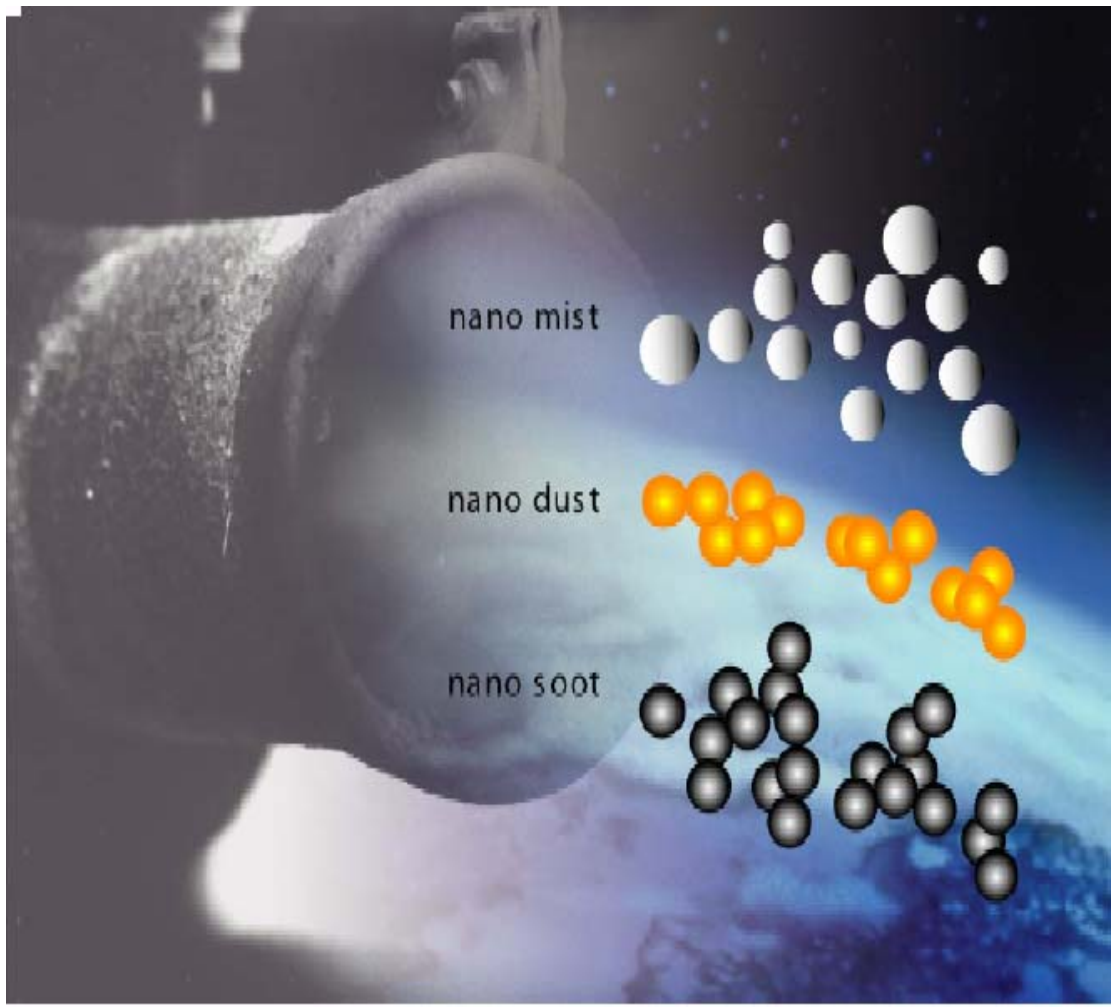
Elimination of Nanoparticles generated by IC-Engines



A.Mayer

NOSA 8.Nov.2007

A.Mayer - TTM

Independent Consultant

Emission Reduction of IC-Engines

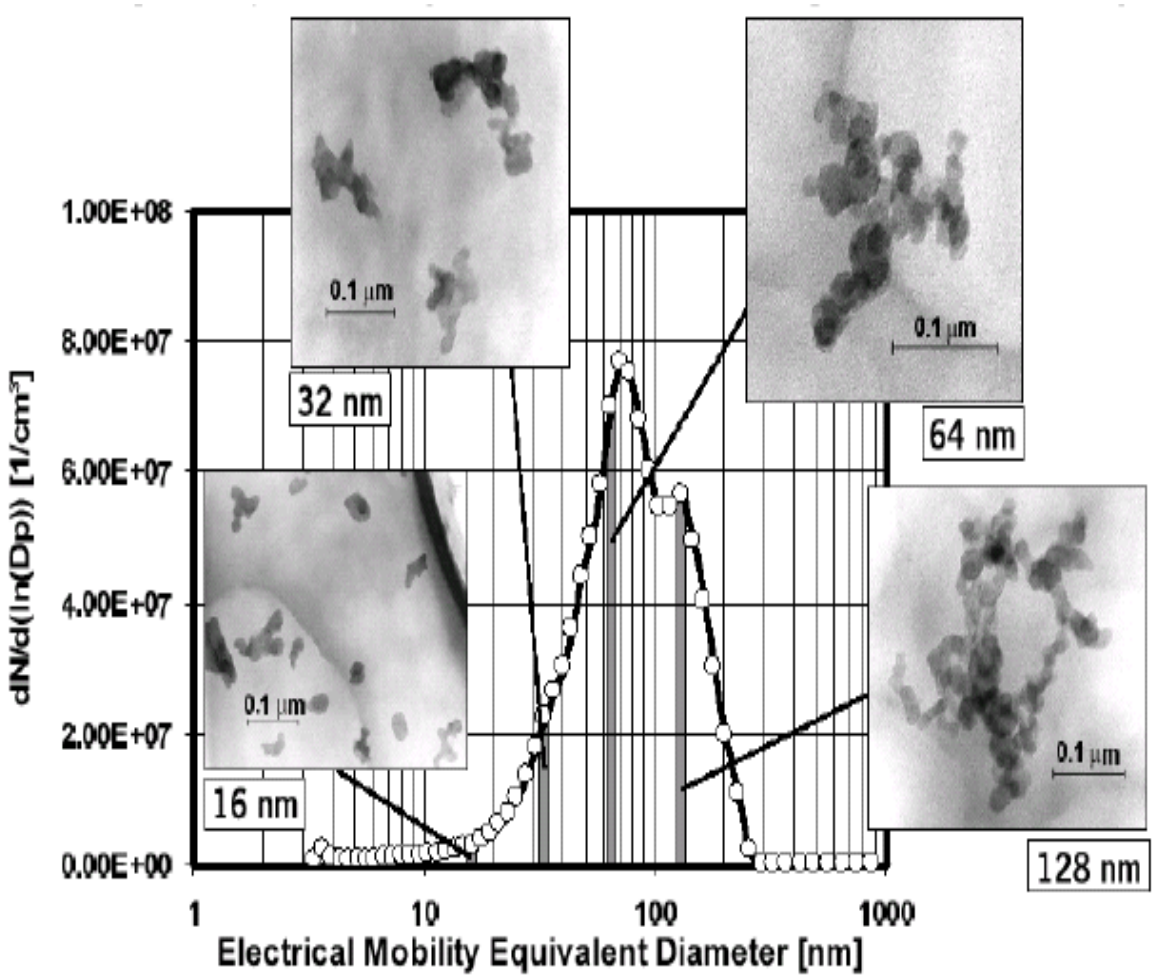
TTM is responsible on behalf of BAFU&SUVA

- VERT Verification of Particle Filter Systems

- Quality Control of Filter Retrofits in Switzerland

- Research and Development in International Projects
- Implementation of Emission Reduction Measures (Germany, Austria, Poland, Italy, California, Canada, Chile, Korea, Japan, Czechia ..),
- Organization of Seminars and Conferences: HDT and ETH-NPC
- 2 books published 2004/5 on “Elimination of Combustions Generated Particles”
- SAE-fellowship 2004
- Award of Swiss Cancer Ligue 2006

