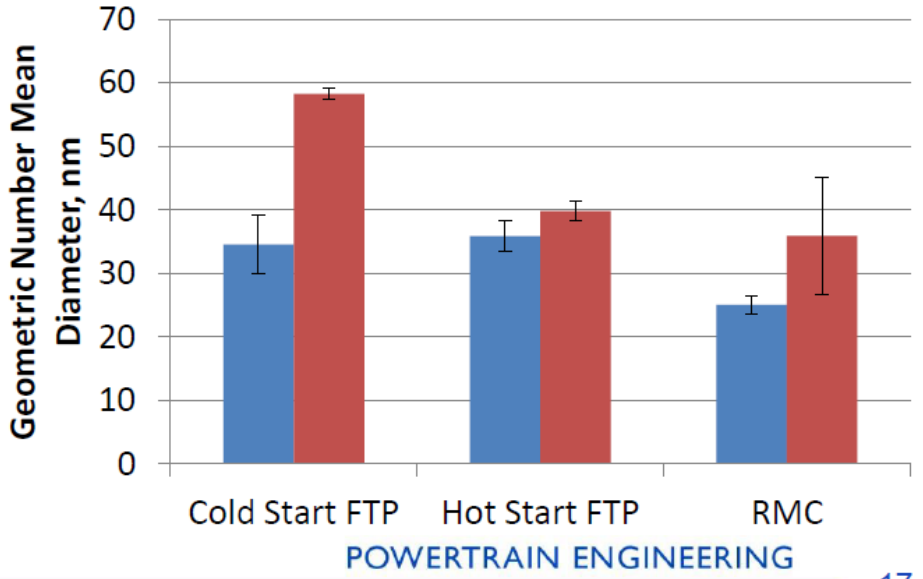


Comparison – Natural Gas vs. Diesel w/DPF









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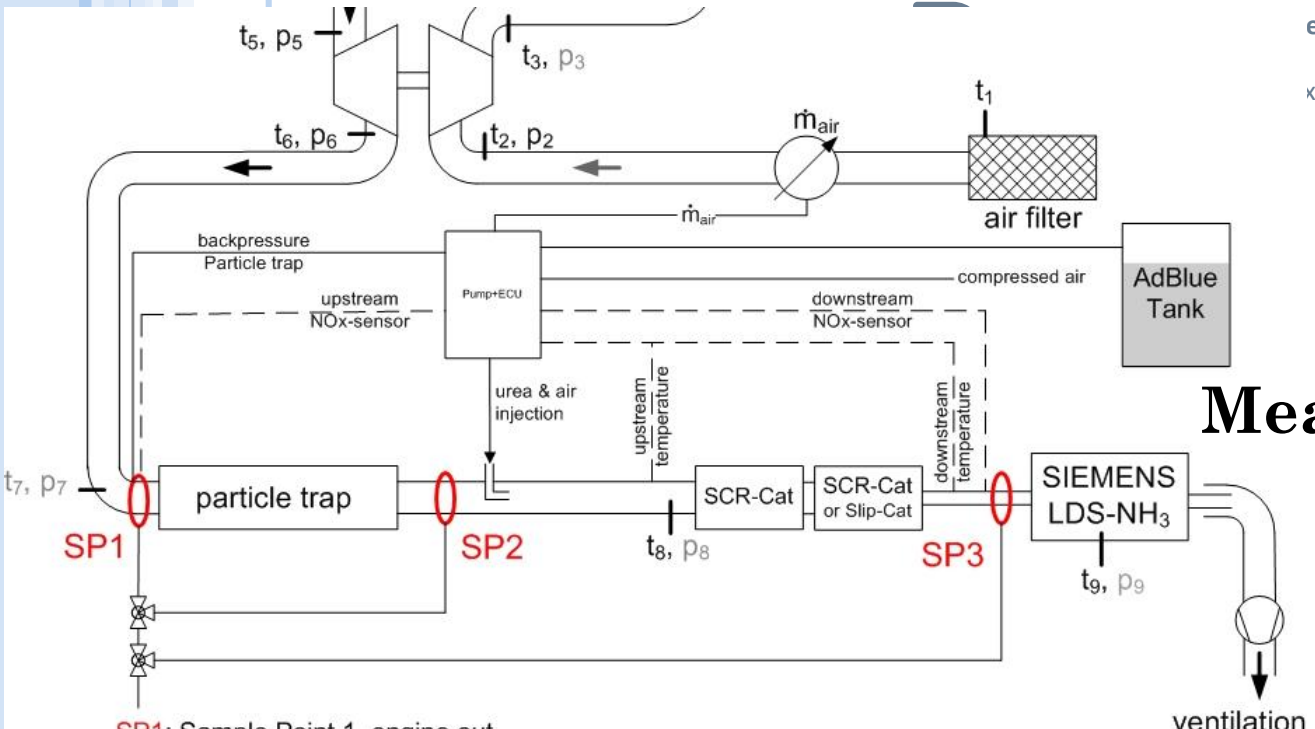
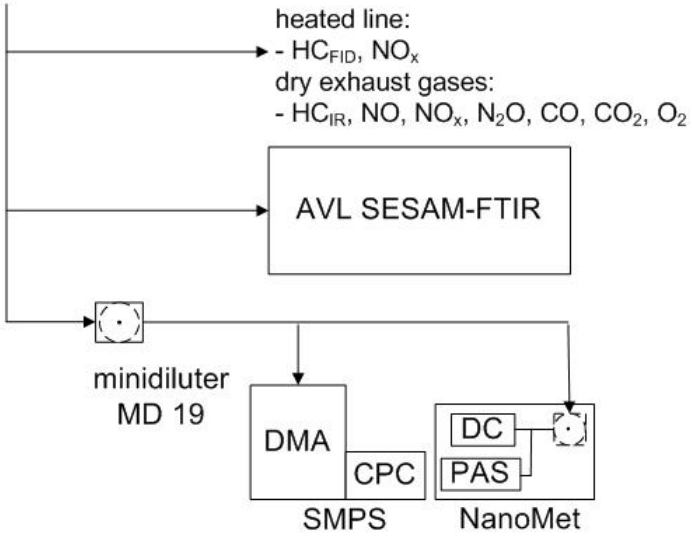
Secondary nanoparticles from SCR system

