

Eliminating Particle Emissions from Diesel Engines in Construction and underground

**Experience based on 7000
Trap-Retrofits in Switzerland**

Andreas Mayer / TTM

MDEC 2004

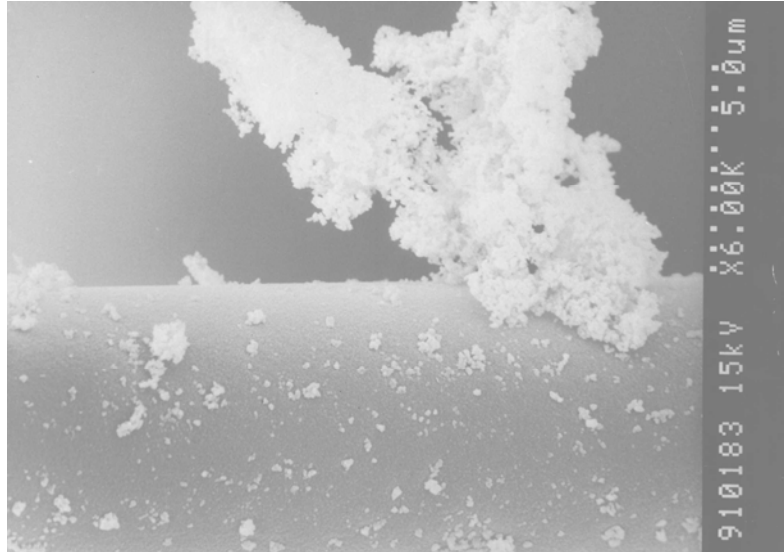
INTRODUCTION

- **Ambient PM10 - Limit exceeded all over Switzerland**
- **60% Ultrafine Particles are emitted by Combustion Engines**
- **Diesel Particles are Lung Penetrating**
- **Diesel Particles are Carcinogenic**
- **Mortality by Air Pollution is 5 x Traffic Accident Mortality**

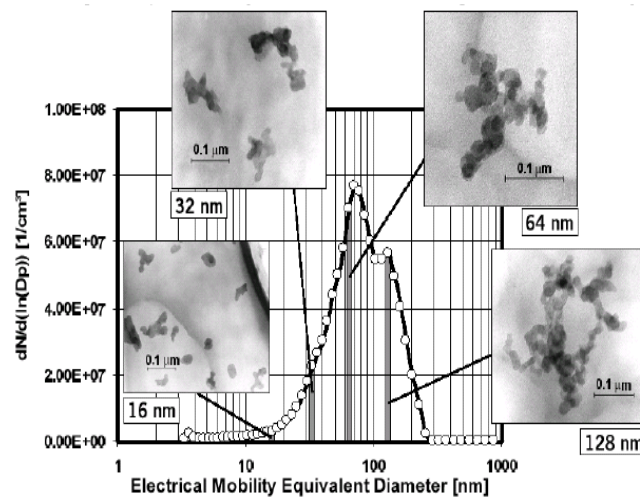
→ **Minimization acc. to Best Available Technology BAT required**

→ **Particle Traps are efficient and available = BAT**

Diesel Particles are Nanosize < 300 nm
→ cell membrane penetrating



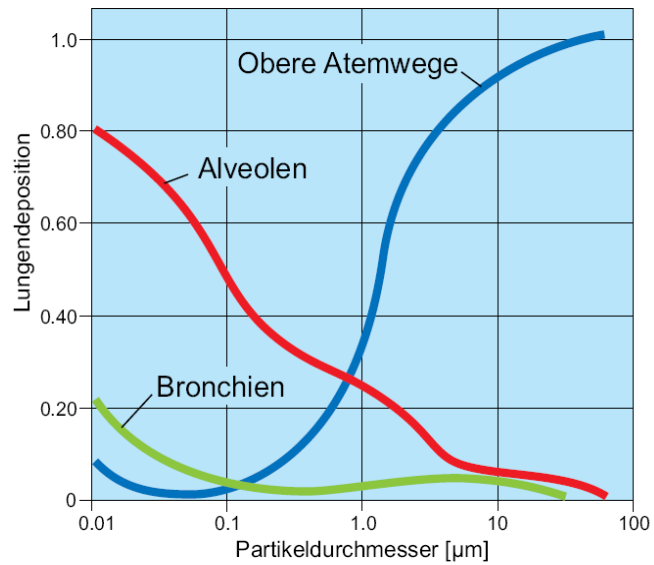
**Diesel
Particles
Morphology
depends on
Particle
Size**



Quelle: METZ, BMW

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Ablagerung kleinster Partikel in den Alveolen

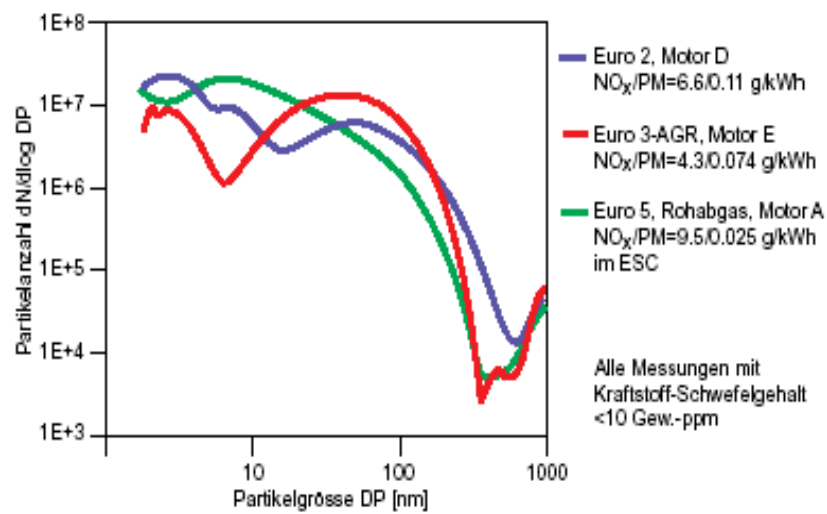


(Quelle: Hinds, Aerosoltechnologie, 1982)