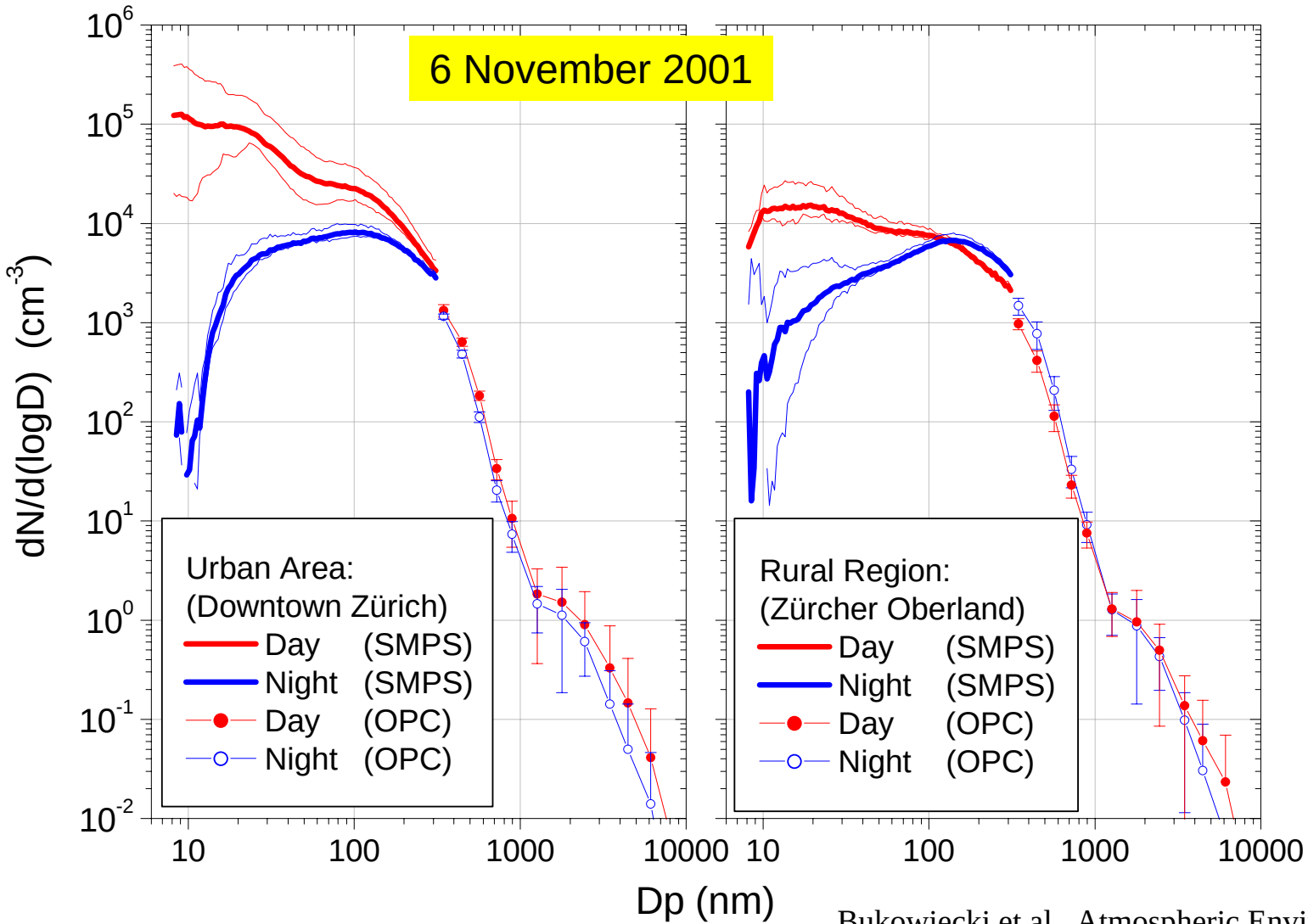
Size-Distribution of Diesel-Particles



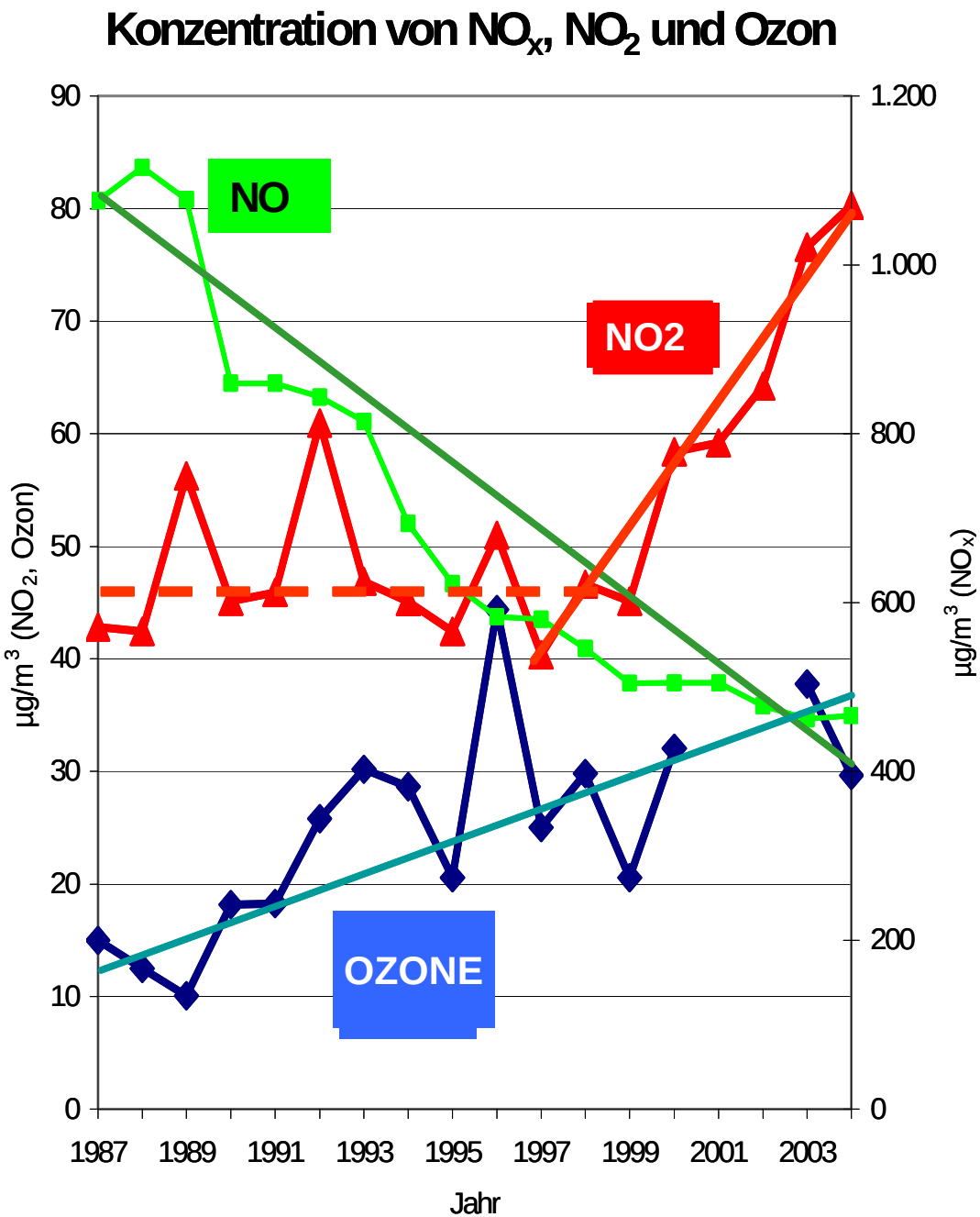
Quelle: METZ, BMW

Aerosol Size Distribution

Zürich Downtown and Zürich Rural



Bukowiecki et al., Atmospheric Environment, 2002

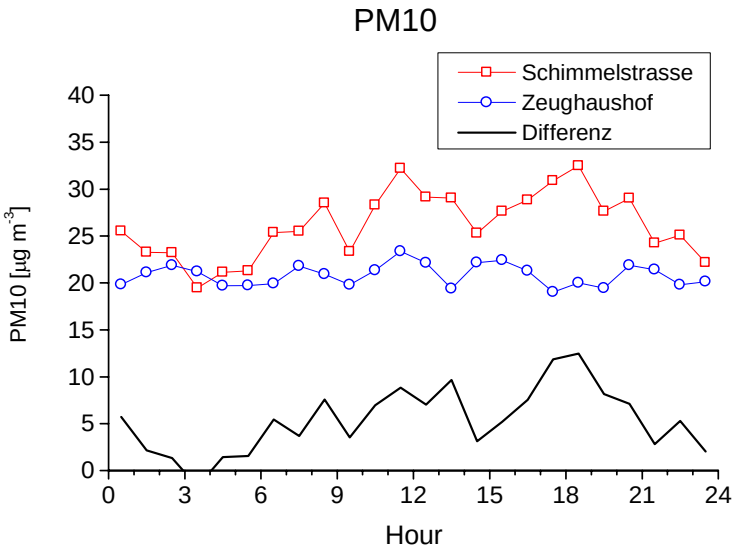


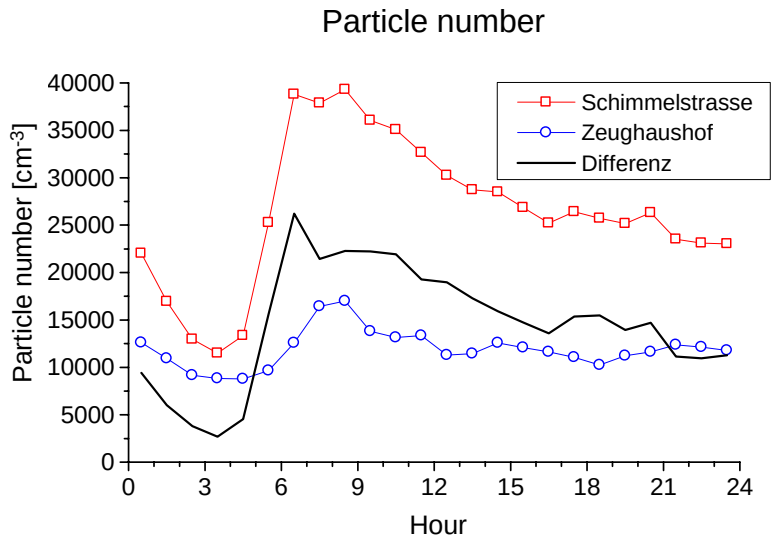
Monitoring German Highway

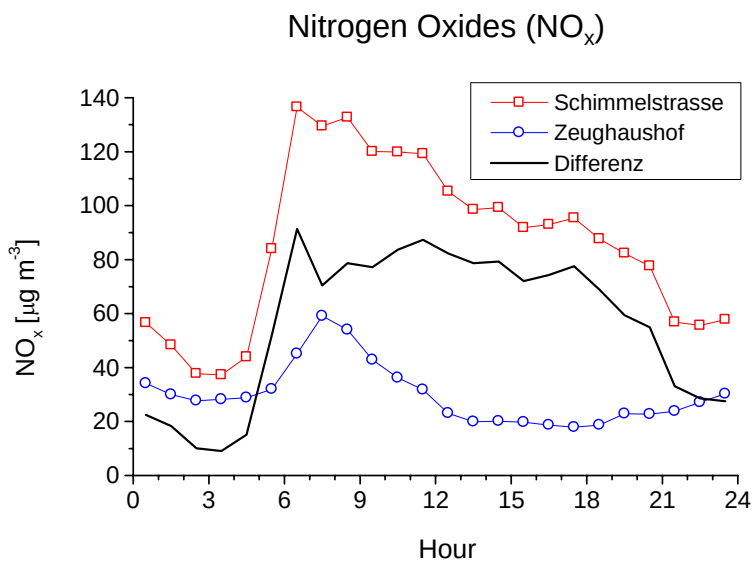
1987-2004

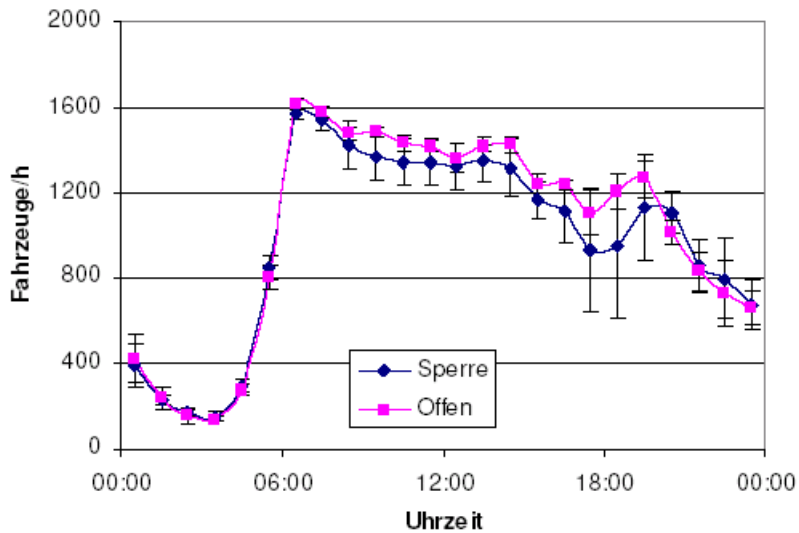
Source: UBA, Umwelt Bundesamt

Transit Road Schimmelstrasse Zürich

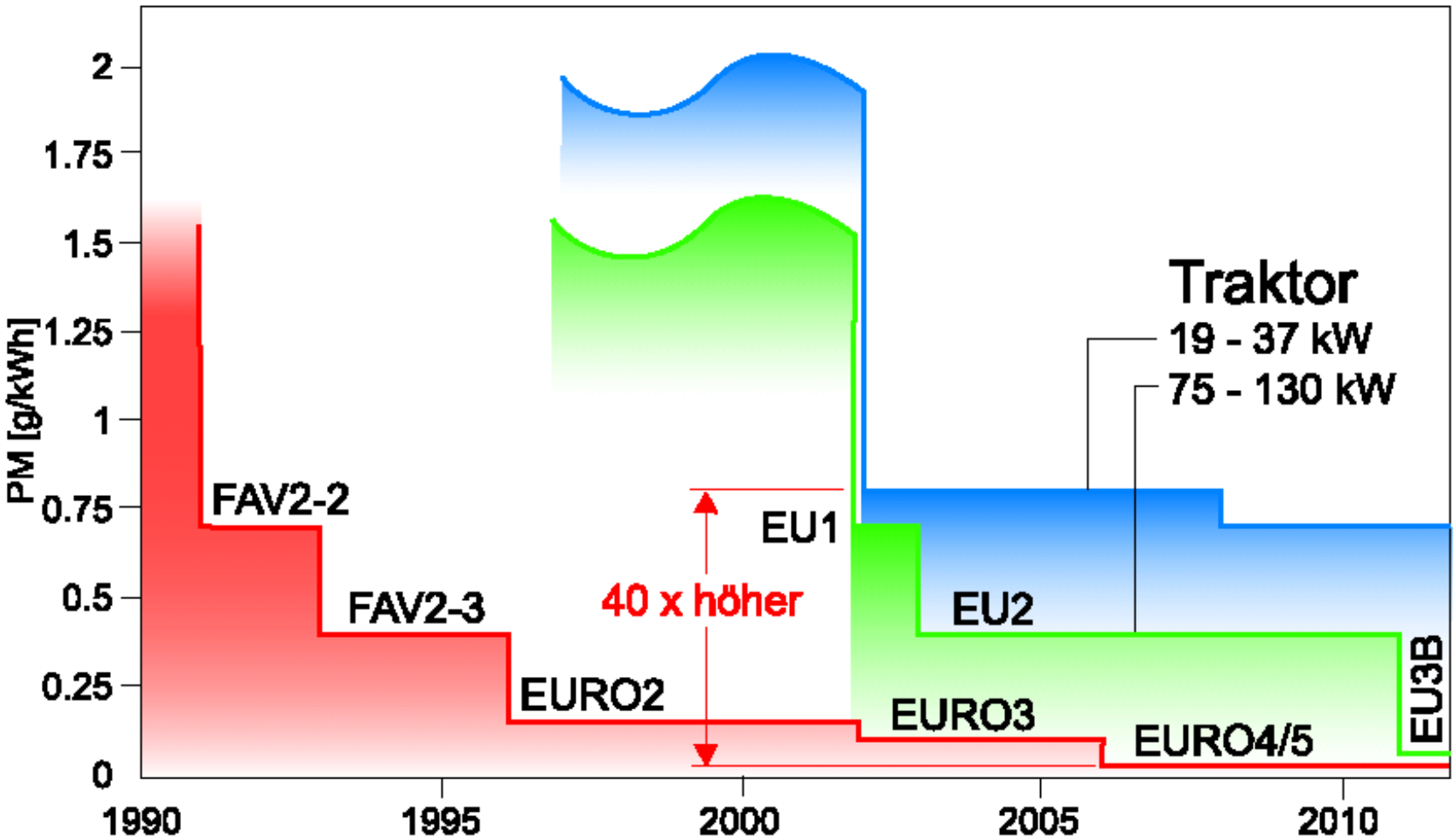






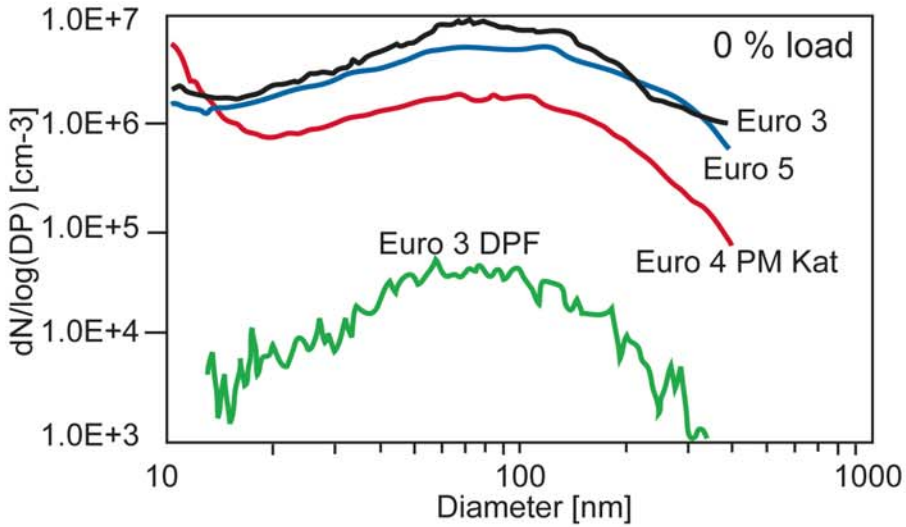


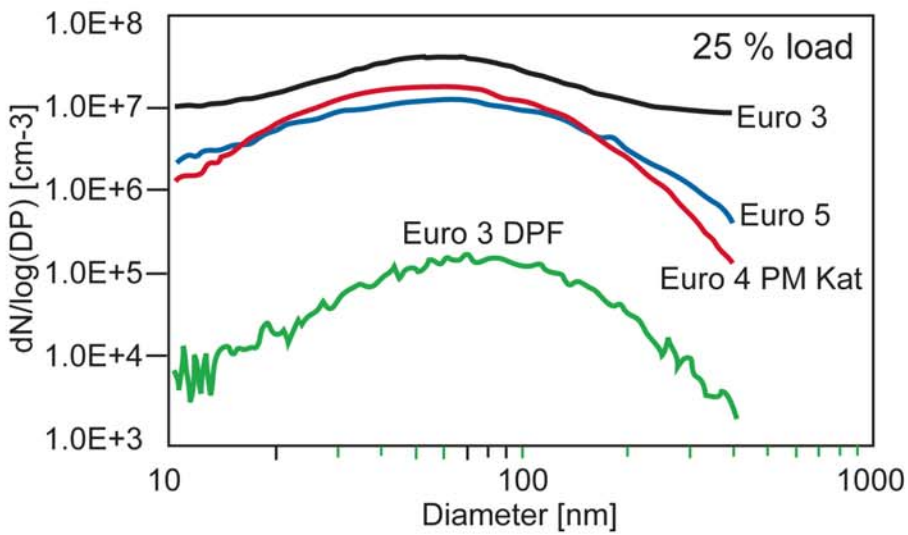
Entwicklung der Emissions-Grenzwerte

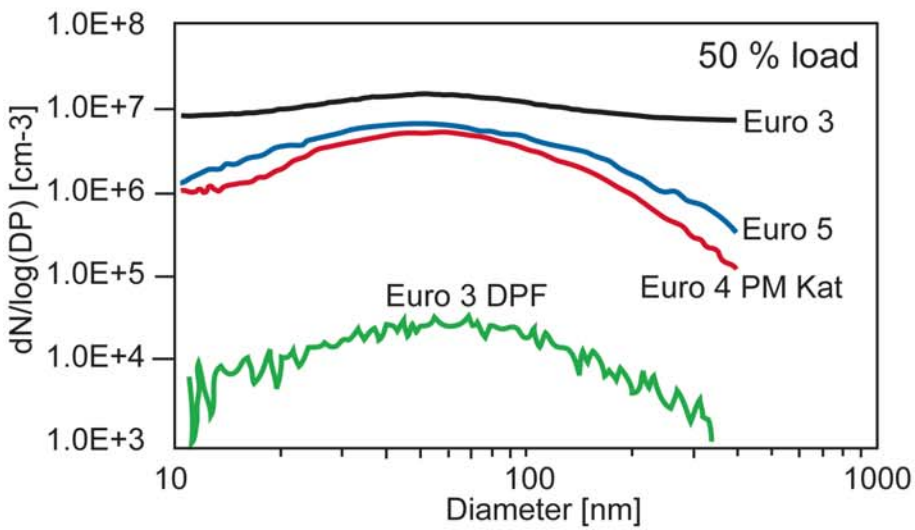


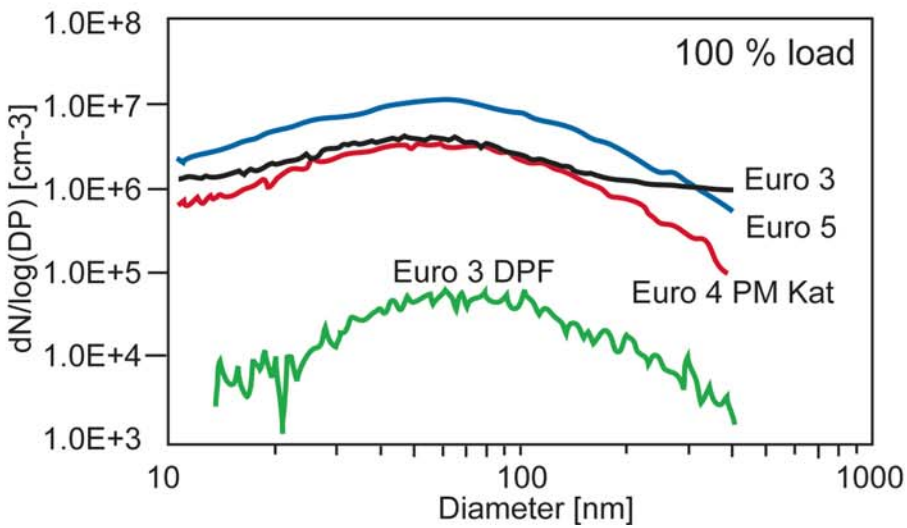
Particle-Emissions EURO 3/4/5 bei 1400 U/min

EURO4: EGR+PM-Kat; EURO5: SCR - no DPF in Europe

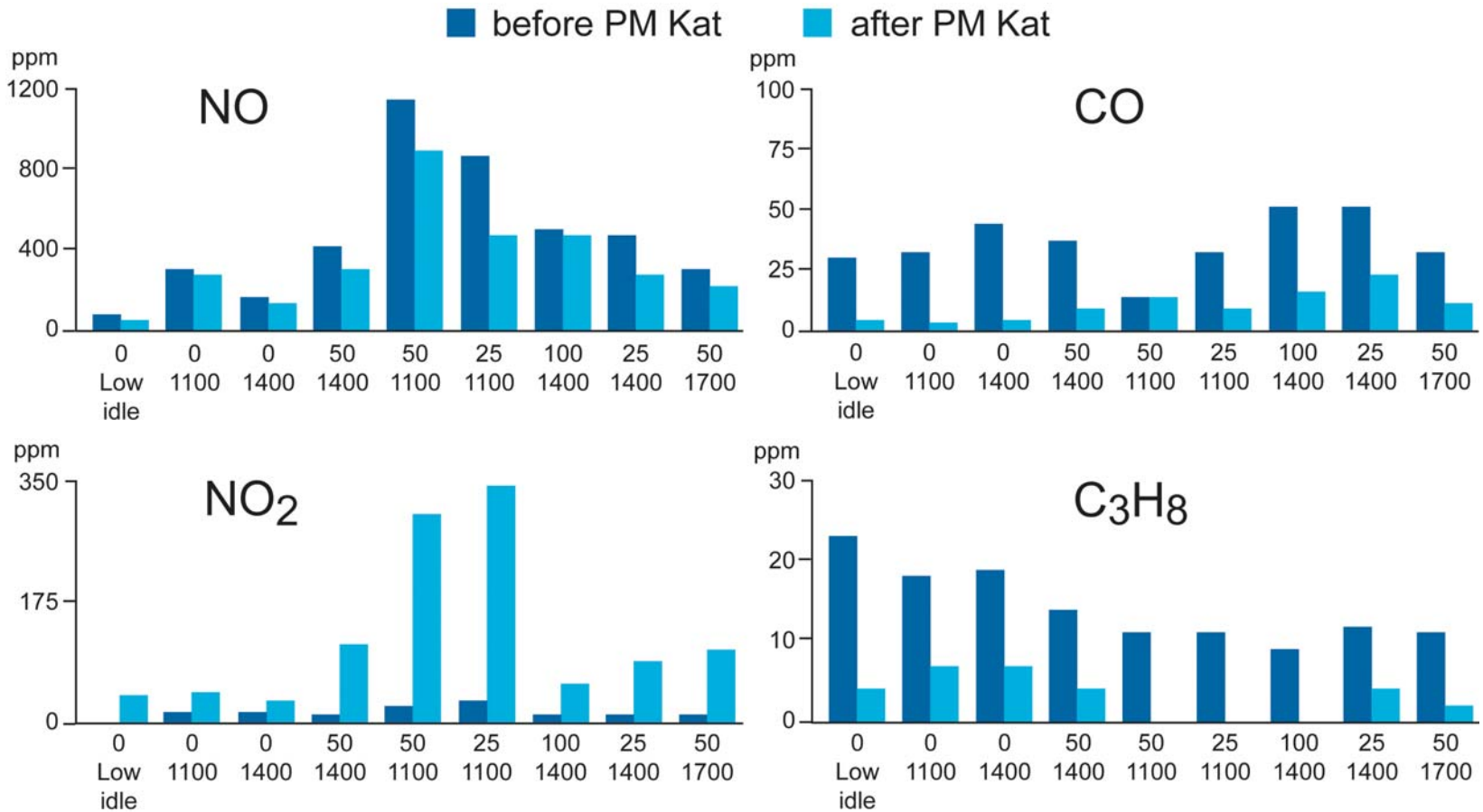




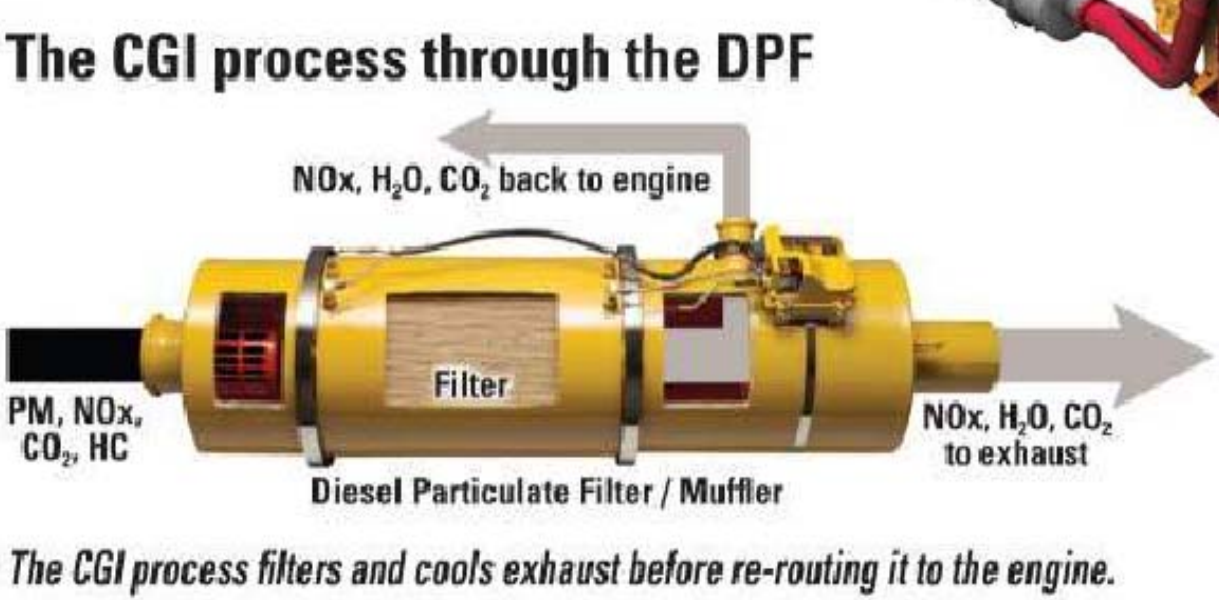




Gaseous Emissions Euro 4 [ppm]