Measuring set-up

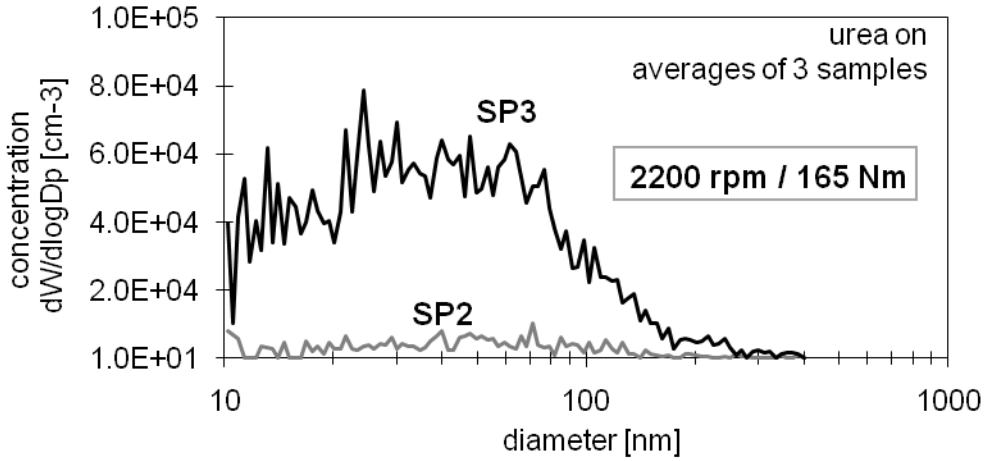


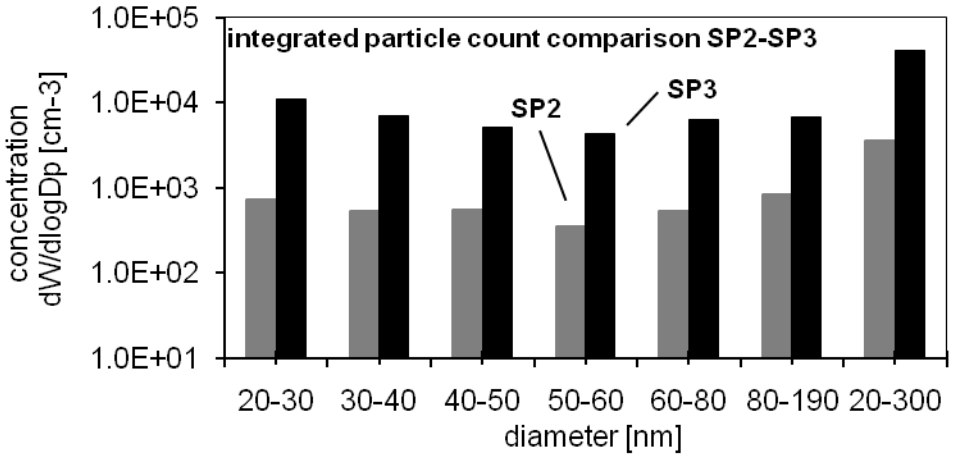
SP1: Sample Point 1, engine out
SP2: Sample Point 2, after PF, before urea injection
SP3: Sample Point 3, tailpipe