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Partikelemission neuer Motoren

Quelle: AVL, P.Zelenka



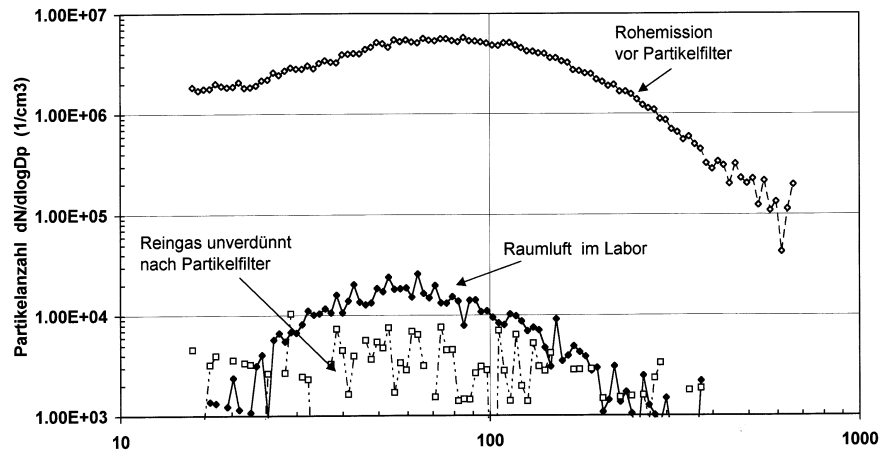
Swiss Regulations to enforce PFS- Introduction

- 1990 (EJPD): Retrofit permitted under Condition:
 - no additional Noise Emission
 - no Formation of **secondary toxic Air Contaminants**
- 1994: SUVA: Diesel-Emissions DME **carcinogenic**
- 1998: LRV: Diesel-Soot **carcinogenic**
- 1998: Limit for steady state Engines < 5 mg/m³
- 2000: **SUVA: PFS mandatory** underground
- 2002: **BUWAL-BauRLL: PFS mandatory** for general construction (B-type construction sites)
- 2003: ASTRA: only VERT approved PFS for Vehicles

Filter-Elements Filter-System Filtration-Characteristics

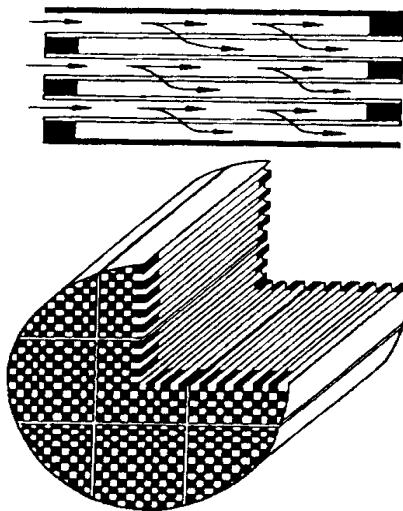
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Filtered Diesel Exhaust cleaner than Ambient Air



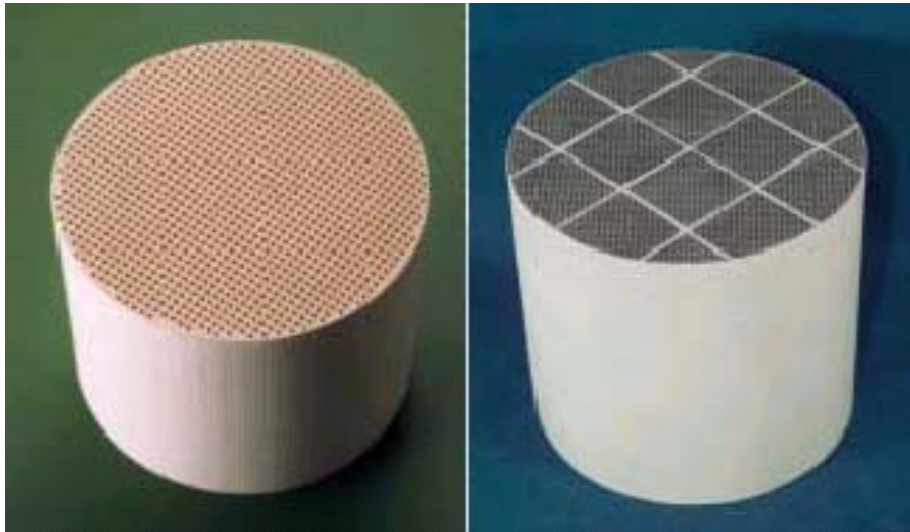
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Typischer Aufbau eines keramischen Zellenfilters Bild CORNING 1982