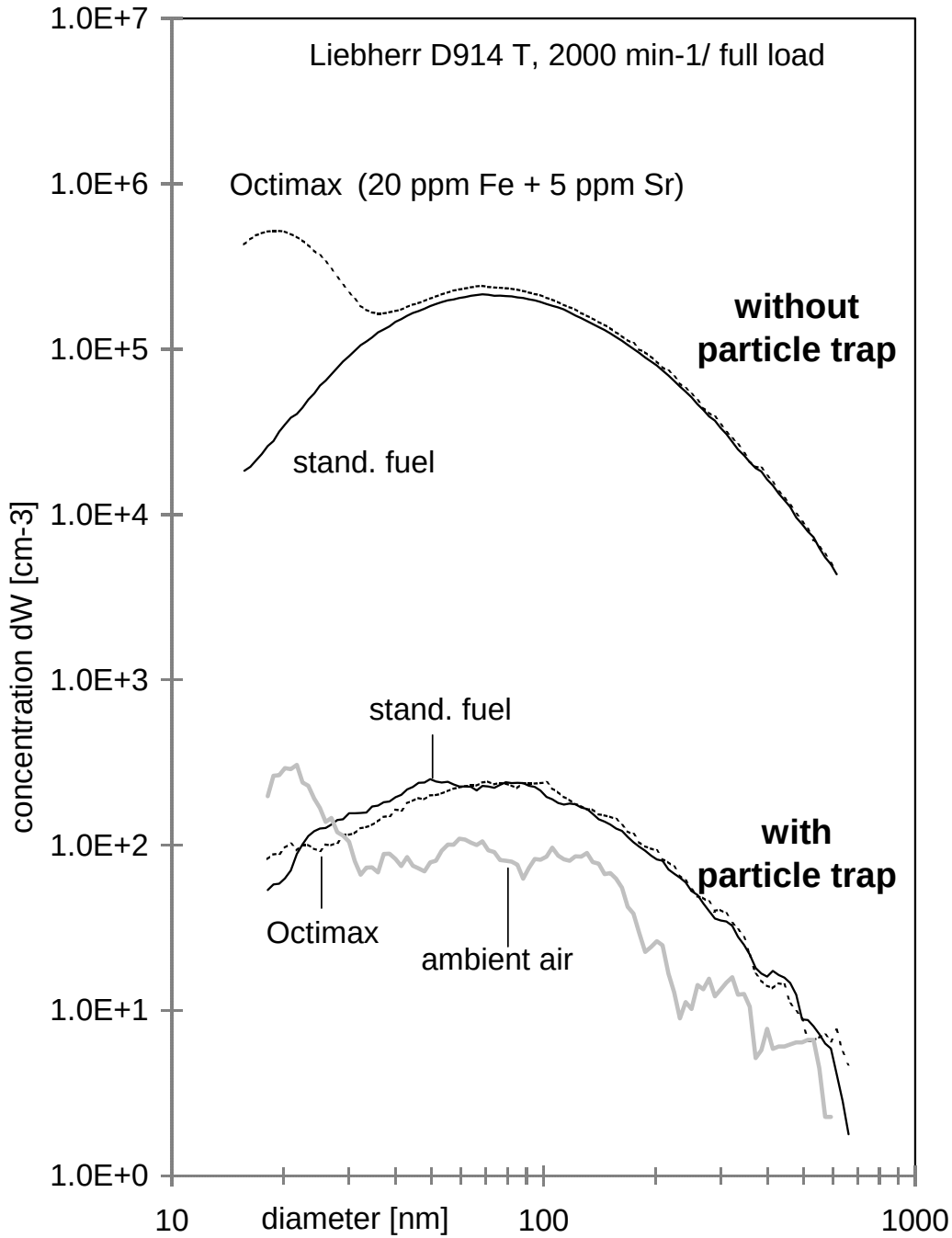


US-HDV-Technology 2007 is different: DPF + EGR



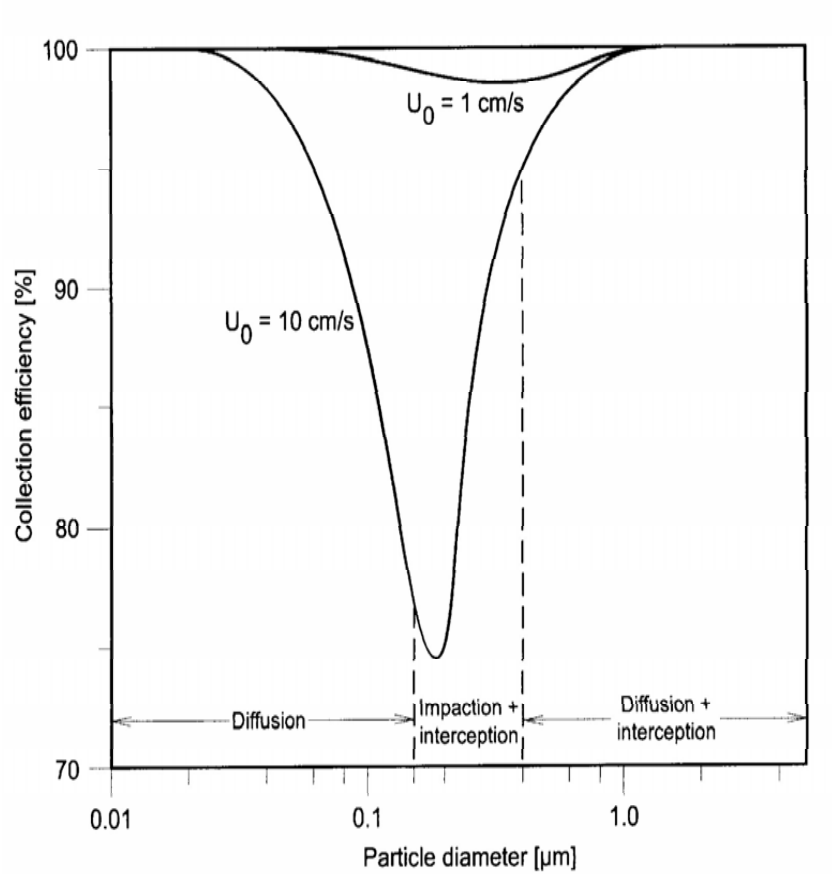
Particle Elimination

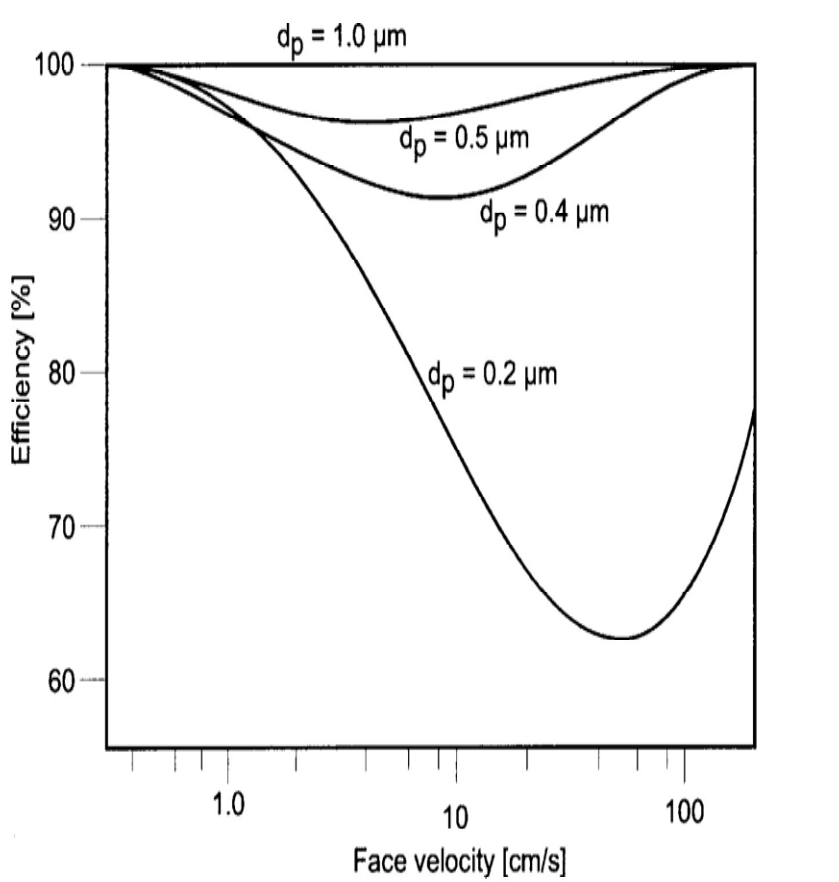
with CORNING-Filter and Fe-FBC



Not all Filters are good Filters

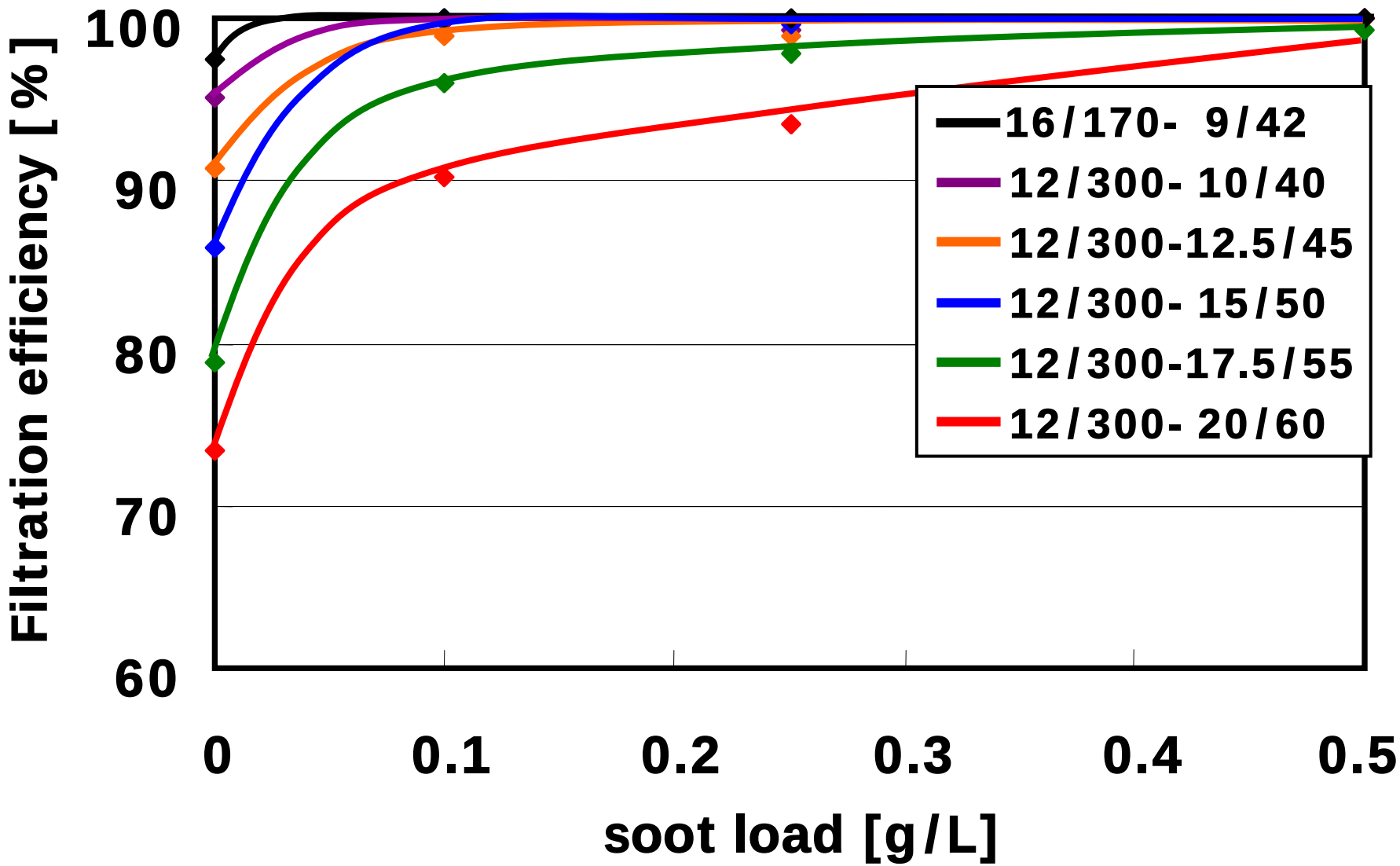
Particle Size matters



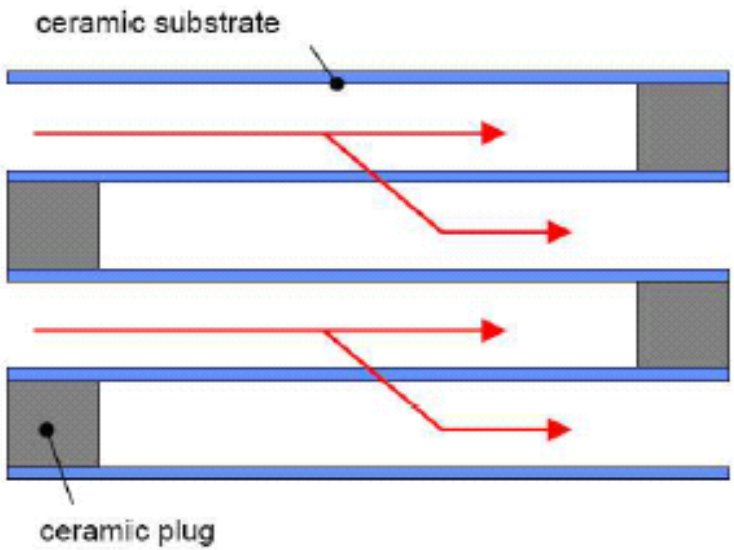


Filtration = f (Time, Soot-Loading)

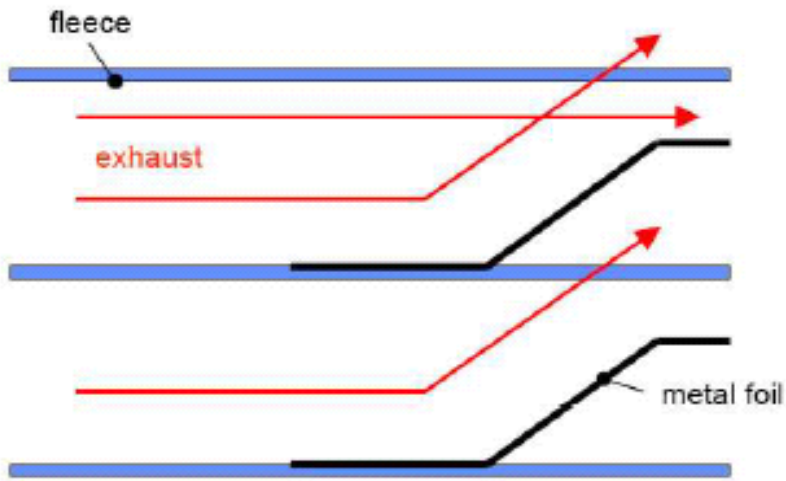
Source: IBIDEN HDT-Seminar 2006



Filters DPF and Partial Flow Systems PMS



- **ceramic substrate** (e.g. silicon carbide, cordierite, alumina titanate) as wall flow monolith, possibly coated
- soot is stored inside the channels
- regeneration is necessary in regular intervals, depending on e.g. exhaust gas backpressure, exhaust gas temperature, soot loading of DPF
- **particulate reduction: > 90%**