Investigated (DPF+SCR) system

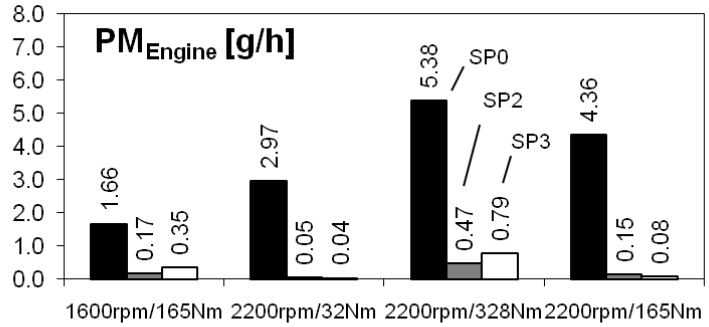


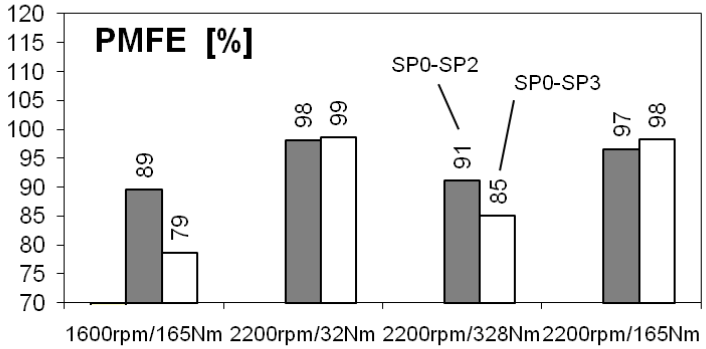
SMPS-Size Spectra at SP2 & SP3, PF1 + SCR, α=0.9