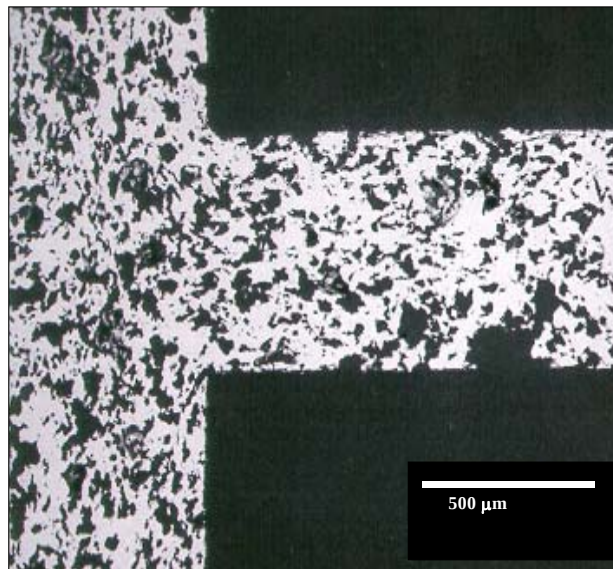


Cordierite und Silicon Carbide typical Ceramics for Particle Filters

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Keramische / metallische Werkstoffe: porös, gasdurchlässig¹²
Porengrösse um 0.01 mm / Partikel um 0.0001 mm



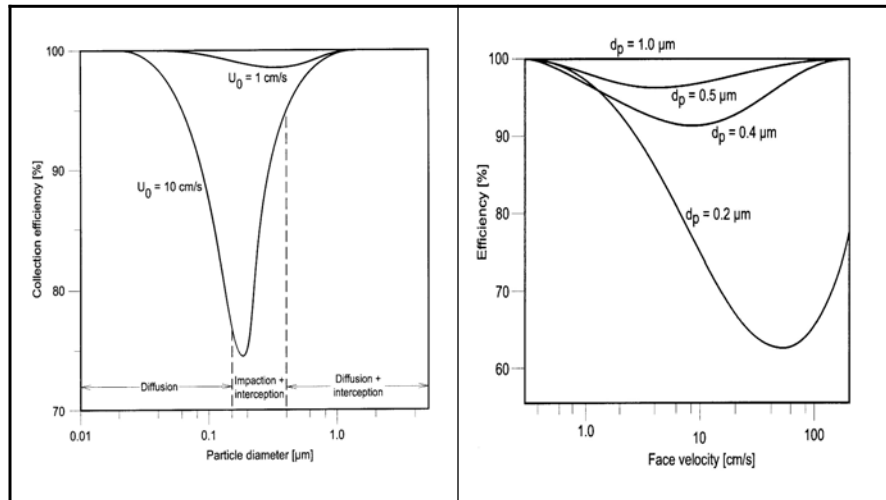
Many other DPF's in use

- metal sinter plates pleated
- metal fiber felts
- ceramic fiber felts and knits
- ceramic and metal deep bed foams
- wire mesh
- papers
-
- some "open structures" appearing ??
- electro and plasma systems not ready yet
- cyclones and scrubbers disappearing

Quality Control Instruments and VERT-Standards

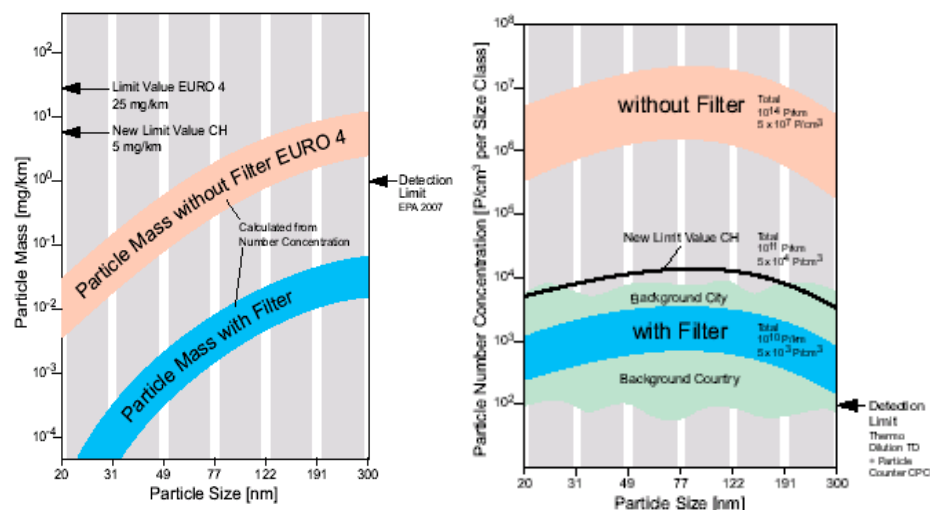
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Weaknesses of Filters in the Size Range of Diesel Soot Particles