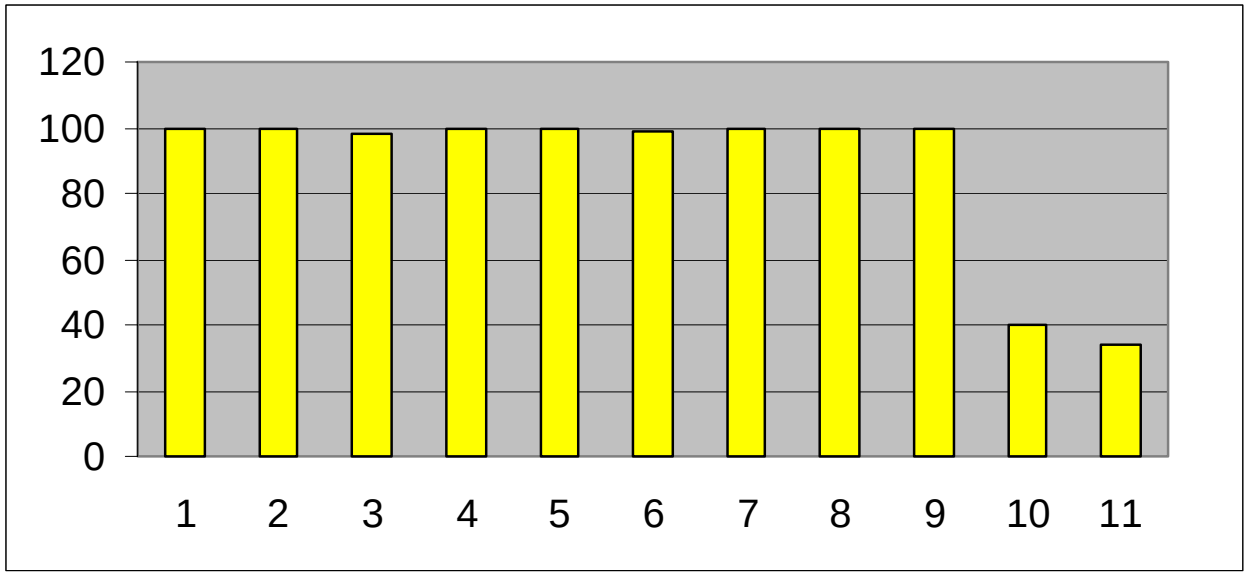


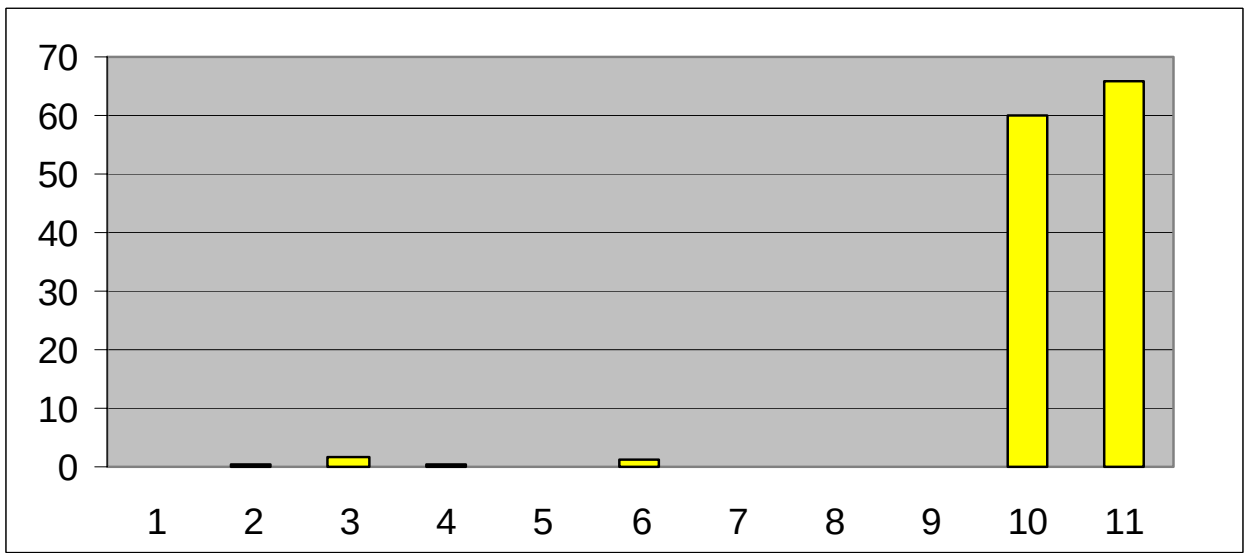
- corrugated, helical **metal foils** with open channels, catalytically coated
- should the fleece be plugged with soot, exhaust flows through open channels (particulate reduction is then zero)
- **thermal regeneration** is not necessary
- typ. average **particulate reduction: 30%**
- Manufacturers: e.g. Emitec, Oberland Mangold, Ecocat

Filtration
or
Emission

3 x less
Filtration
oder
3000 x more
Emission

what counts ?





Schweizer Regel
Règle Suisse
Regola Svizzera
SNR

INB Interdisziplinärer Normenbereich
Secteur interdisciplinaire de normalisation

SNR 277205

EINGETRAGENE NORM DER SCHWEIZERISCHEN NORMEN-VEREINIGUNG SNV NORME ENREGISTRÉE DE L'ASSOCIATION SUISSE DE NORMALISATION

Ausgabe/Edition: 2007-09

Prüfung von Partikelfiltersystemen für Verbrennungsmotoren

Test de systèmes de filtres à particules pour moteurs à combustion

Collaudo di sistemi di filtri antiparticolato per motori a combustione

Testing of Particle Filter Systems for Internal Combustion Engines

Für diese Norm ist in der Schweiz das nationale Komitee «VERT Partikelfilter» des interdisziplinären Normenbereiches zuständig.

En Suisse la présente Norme est de la compétence du comité national «VERT systèmes de filtres à particules» du Secteur interdisciplinaire de normalisation

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Swiss New Norm

SNR 277205

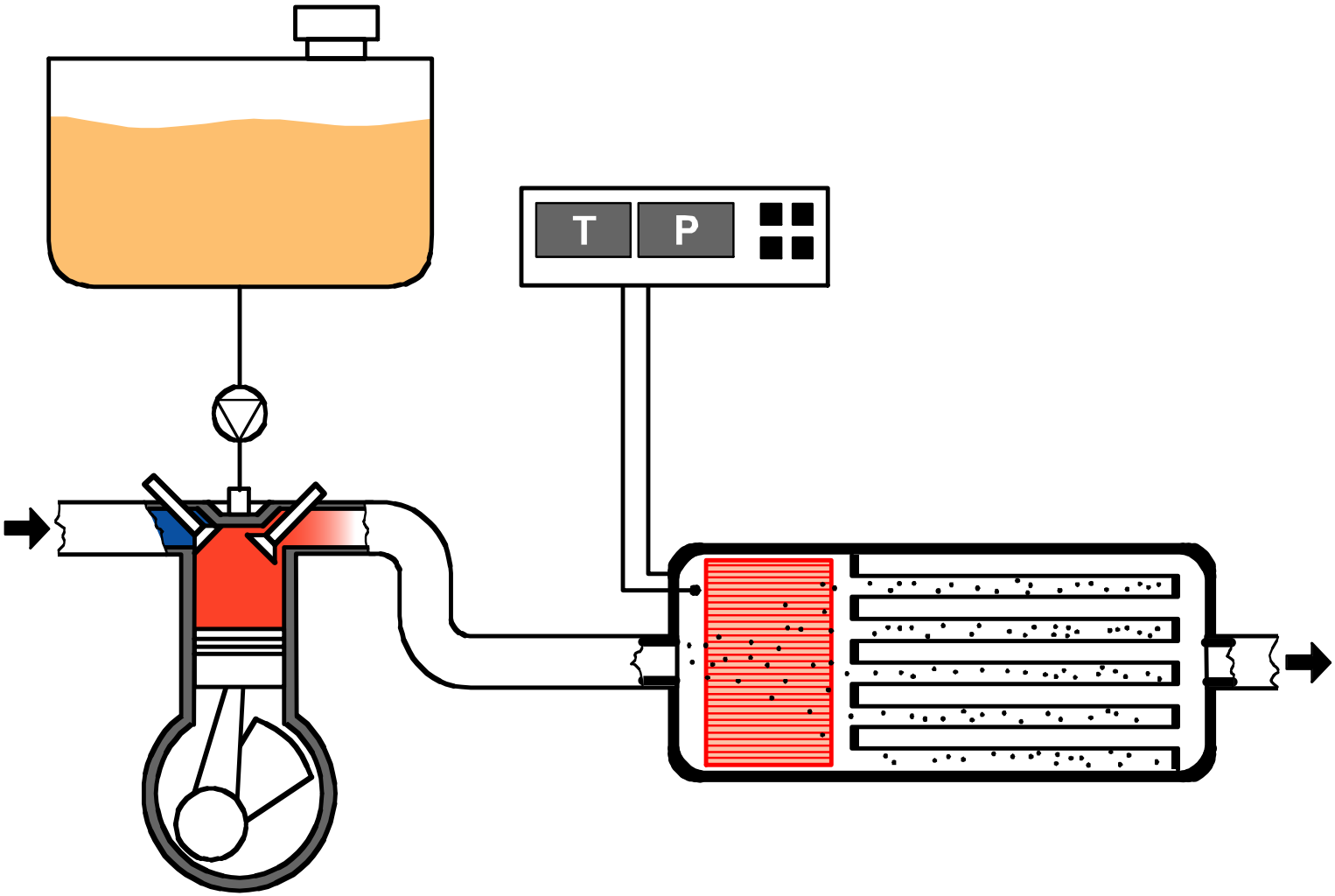
for the Measurement and Certification of Diesel Particle Filter Systems

with Respect to Nanoparticles and Secondary Emissions

ISO-Working Group started

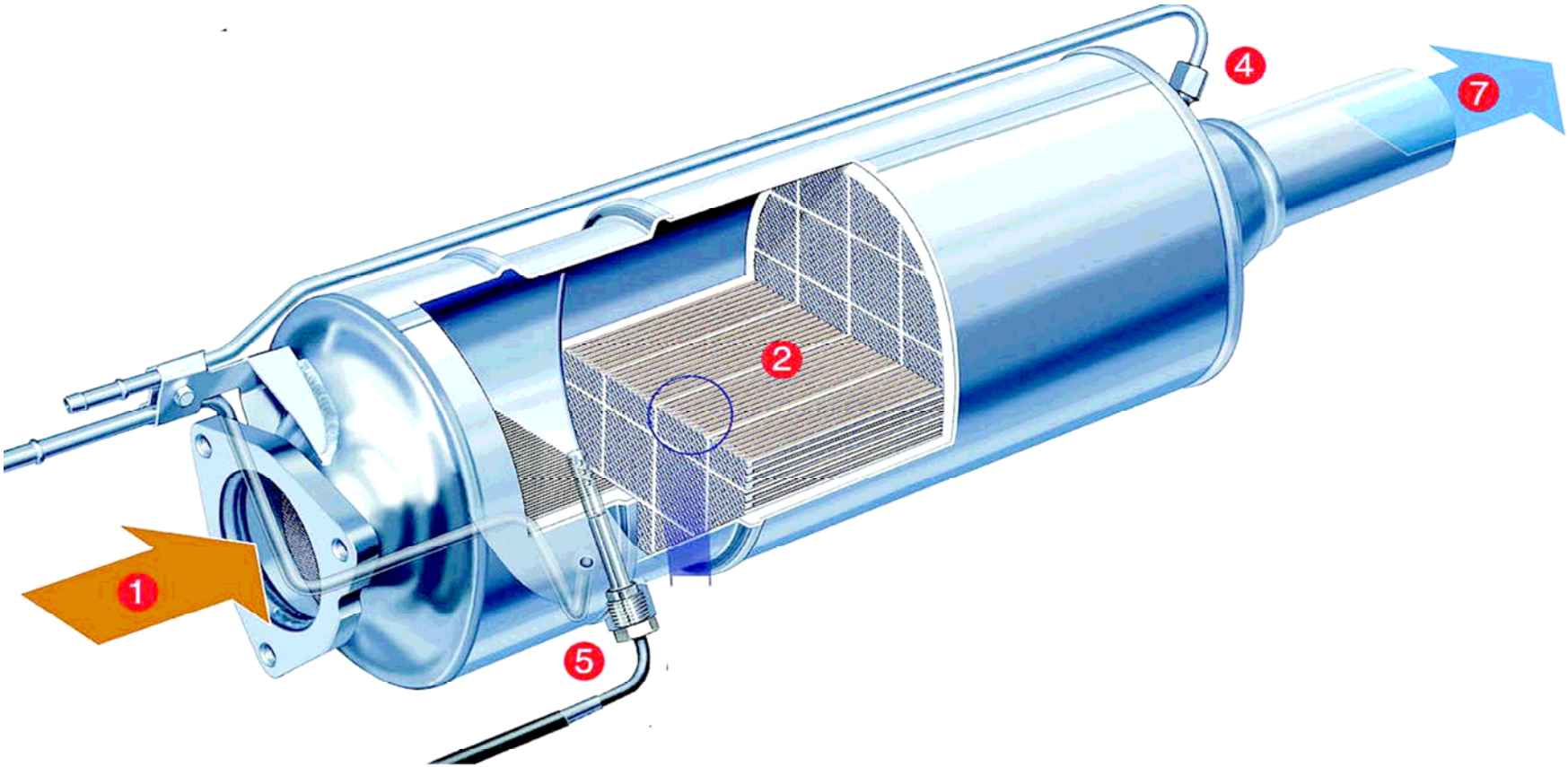
CRT: Passive Regeneration with NO_2 > 230 °C