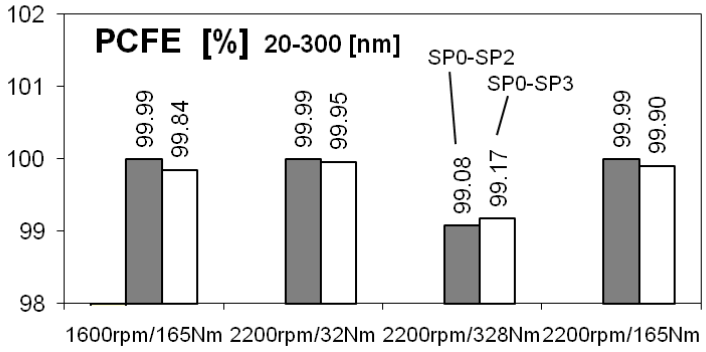


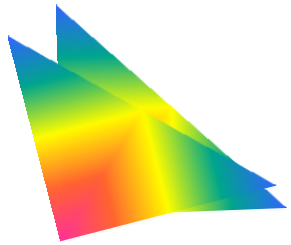


Particle Mass and Counts Reduction in the 4 Points Test, PF1 + SCR, α=0.9





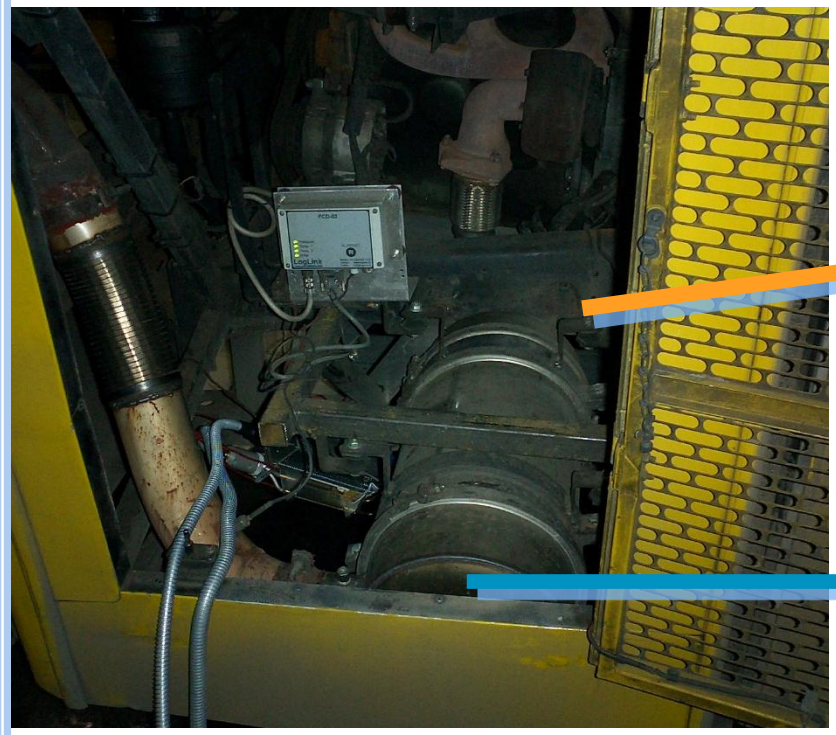


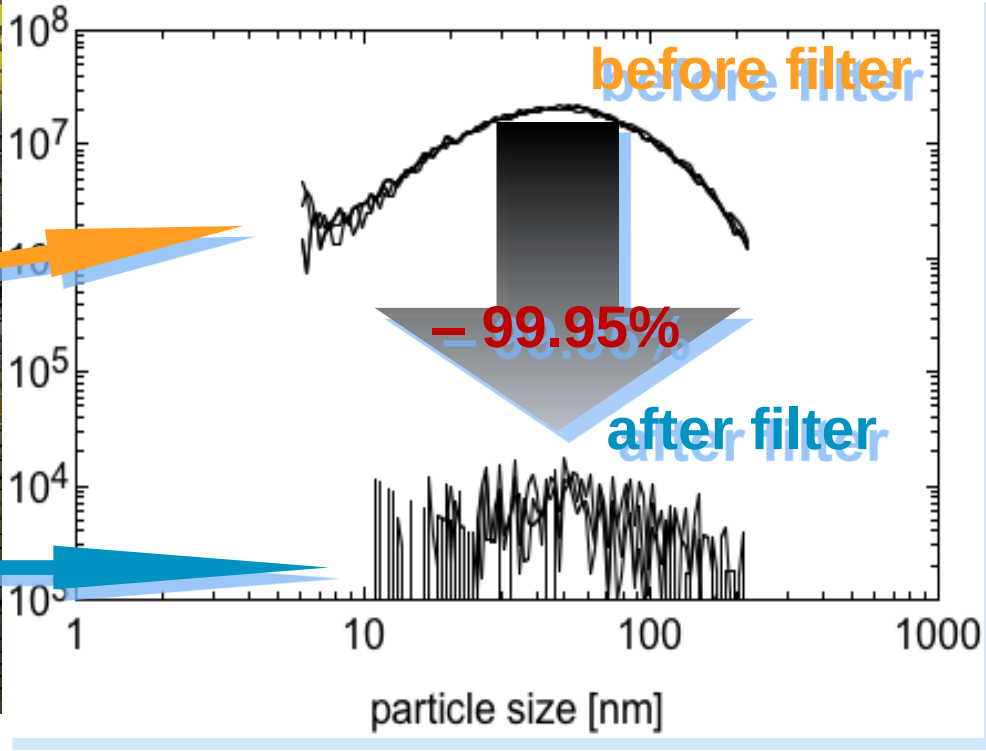



What to do
?
Worth1000.com

Exhaust gas filtration

Filter Efficiency Measurement





Conclusions

- Ambient PM 10, PM 2.5 are far from NP (size, composition, penetration)
- Engine PM ≠ PN
- PN is a very sensitive parameter
- Nearly all engines have operating conditions with high PN
- … and not only engines
- Filtration helps a lot

Consequences and potential improvements

- Solids/solubles in the body: exposure time, dosis, persistence, clearind, individual metabolizm
- Potentials of DPF/GPF not entirely used by the legal limits
- No legal consideration of lube oil


Thank you for
your attention