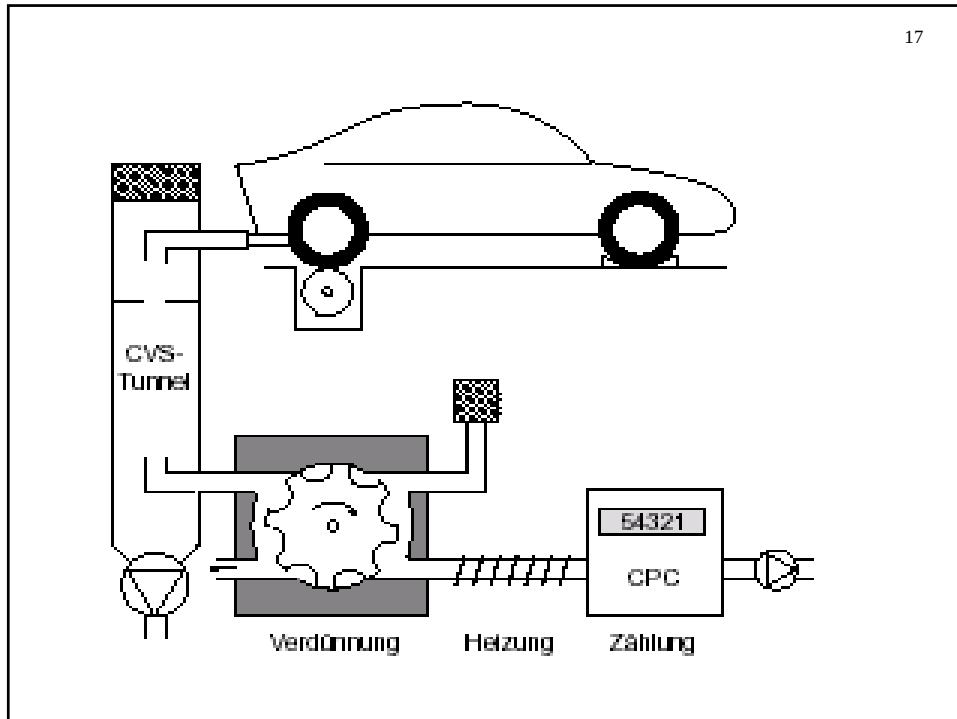


Only Number Count guarantees the Selection of high Quality Filters

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VERT specifications for particle trap systems

	New	2000 op.hours
Filtration efficiency number count Number concentration of solid particles in the size range 20-300 nm	> 95%	> 95%
Filtration efficiency EC mass EC mass concentration	> 90%	> 85%
Opacity during free acceleration	0.12 m ⁻¹	< 0.12 m ⁻¹
No increase of limited emissions CO, HC, NO _x and PM		
No relevant increase of secondary toxic emissions		

VERT Filter Suitability Test

- **VFT1:** PFS new
- **VSET:** Secondary Emissions Test
(PAH, Nitro-PAH, PCDD/F and ...total > 150)
- **VFT2:** 2000 Operation Hours Field Test
- **VFT3:** Repetition of VFT1 after Field Test

VERT-Approval → BUWAL Filterlist

VERT-Approval is lost at a Failure Level > 5 % pa

VERT- tested PFS Status 8/2003

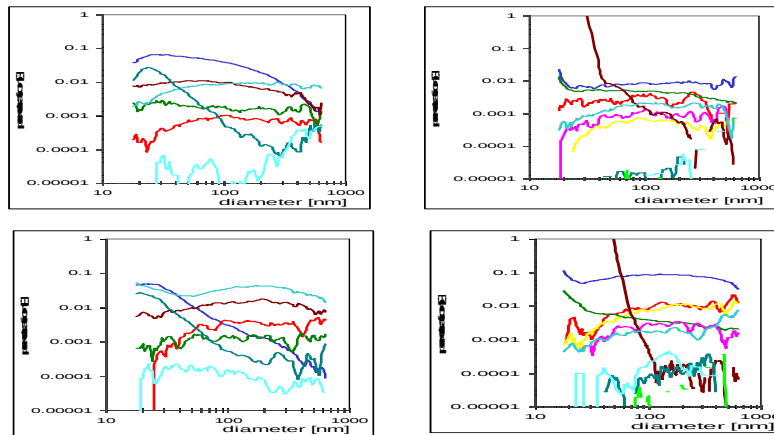
	Active Regeneration	Passive Regeneration	Filtration-Efficiency
DEUTZ	Full Flow Burner		98 old data
ECS-UNIKAT	Electr.Heating	Catalyt.Coating	99.99
HJS		CRT, FBC (Additives)	99.40
JOHNSON MATTHEY	Electr.Heating	CRT, FBC	99.50
HUSS	Electr.Heating Standstill-Burner		99.99
DCL	Electr.Heating Intake Throttling	FBC, Catalyt.Coating	99.99
ARVINMERITOR	Full Flow Burner		99.84
ENGELHARD		CSF	99.60
HUG	Full Flow Burner	Catalyt.Coating	98.60
INTECO		FBC	99.24
EHC	Exchangable		96.70
TSH	Electr.Heating	Catalyt.Coating	98.90

Filter Penetration for 10 VERT-PFS

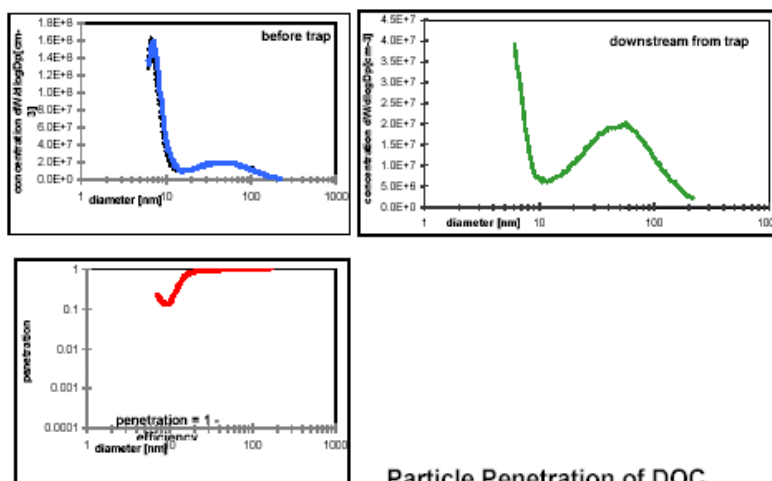
Nominal RPM; full load (top), half load (bottom)