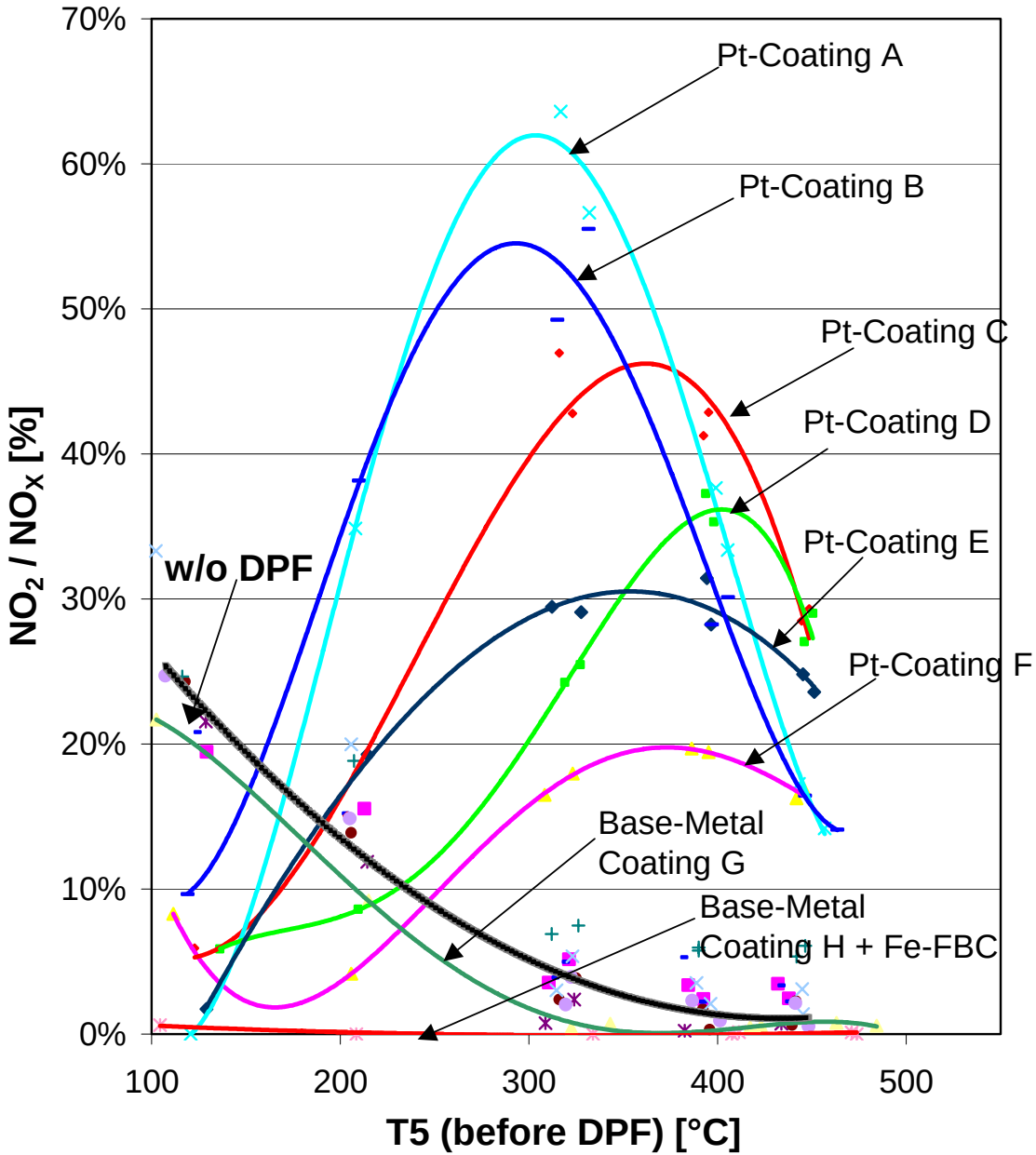
JOHNSON MATTHEY / HJS-DES / EMINOX



CRT-Filter System

Johnson Matthey Patent 1988

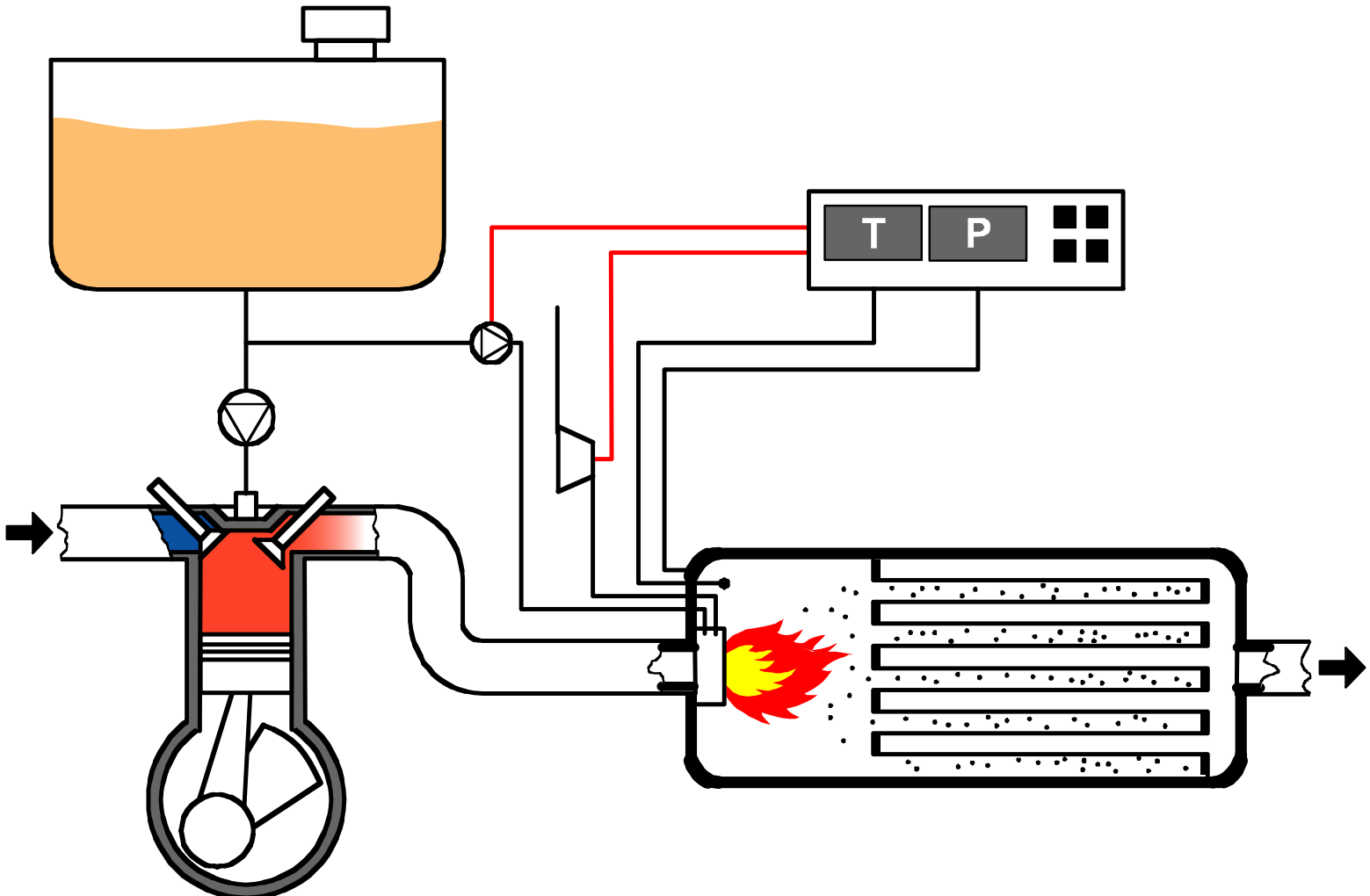




NO_2/NO_X with Pt-Coating or Fe-FBC

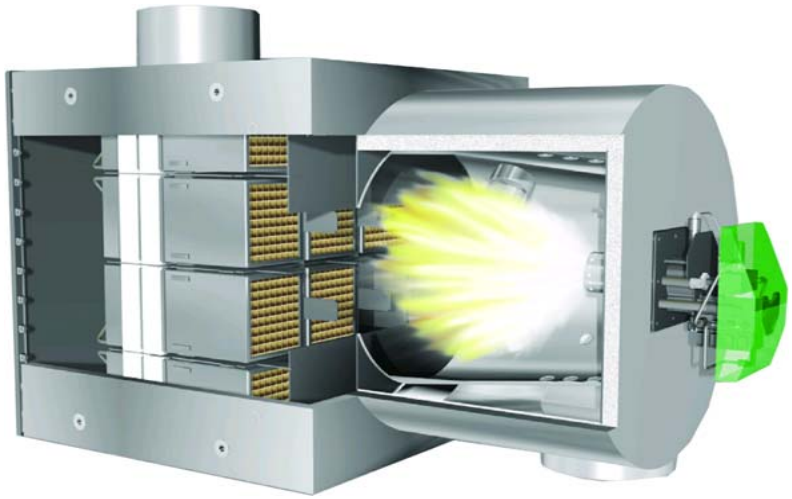
Full Flow- and Standstill – Diesel-Burners

DEUTZ, HUG, ARVIN MERITOR, ATH, HUSS, PHYSITRON



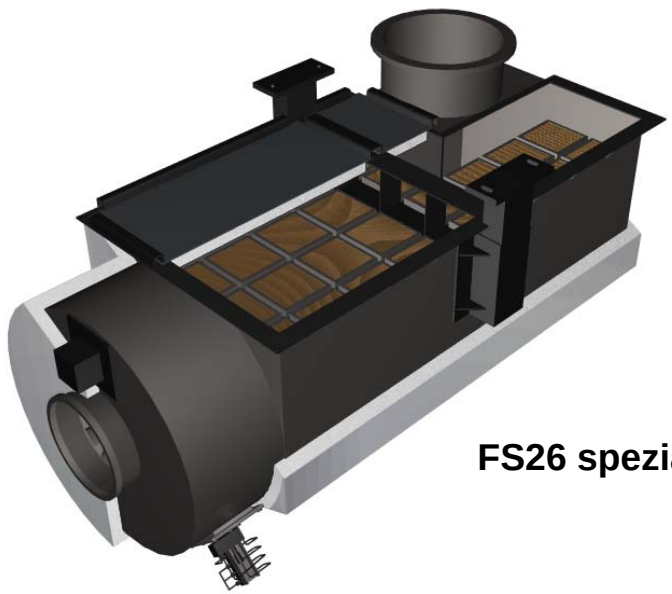
PFS in Locomotives, Ships and Gensets

300 Locomotives 200-3000 kW – up to 50‘000 Bh



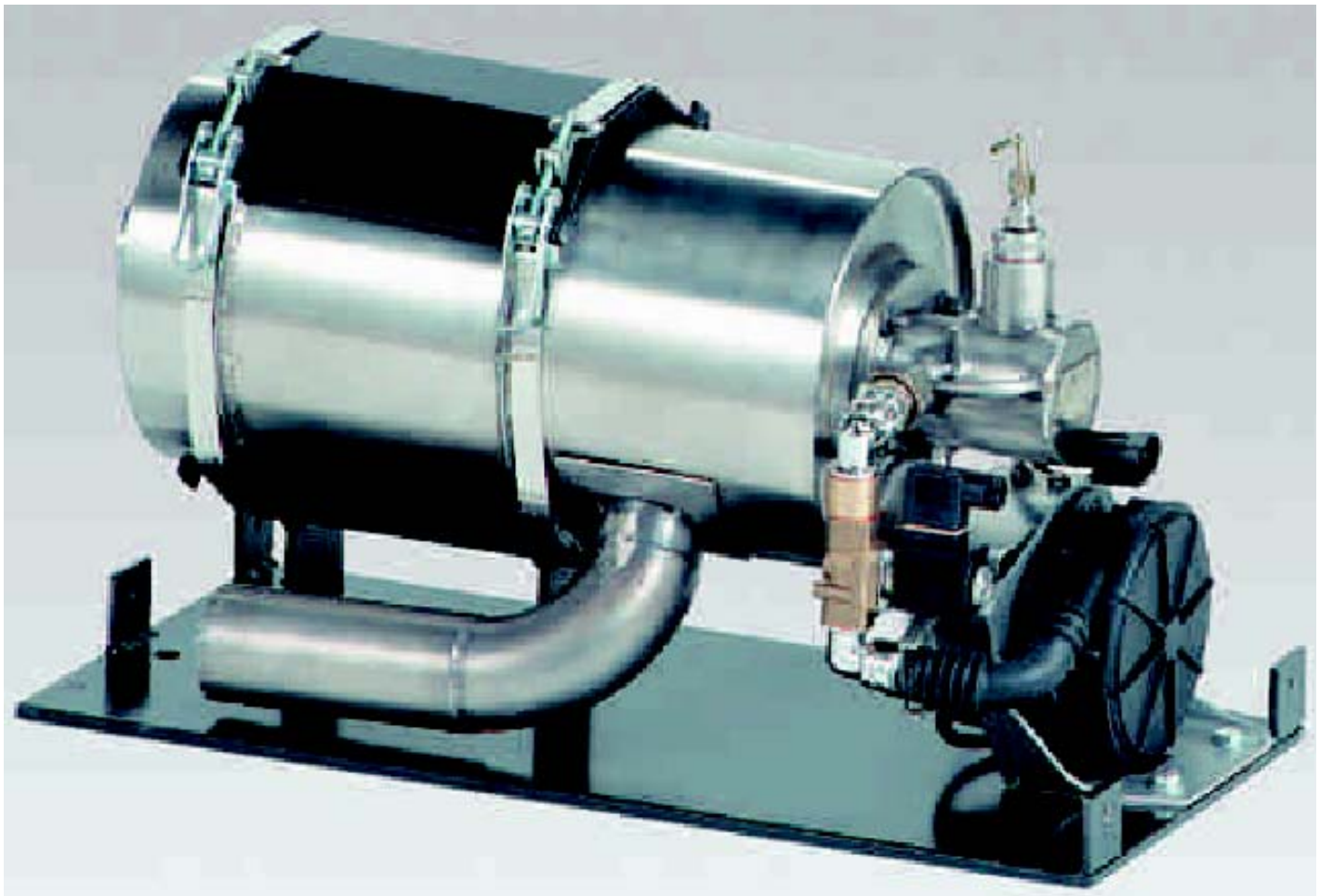
Standard Filtermodul

Restsauerstoff im Abgas:	> 8%
Heizleistungen:	30 – 400 kW
Druckluft > 5 bar:	20 Nm^3/h
Dieselkraftstoff:	3 – 40 l/h
Stromversorgung:	24 VDC