left: new

right: after 2000 op.hrs



Penetration of DOC for Comparison



Particle Penetration of DOC

VERT FILTER LIST

Tested and approved Particle-Trap-Systems for
retrofitting Diesel Engines

accepted by

BUWAL, SUVA, TBG, AUVA, TRGS, UBA, MSHA, DEEP, CONAMA-CHILE, DTI-DANMARK



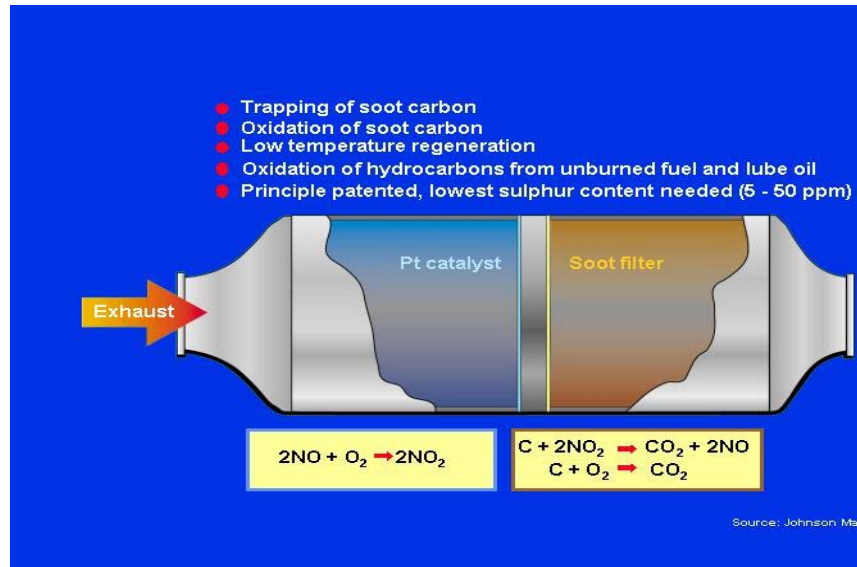
<http://www.umwelt-schweiz.ch/buwal/eng/fachgebiete>

Regeneration Procedures

passive and active Regeneration

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CRT-Filter

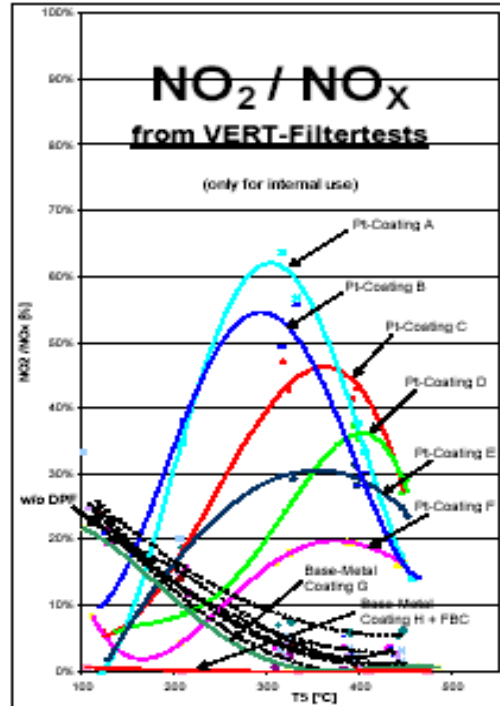


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Fuel-Additives to support Regeneration by Catalysis

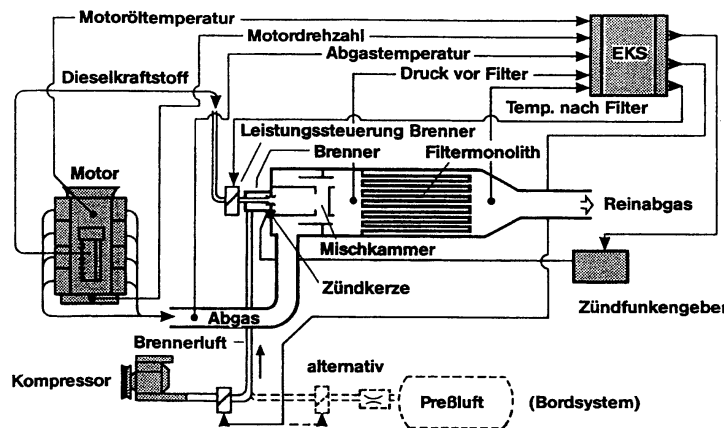
- Cerium-Oxide – Product EOLYS / RHODIA
- Ce/Fe - RHODIA
- Fe as Ferrocen – Product satacen / OCTEL
- Fe/Sr - OCTEL
- Ce/Fe - RHODIA
- Fe - INFINEUM
- Ce/Pt - CDT

**NO → NO₂-
conversion
with
catalytic
coatings
and FBC**

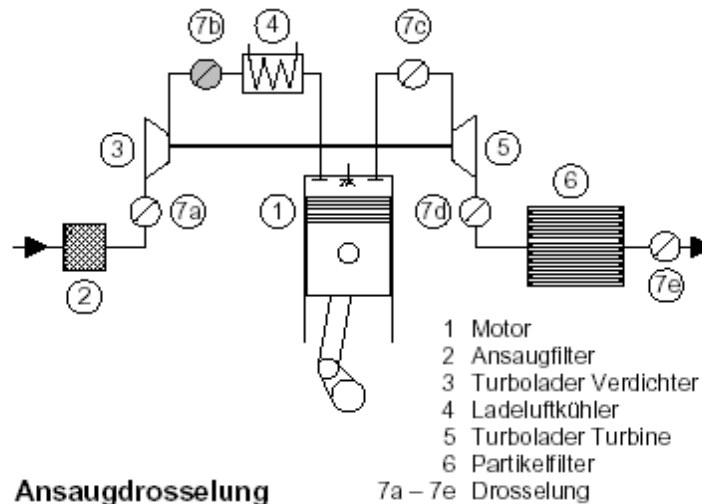


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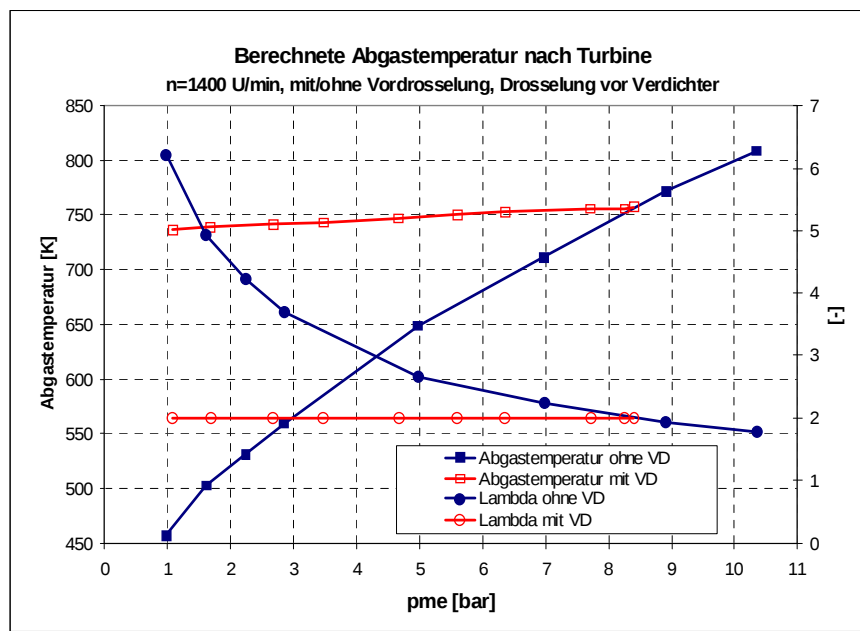
PFS with Full-Flow-Diesel-Burner (DEUTZ)

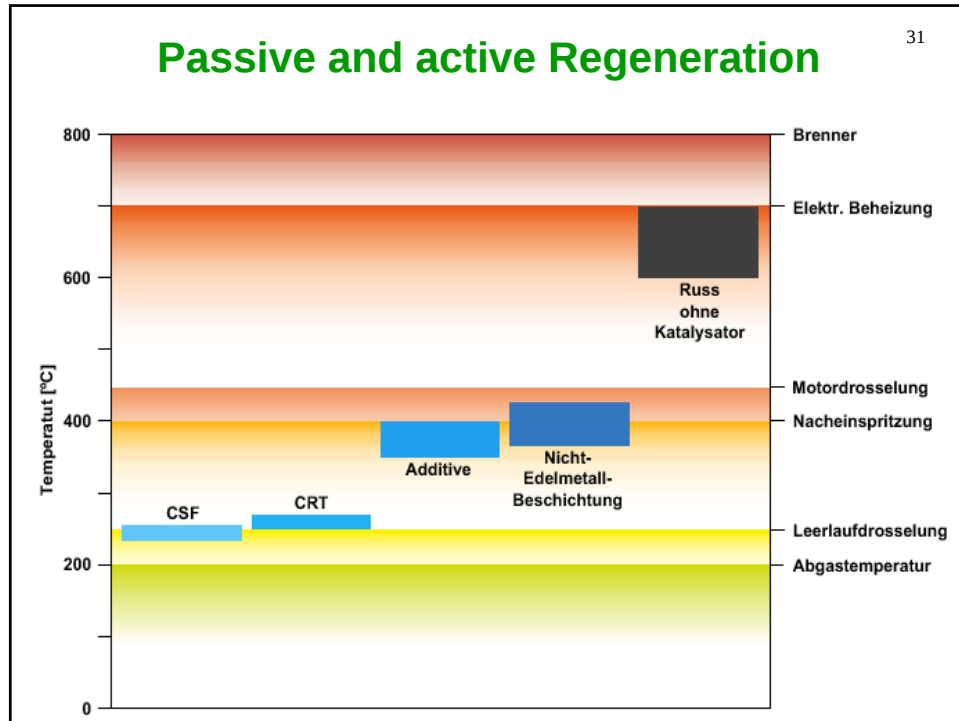


Throttling of Intake Air or Exhaust Gas increase Temperature by 200-300 °C spontaneously



Effect of Throttling





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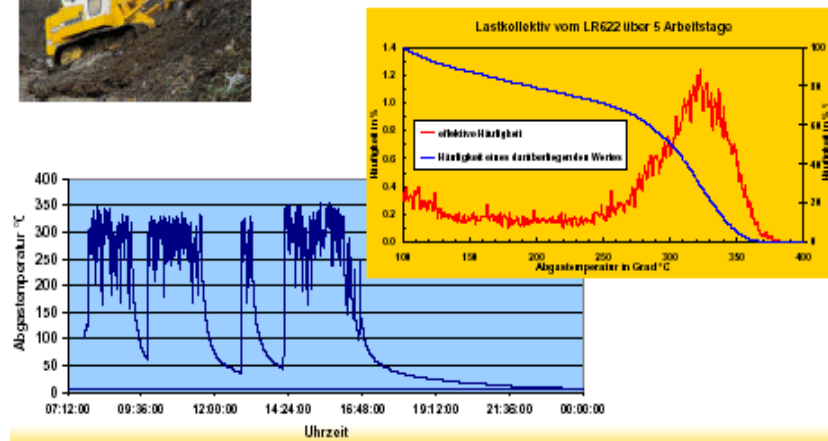
DPF-Selection and Installation