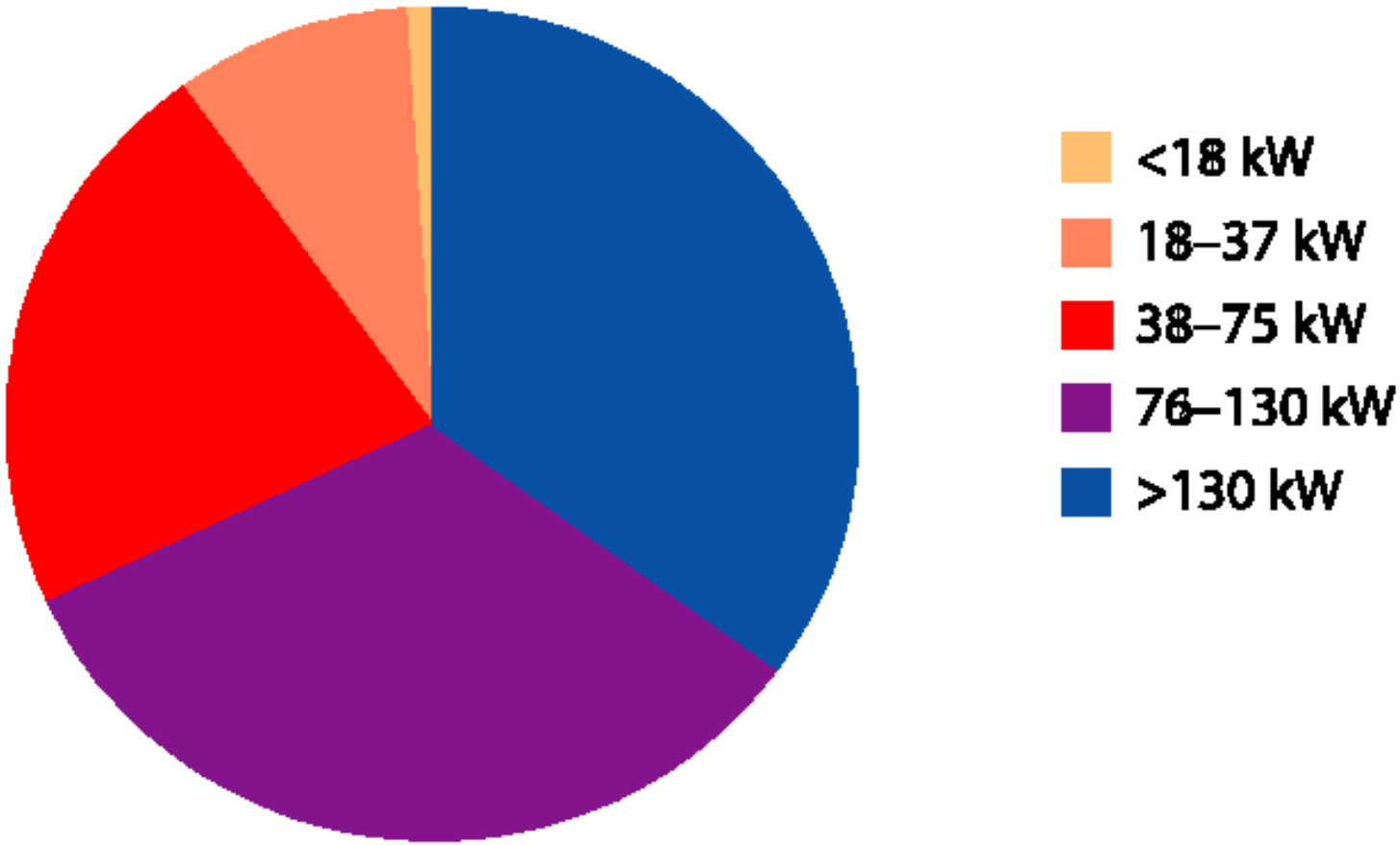
FS26 spezial

HUSS-Standstill-Burner
for small Engines

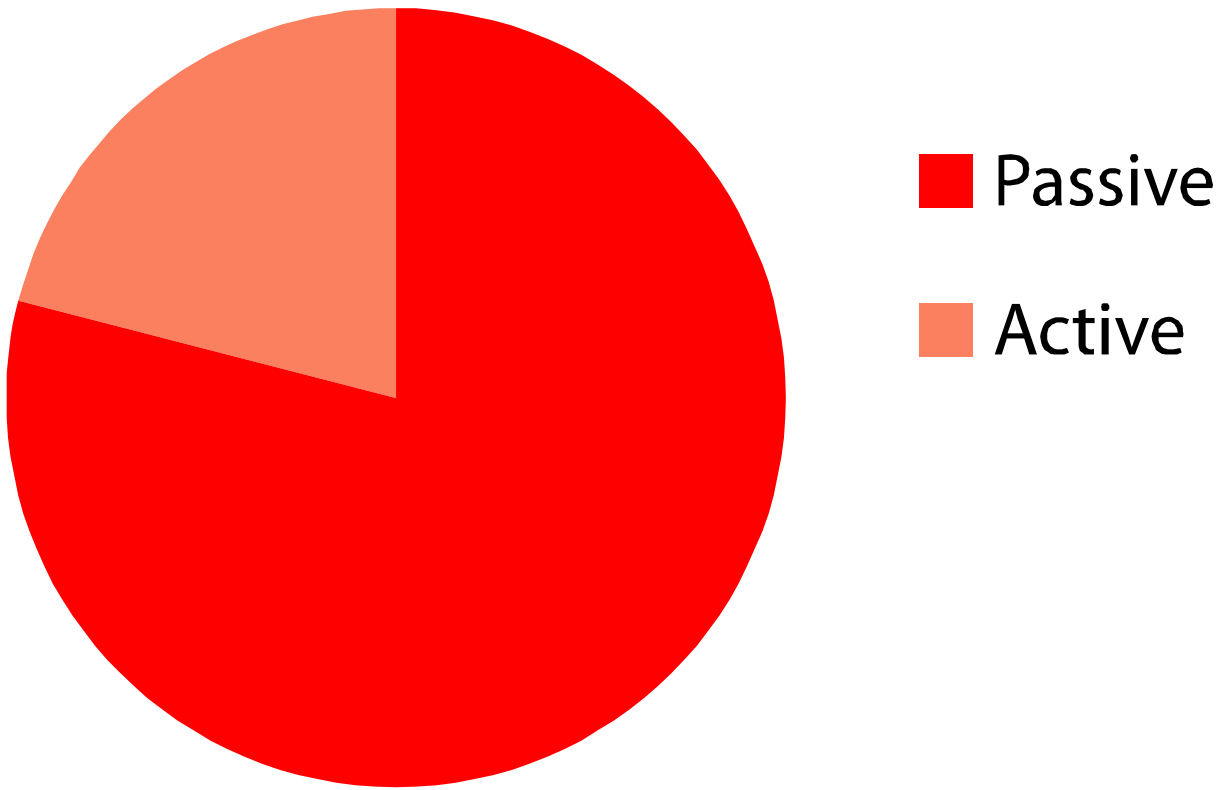


2007 14‘000 PFS bei Baumaschinen

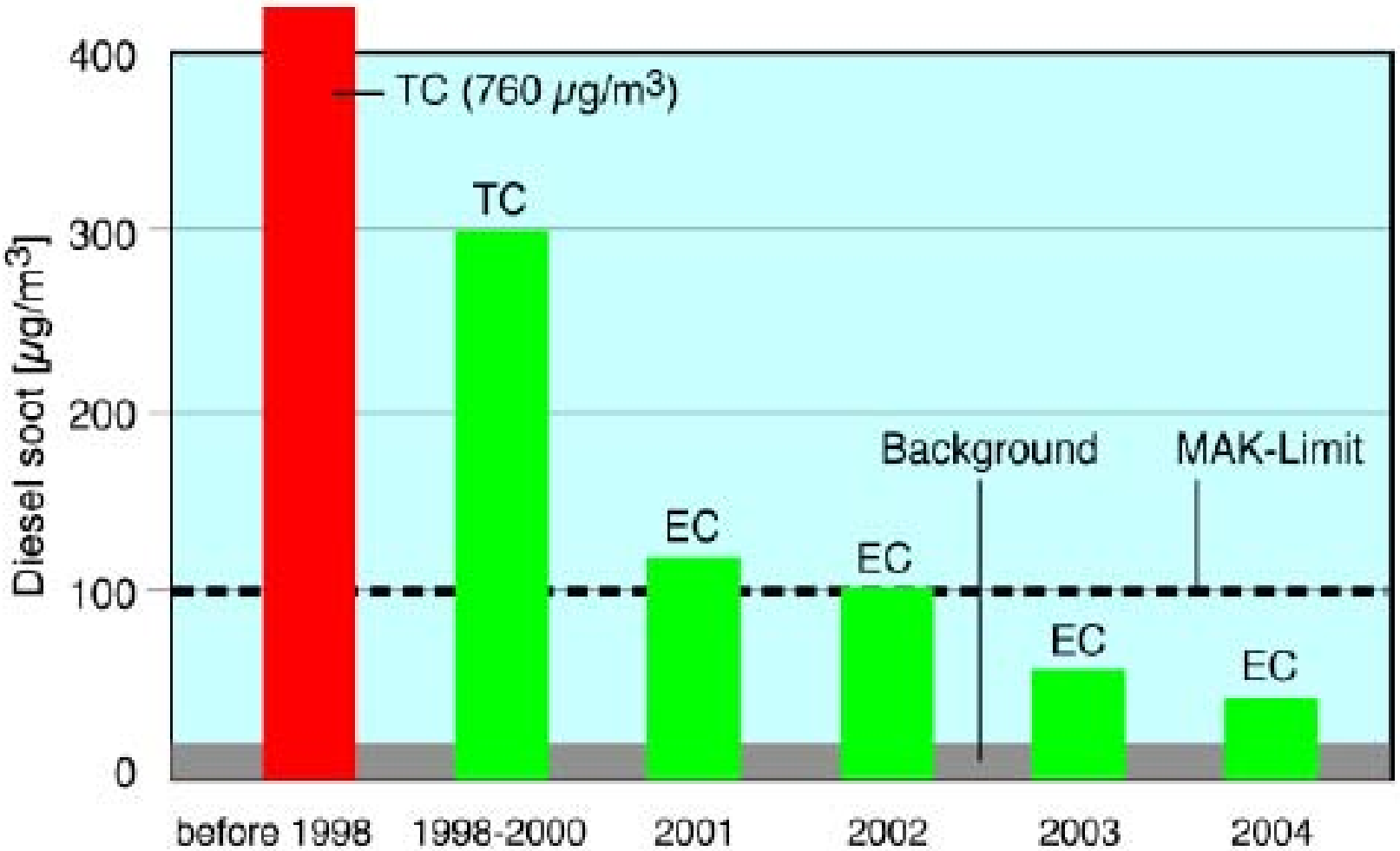
700 Busse, 300 Lokomotiven 500 Gabelstapler, LKW uam



Share of Active Regeneration is growing



In Tunneling every Diesel Engine must have a VERT- certified PFS



Cleaning Air in Swiss Tunneling

by SUVA PFS-Regulation


Radlader Caterpillar 950 G II 137 kw
Motor Caterpillar 3126
PR.mobiclean Typ R 98
950G
CAT
avesco


ZH
62808
20
Bagger Neuson 6503 42.5 kw
Motor Yanmar 4TNV98-VHS
PR-mobiclean Typ R 5.4
PICO


Traktor Fendt 308 C 69 kw
Motor Deutz BF4M2012C
PR-mobiclean Typ K 4,086/400
308 Ci


infra

Interactive CD for Selection of the right Filter for a given Application

Databank with Filter Applications www.akpf.org

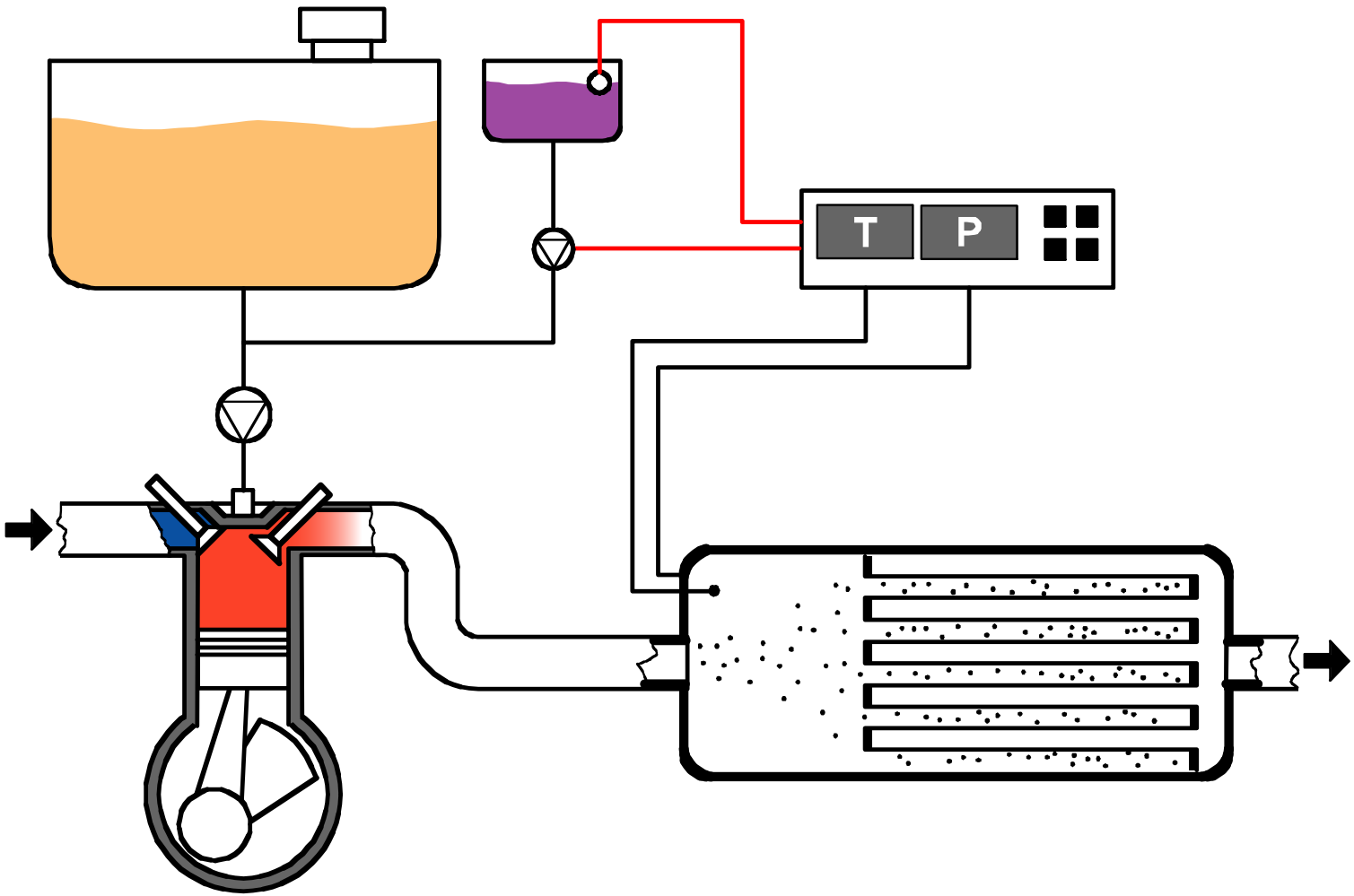
Development-Targets

- Active Regeneration
- no additional NO_2-Emissions
- less bulky
- less costly
- Combination with DeNOx

Passive Regeneration with FBC > 360 °C

EMINOX / AIRMEEX / HUSS / GREENTOP / DAUGBJERG

INTECO / ETB / PIRELLI, PSA



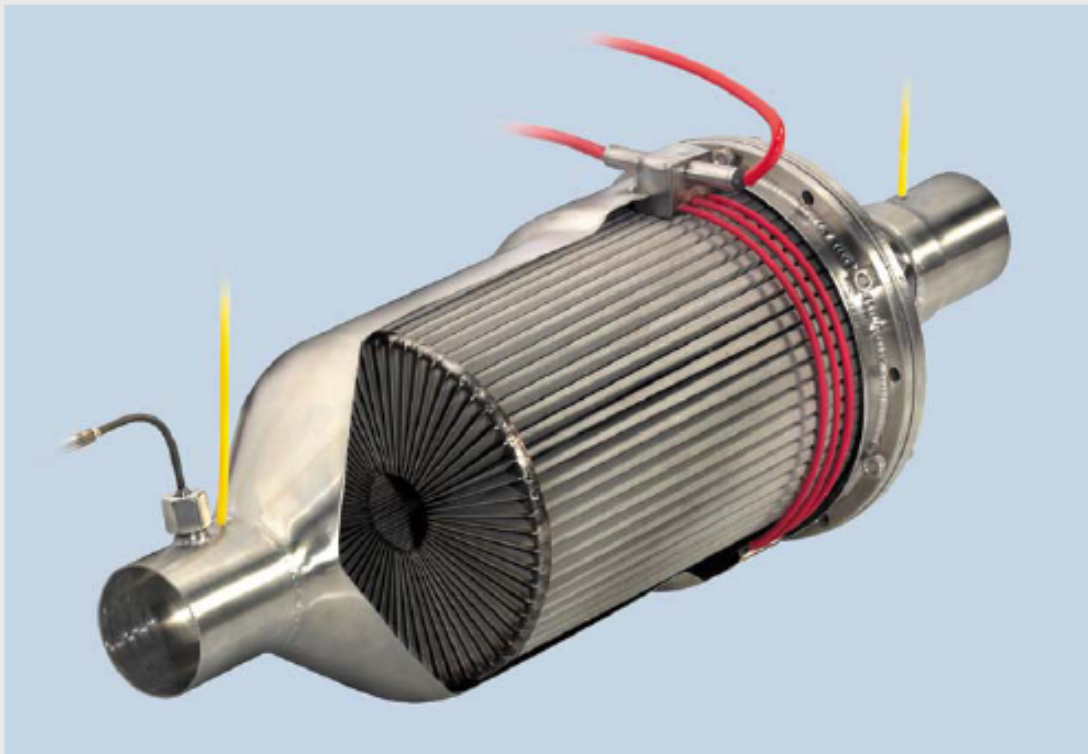
Peugeot with FAP since Y 2000
2,5 Mio Vehicles successful on the Road !

Active Regeneration: Ignition of FE-additized Soot

HJS-DES/ Mann&Hummel

HJS Fahrzeugtechnik GmbH & Co KG

HJS SMF® – System mit autarker Regeneration

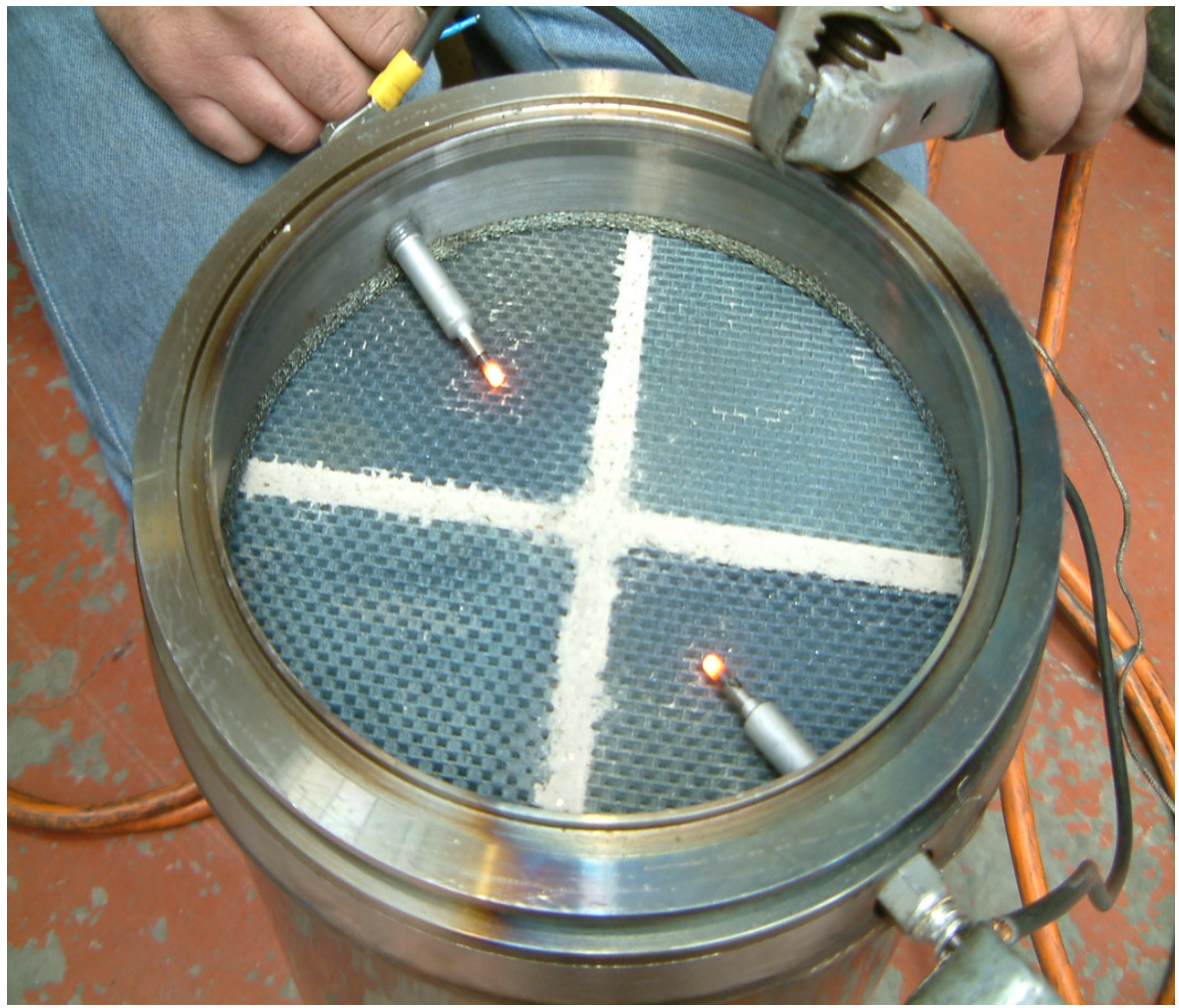


HJS

28.04.9007

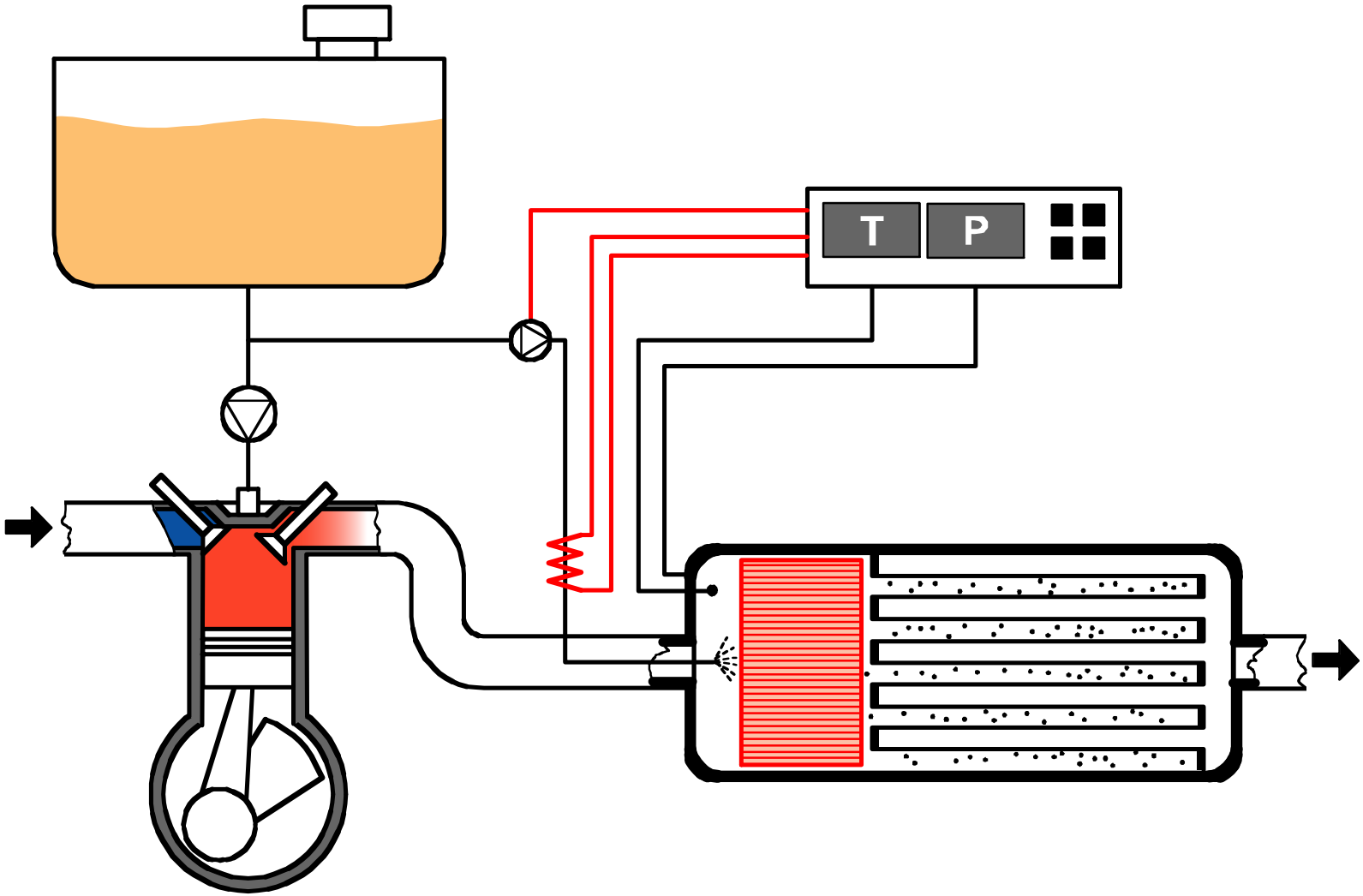
Active Regeneration by EMINOX

- Active Regeneration to suit
  - Older engine technology
  - Off highway applications
  - Low temperature
  - High sulphur fuel
- Robust SiC filters
- Compact designs
- Small additional parts may count