Datalogging Driving Cycle Parameters before PFS-Selection

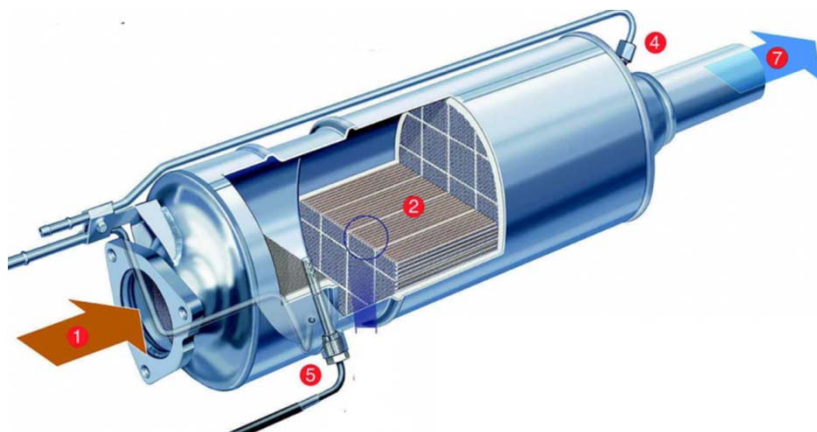


Abgas Temperatureaufzeichnung mittels Datalogger im Praxiseinsatz.

► PFS-Wahl (für Systeme mit Passiv-Regeneration unerlässlich !)



Particle Filter System PFS



**Truck-Installation
in place of
Muffler**



Installation on an hydraulic Excavator

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Filter replacing Silencer



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Influence on Noise



Hydraulikbagger A 914

- Motorleistung 112 kW
- PFS: CRT
- Schalleistungspegel LwA:

Grenzwert:	106.0 dB(A)
mit Originalschalldämpfer :	102.1 dB(A)
Nach Umbau :	102.4 dB(A)

Drawbacks, Failures and Measures for Improvement

Cost

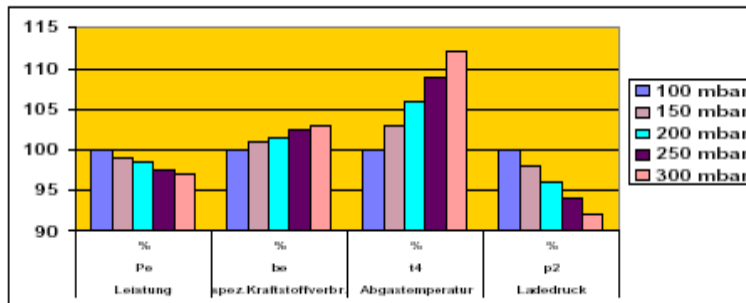
- **Retrofit Cost at low volume today**
 - 25 kW : 125 Fr/kW - 20 % of vehicle cost
 - 100 kW: 100 Fr/kW - 8 % of vehicle cost
 - > 250 kW: 80 Fr/kW - 5 % of vehicle cost
- **Cost Reduction expected**
 - Manufacturing Cost by 1/3 within 2 Years
 - Installation Cost will stay high
- **Cost of high volume DPF production**
 - LDV: 2 % of vehicle cost
 - HDV: 2 % of vehicle cost

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Influence of Backpressure → Limit 200 mbar



Einfluss des Abgasgegendruckes auf
Motorenkennwerte
(Nenn Drehzahl und Vollast)

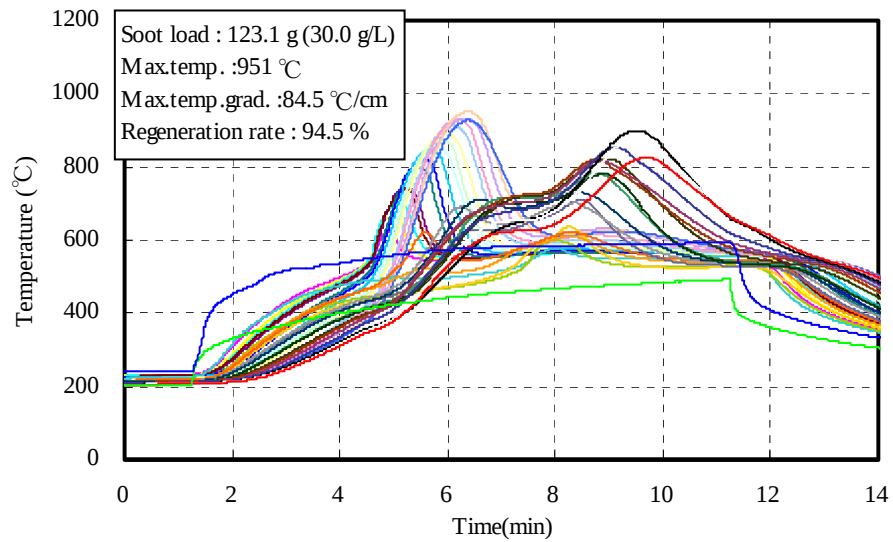


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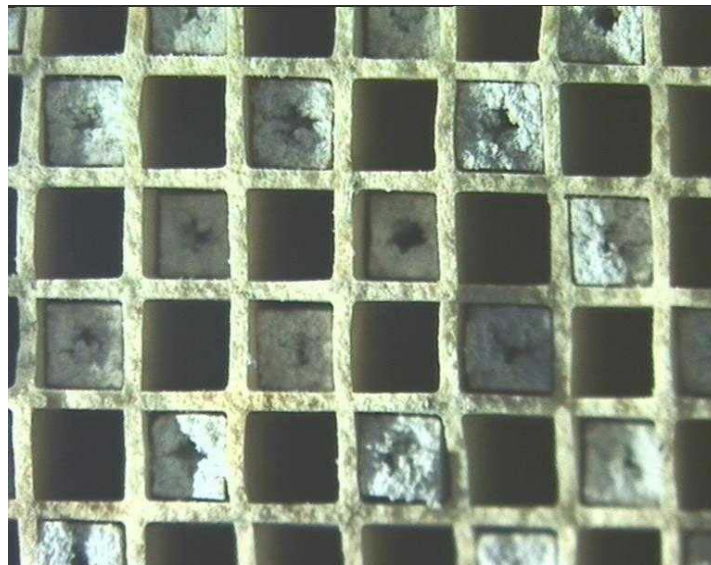
**Spectacular
Filter Damage
Ring-off-Cracks
and Melting of the
Cordierite Material**
source Johnson Matthey