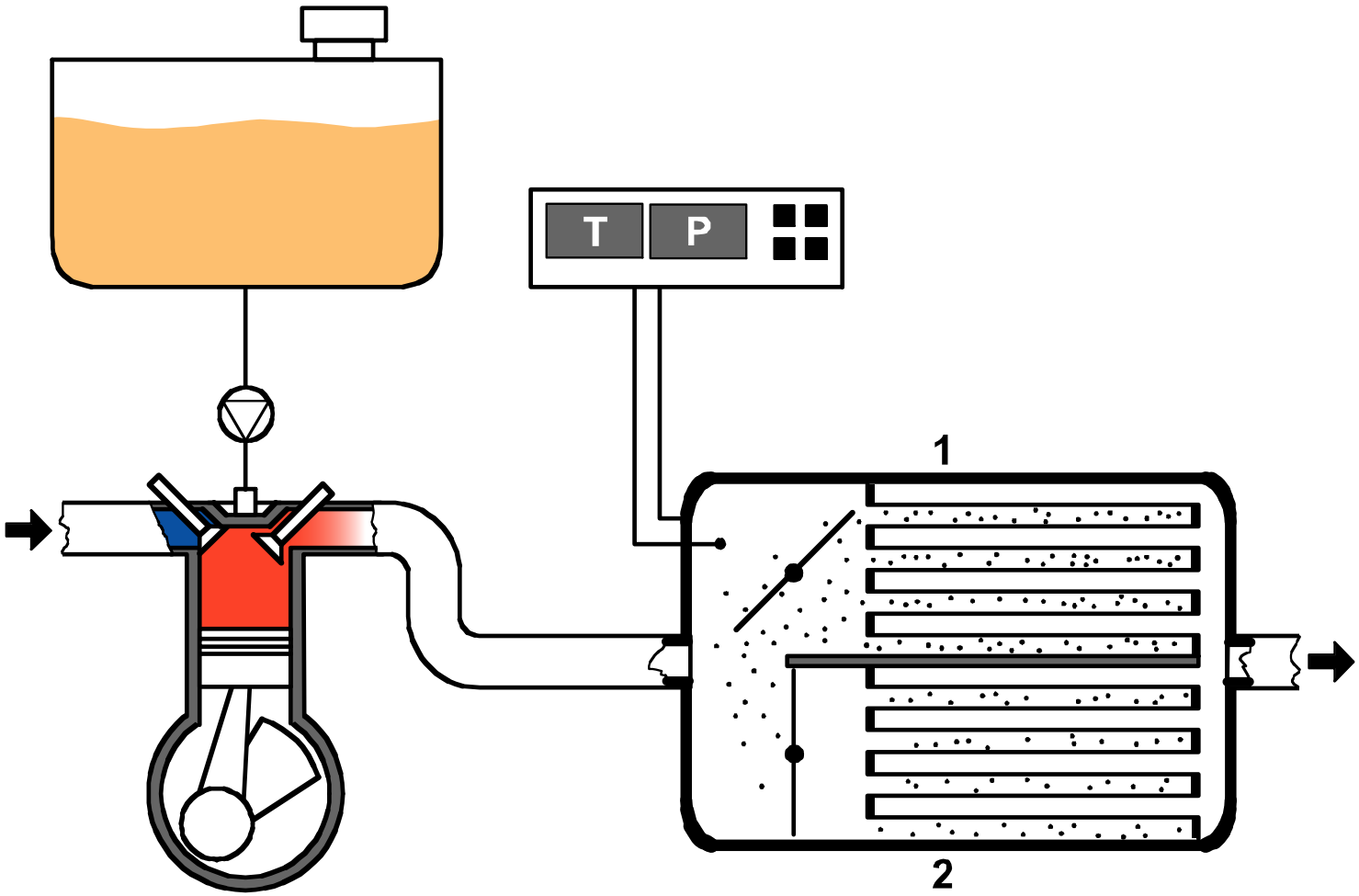
Catalytic Combustion

COMELA, EMT, PURITECH, DONALDSON, EBERSPÄCHER



Heat-Storage and Heat Management

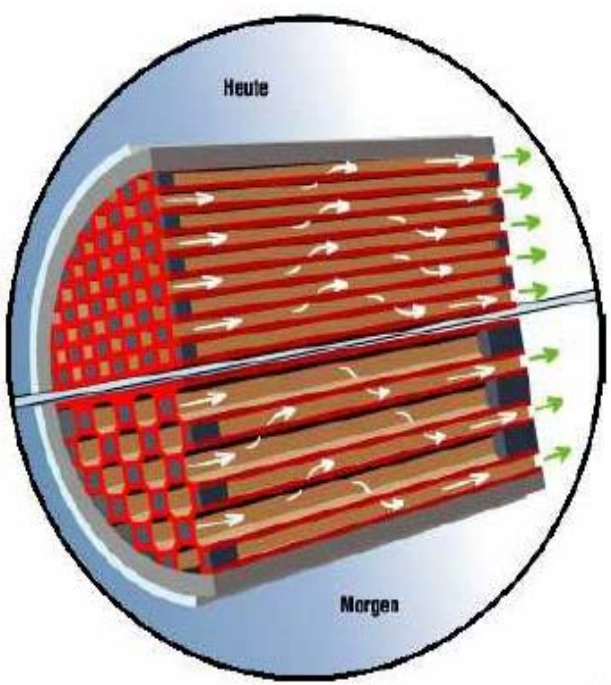
COMELA, MAN, ENWA



Paper-Filters (< 300°C)

Endeavour, Ahlstrom – Useful Life 6’000 – 10’000 km

„Octosquare“



« Octosquare », Fa.Ibiden

« Duratrap », Fa. Corning

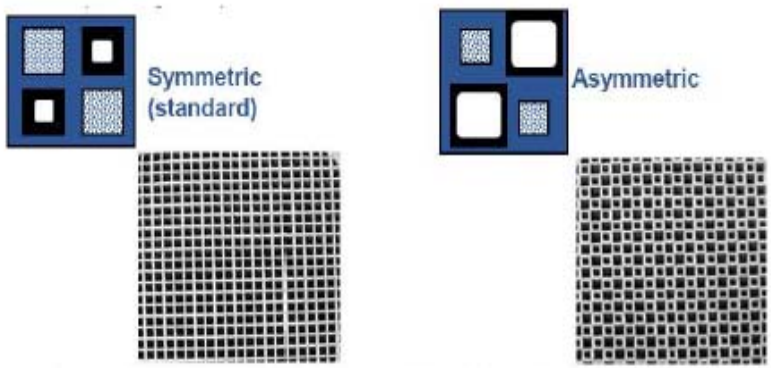
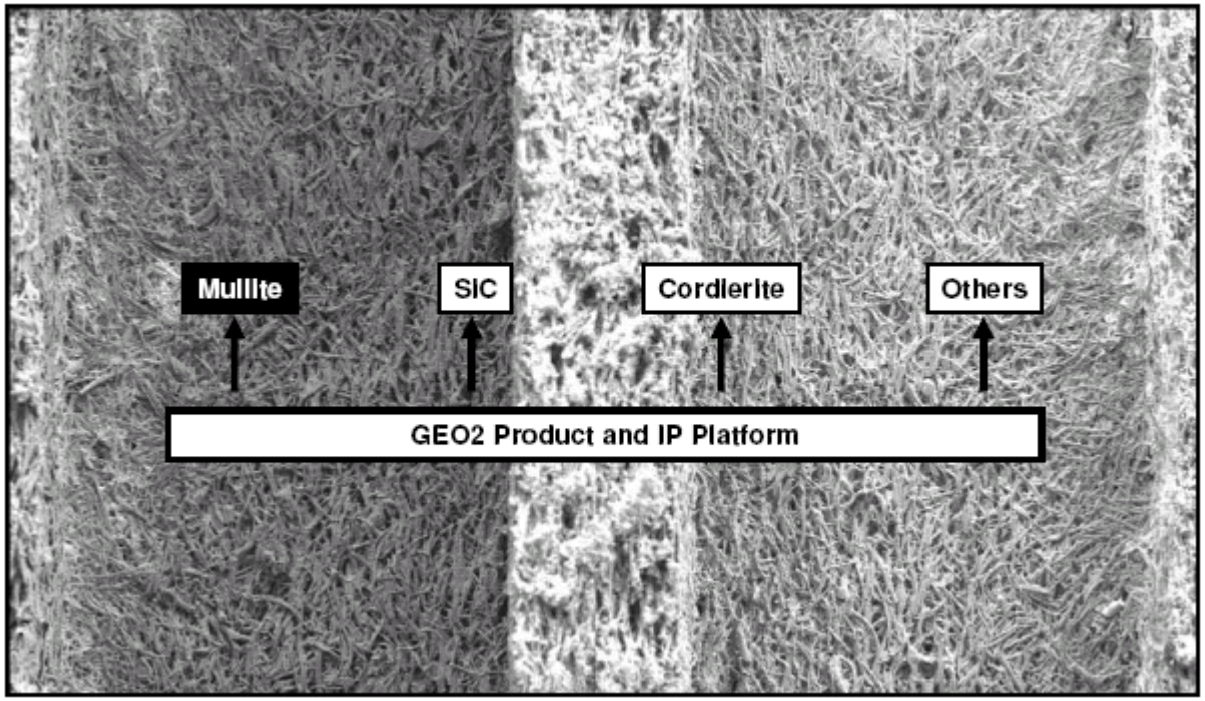
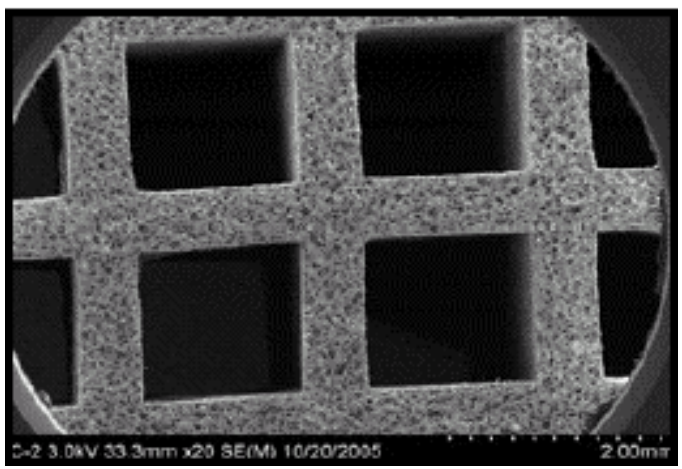


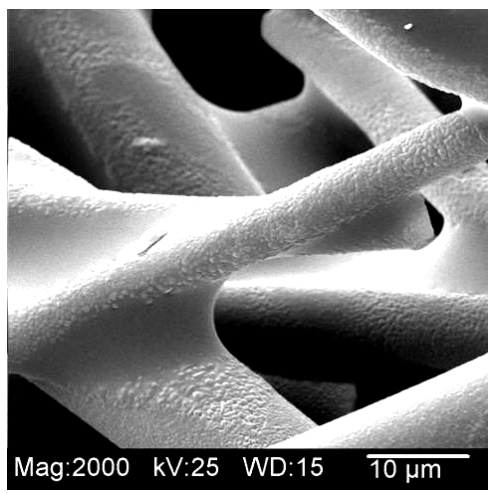
Figure 3: Comparison of a standard (symmetric) cell configuration and Corning´s proprietary Asymetric Cell Technology (ACT). Note, that the pictures show cells without the plugs.

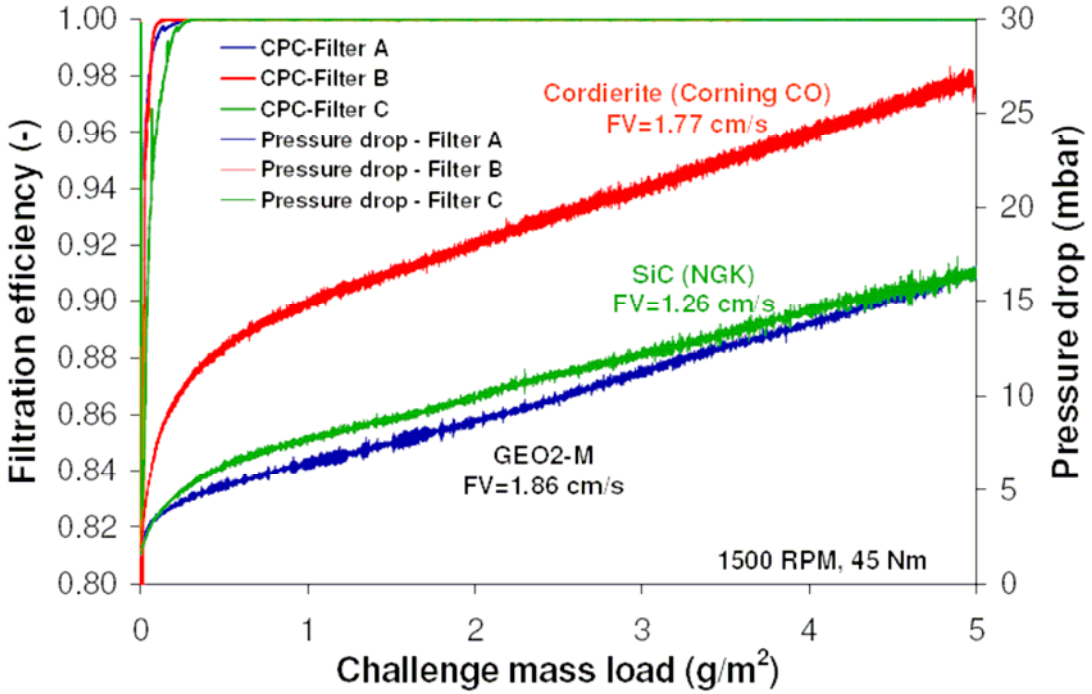


GEO 2

Fiber-Extrusion



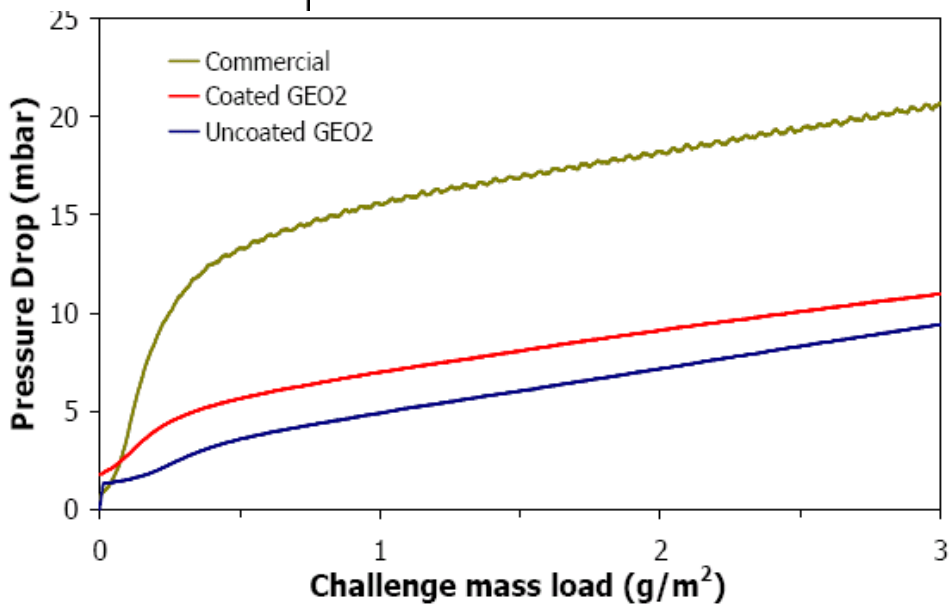




GEO 2

much lower backpressure → smaller

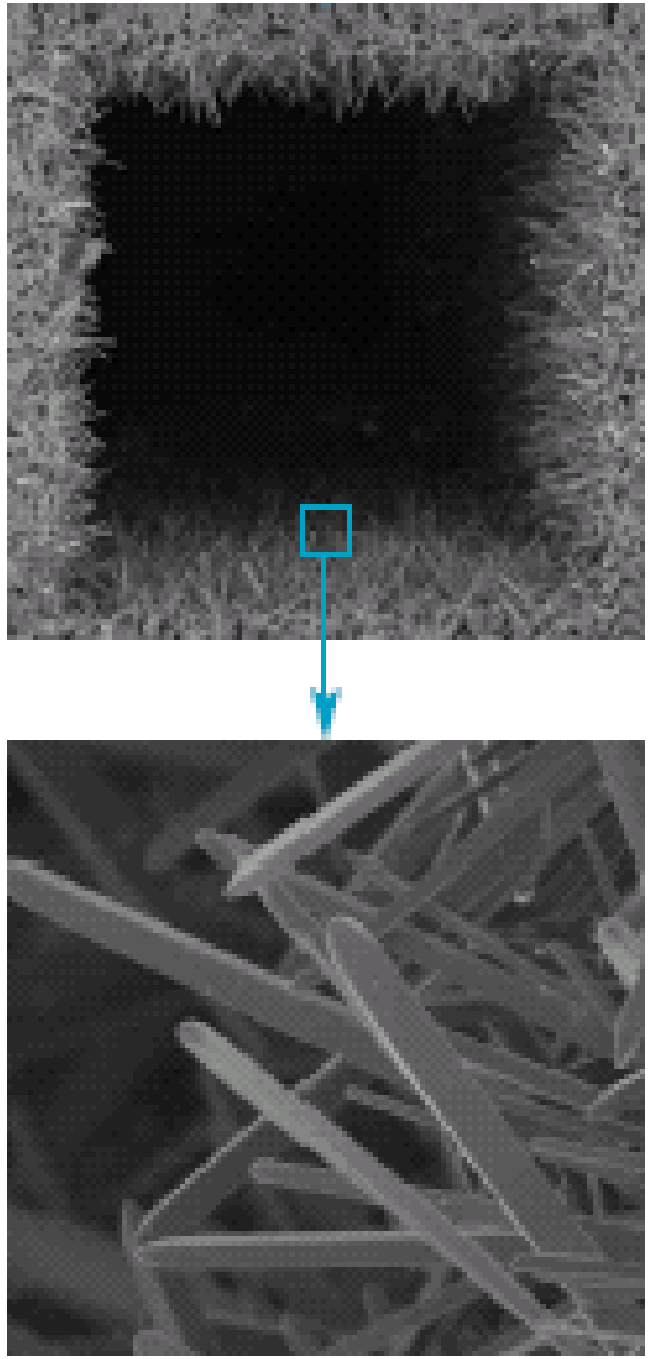
locity: 2 cm/s, Exhaust temperature: 250 C



DOW Automotive

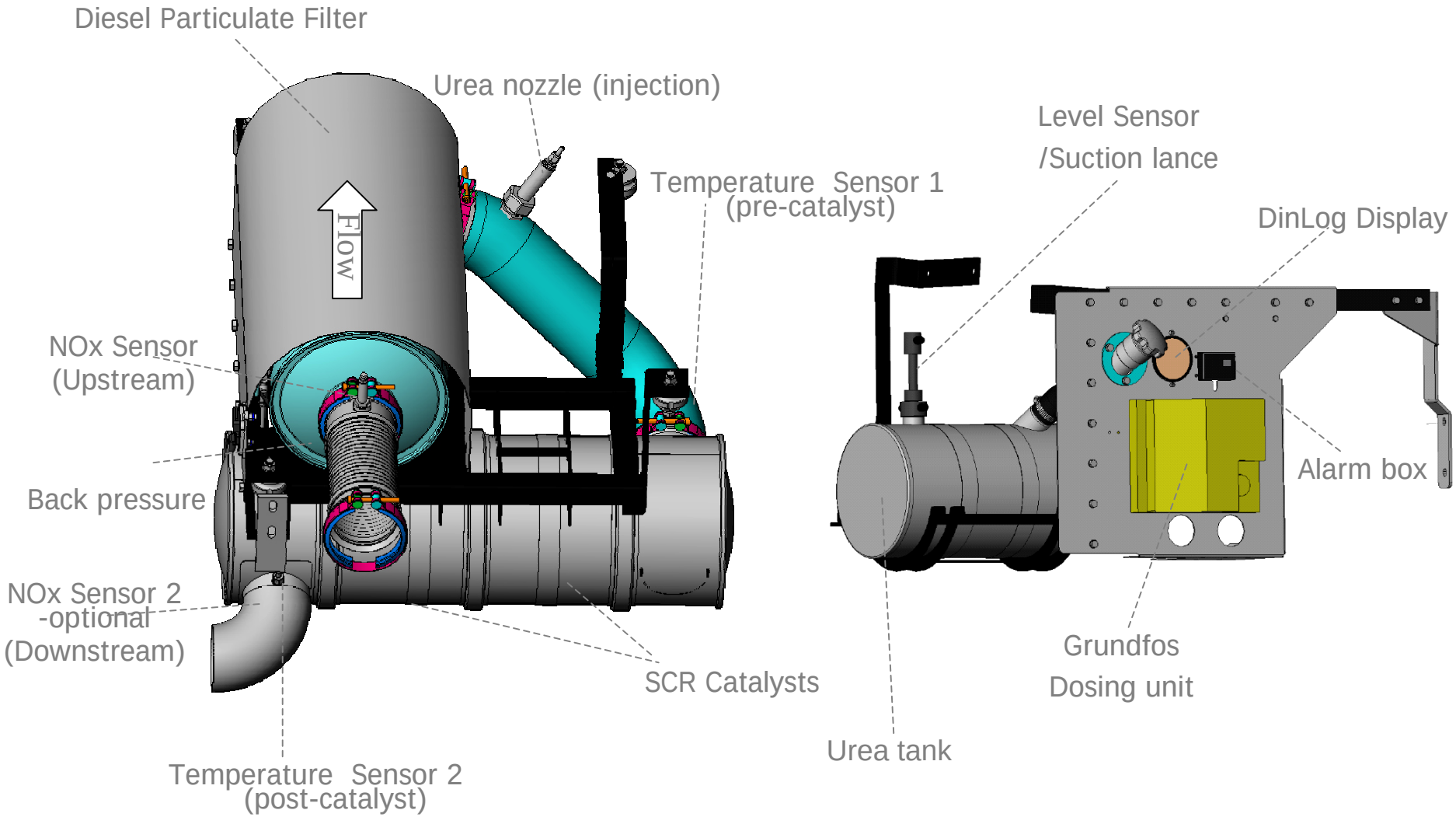
Champion 24h Le Mans 2006 AUDI with DPF

Filter DOW half the size of all competitors



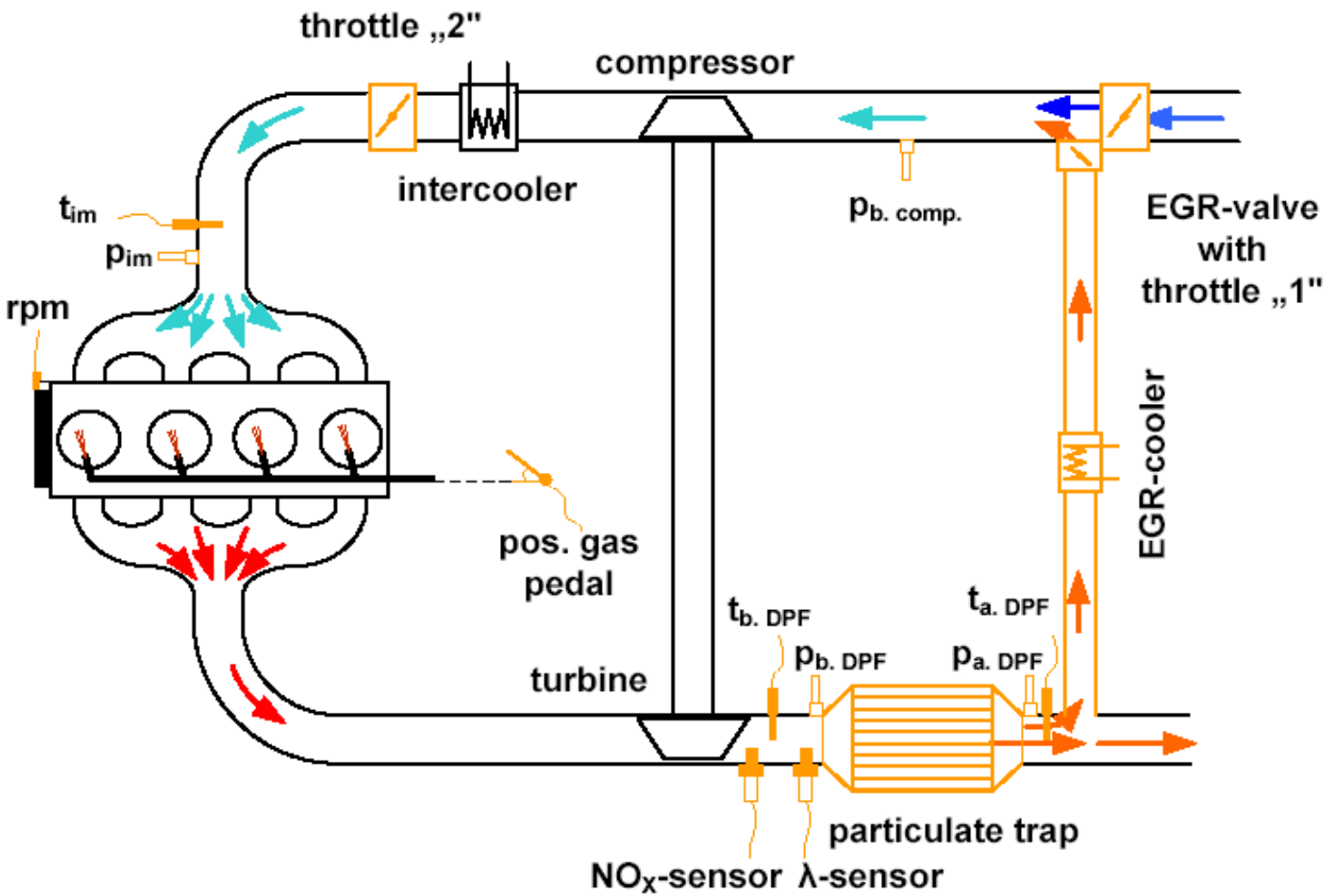
DeNOx-System DINEX

available + effective > 250 °C



AGR – with superclean Gas

Closed Loop Lambda controlled and combined with PFS and Trottle Regeneration



- Instruments

for Solid Particle Size and Number Concentration for Homologation and Curb Side Control

- Legislation

must include Number Concentration, Particle Size and Particle Substance

VERORDNUNG (EG) Nr. 715/2007 DES EUROPÄISCHEN PARLAMENTS UND DES RATES

vom 20. Juni 2007

über die Typgenehmigung von Kraftfahrzeugen hinsichtlich der Emissionen von leichten Personenkraftwagen und Nutzfahrzeugen (Euro 5 und Euro 6) und über den Zugang zu Reparatur- und Wartungsinformationen für Fahrzeuge

(Text von Bedeutung für den EWR)

Um sicherzustellen, dass Emissionen von ultrafeinen Partikeln (PM 0,1 µm und weniger) kontrolliert werden, sollte die Kommission so bald wie möglich und spätestens mit Inkrafttreten der Stufe Euro 6 zusätzlich zur derzeit festgelegten Partikelmasse eine Partikelzahl festlegen. Die

Tabelle 2

Euro-6-Emissionsgrenzwerte

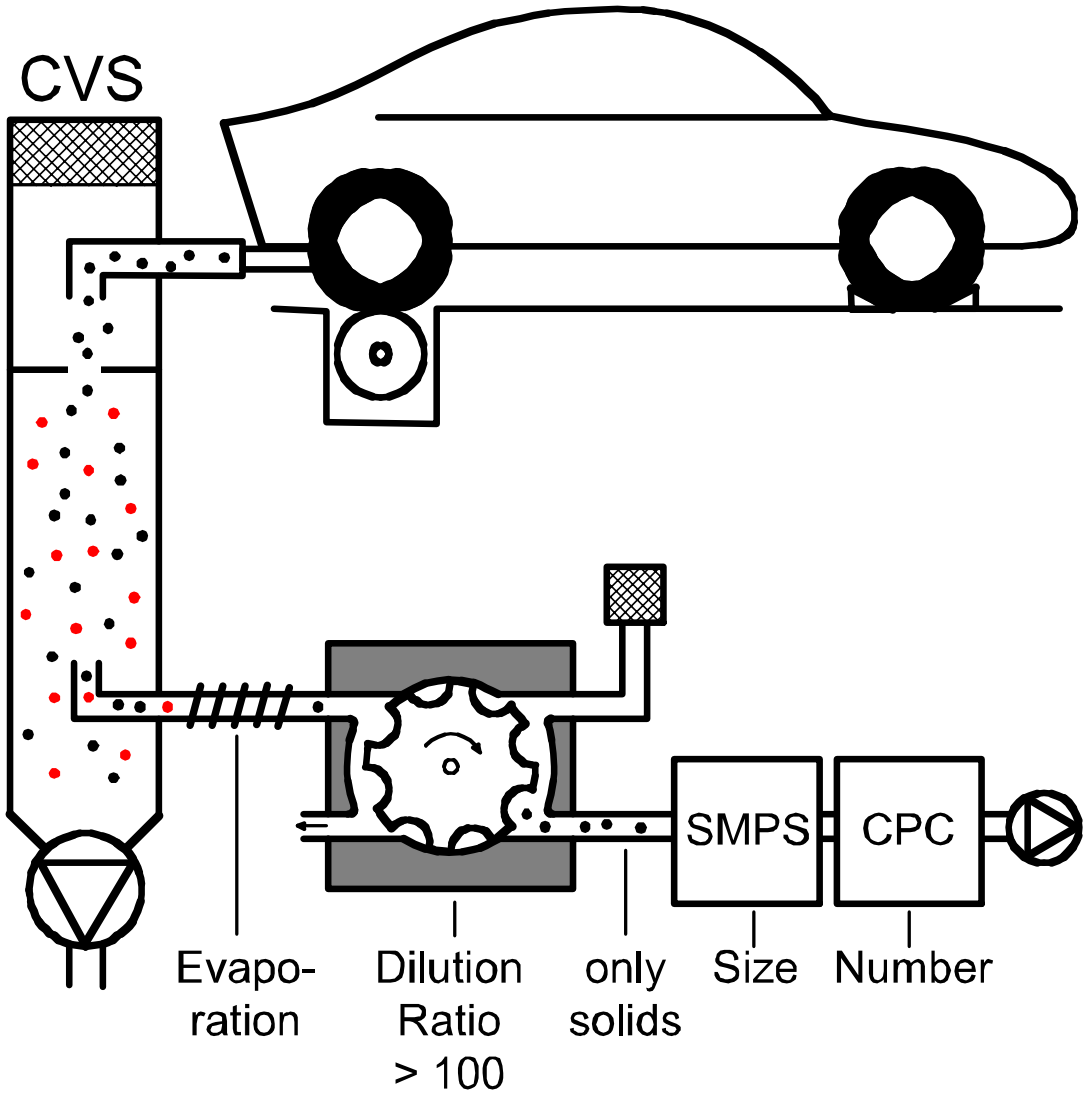
		Bezugsmasse (RM) [kg]	Grenzwerte													
			Masse des Kohlenmonoxids (CO)		Masse der Kohlenwasserstoffe insgesamt (THC)		Masse der Nichtmethankohlenwasserstoffe (NMHC)		Masse der Stickstoffoxide (NO_x)		Summe der Massen der Kohlenwasserstoffe und der Stickstoffoxide ($HC + NO_x$)		Partikelmasse (PM)		Partikelzahl 1) (PN)	
			L_1 (mg/km)		L_1 (mg/km)		L_2 (mg/km)		L_2 (mg/km)		$L_1 + L_2$ (mg/km)		L_3 (mg/km)		L_4 (#/km)	
Fahrzeugklasse	Gruppe		PI	CI	PI	CI	PI	CI	PI	CI	PI	CI	PI [3]	CI	PI	CI
M	—	Alle	1 000	500	100	—	68	—	60	80	—	170	5,0	5,0		
N_1	I	RM ≤ 1 305	1 000	500	100	—	68	—	60	80	—	170	5,0	5,0		
	II	1 305 < RM ≤ 1 760	1 810	630	130	—	90	—	75	105	—	195	5,0	5,0		
	III	1 760 < RM	2 270	740	160	—	108	—	82	125	—	215	5,0	5,0		
N_2			2 270	740	160	—	108	—	82	125	—	215	5,0	5,0		

Erläuterung: PI = Fremdzündungsmotor, CI = Selbstzündungsmotor.

1) Der Grenzwert für die Partikelzahl tritt 3 Jahre nach dem unten festgelegten Datum in Kraft.

2) Der Grenzwert für die Partikelmasse für Fremdzündungsmotoren gelten nur für Fahrzeuge mit Direkteinspritzung.

Volatile Separation, Size Classification and Particle Counting acc.to ECE-PMP



How a Vehicle Tailpipe can look
after 85‘000 km

Further TTM Information

- **Nanopartikel-Konferenz ETH Zürich**
  www.nanoparticles.ethz.ch
- **Partikelfilter-Seminar HDT TTM**
  www.hdt.de
- **VERT Filter Liste**
  www.environment-switzerland.ch/uv-0607-e
- **Database 4500 DPF in Switzerland**
  www.akpf.org
- **2 Books on DPF published 2004/5 by EXPERT**
  www.expert.de
- **30 SAE-Papers and other technical Publications**