Reasons for Failures: Local Temperature Peaks during Regenerations ⁴³ (source IBIDEN)



Ash Plugging of Filter Cells ⁴⁴ (source SHELL)



Reliability of PFS in Switzerland

- 1990: 230 Filters installed in Buses (DB/M&H-System)
1998: still 200 in Operation
- 2000: 2400 PFS in Operation, > 6% Failures pa
→ too many Failures → **Measures**
- 2003: **> 6500 PFS in Operation**
 - Failures < 2 % per year
 - PFS > 750'000 km with Trucks and Buses
 - PFS > 10'000 Bh with Construction Machines
 - PFS > 28'000 Bh on a Ferry Boat
- 2005: Construction Directive > 15'000 PFS expected
Failure Target: < 1% pa

Measures to improve Quality introduced Y 2000

- One Filter Family lost VERT-Approval
(disappears immediately after from Swiss Market)
- Introduction of the 2000-hrs Operation Test (VFT2)
- Introduction of electronic On-board-Control
and further mid-term measures
- Increase Use of active Filter-Systems
- Obligation for Engine Maintenance and Emission Control
- Access upstream of PFS for Emission Diagnosis
- Systematic PFS-Selection (CD available)

Character of Failures (1)

Most Failures immediately after Retrofit

- **Canning Failures** of the Ceramic Monolith
- **Material Failures** of the Filter Media
- **Cementing Failures** with segmented Filters
- **Mechanical Shock:** during Transport or Installation
- **Installation:** often insufficient Vibration Decoupling
- **Operation:** wrong Fuel – Sulfur Content too high
- **Application:** wrong System selected
- **High Lubrication Oil Consumption**

Character of Failures (2)

Failures rare after long Operation:

- Backpressure-Alarms not respected
- Ash-Cleaning unprofessional
- Engine Maintenance careless

Experience proves that VERT-Filters show no aging effects – loose no Filtration Quality

Outlook and Conclusions

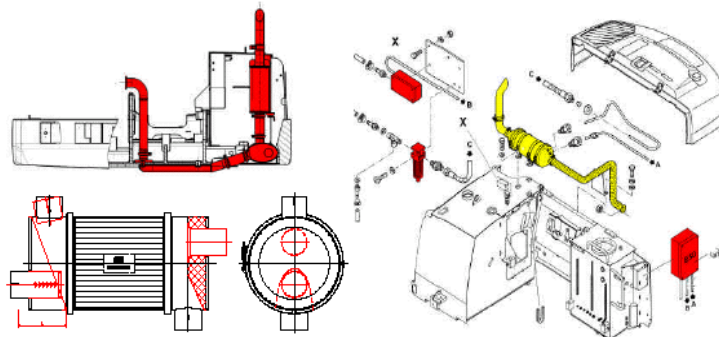
OEMs offer options

Tagung : „Minimierung der Partikelemissionen von Verbrennungsmotoren“

Haus der Technik

München

23.-24. Juni 2004



François Jaussi, Dipl. Ing.
Leiter Dieselmotorenversuch
Liebherr Maschinen Bulle AG

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Projektleiter Abgasnachbehandlung
Liebherr Maschinen Bulle AG

LIEBHERR
DIESELMOTOREN

LMB

HDT-Tagung München, 24. Juni 2004

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Planning for Switzerland

Retrofits

- Construction 25'000 (total 55'000) **today: 5'300**
- Agriculture 30'000 (total 110'000)
- Trucks 20'000 (total 65'000)
- Buses 3'500 (total 5'500) **today: 1'200**

Incentives for new Vehicles

- LD-Vehicles Reduction of Import Tax (4%)
- HD-Vehicles Reduction of Road Tax LSVA

Quality Criterion

- Ultrafine Particle Number Concentration

Classic DPF-Retrofit-Applications

- | | |
|-------------------------------|-------------|
| • Sweden, environmental zones | 8'000.- |
| • Cities | |
| - Berlin Y 2000 | 1'000 |
| - Paris Y 2001 | 3'000 |
| - New York | 2'000 |
| - Zürich Y 2004 | 500 |
| - London Y 2004 | 6'000 |
| • Forklifts | > 40'000 |
| • Construction machines | 10'000 |
| • Mines | 4'000 |
|
• Total worldwide |
100'000 |

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Large DPF-Retrofit Plans

- | | |
|---|-----------|
| • USA Y 2006 ? | 100'000 |
| • Kalifornien Y 2008
all Diesel on-road und off-road | 1'200'000 |
| • Tokyo Y 2008 | 500'000 |
| • Seoul Y 2010 | 220'000 |
| • China: grüne Olympiade Y 2008
>100'000 | |
| • Santiago / Chile Y 2005 | 4'000 |
| • Copenhagen Y 2006 | 20'000 |
| • Germany: passenger cars starting Y 2006 | ? |

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**Peugeot with FAP – 850'000 cars
successfully on european roads !**



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Summary and Conclusions

- PFS are BAT to minimize high Health Risks of Machine Operators and Population → nanosize solid particle emissions from engines can be eliminated → Diesel = zero emission engine
- PFS can be applied on Diesel Engines of any Age, Design and Application
- PFS will become a Standard Component of Diesel Engines (like 3-way Cats for SI-Engine)

Thank You for your kind Attention

**We are ready for Questions
now or later**

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