

Technical Workshop on NPTI – Tehran 14.-15.December 2016

# Technical Risks and Failures with DPF and how to avoid them

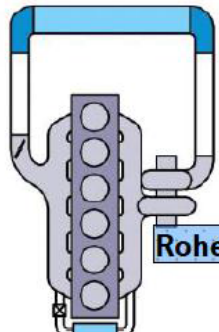
Andreas Mayer / TTM

# Contents

- **How does the Filter effect the Engine**
- **How does the Engine effect the Filter**
- **Effect of Backpressure on**
  - Engine Performance
  - Fuel Consumption
- **Effect on Noise**
- **Operation Conditions**
- **Typical Failures**
- **Trouble Shooting**
- **Not all Filters are good Filters**
- **Why only use VERT-certified filtes**
- **Why local approval is required**
- **Conclusions**

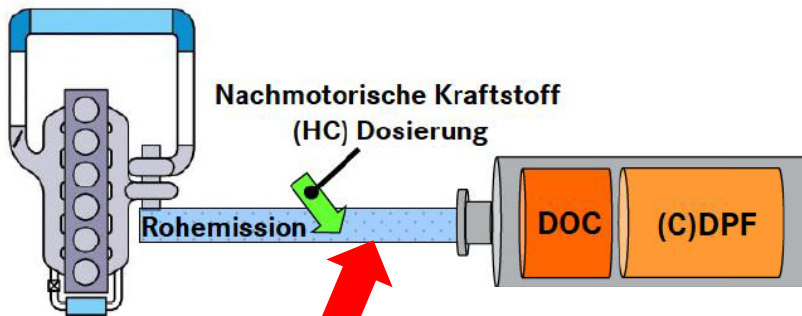
# Aftertreatment masks the Engine

→ tailpipe control alone might be misleading



Old engine: raw emission permits engine-diagnosis by noise, smoke, smell, colour

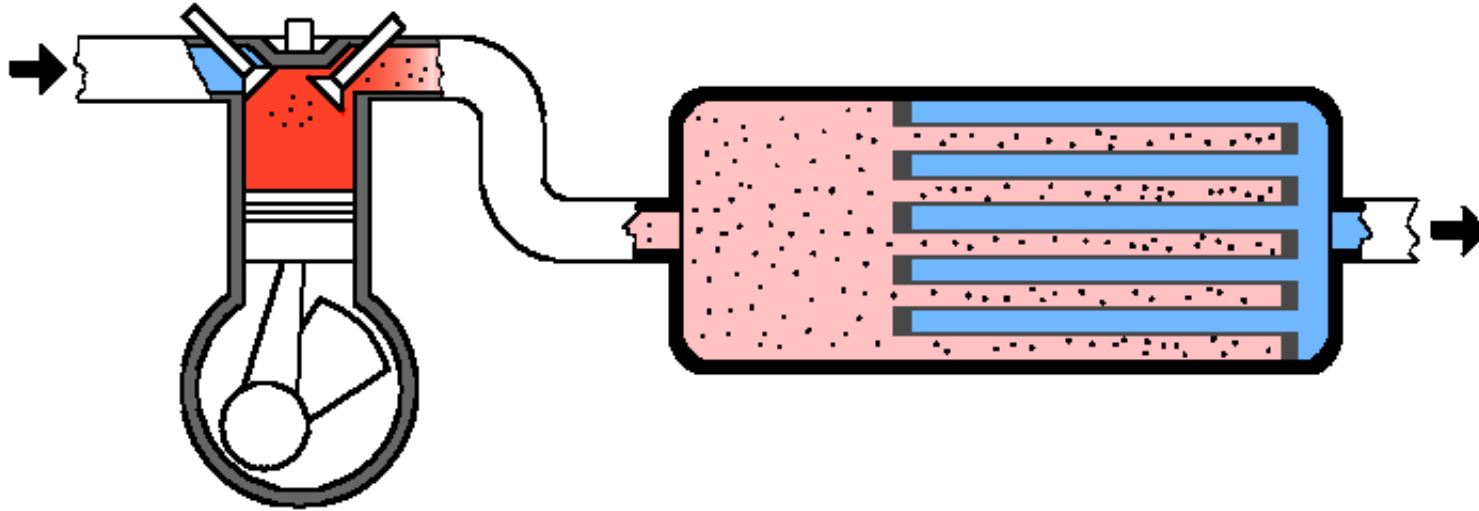
Free acceleration revealed all problems



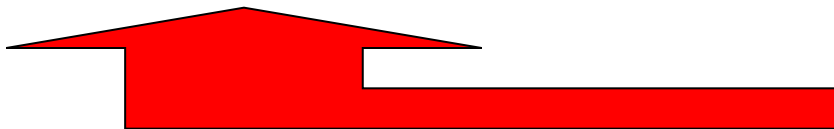
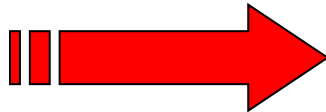
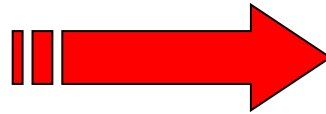
DPF and DOC mask smell and smoke, change noise and colour → engine diagnosis impossible

→ Engine-Out emission control is important for Engine protection and preventive maintenance

# Mutual Effects Engine $\leftrightarrow$ Filter



- Exhaust Flow
- Soot Emission
- O<sub>2</sub>- & NO<sub>x</sub>- Content
- Exhaust Temperature



- Filter Loading = f (Time); max 10g/l  
max 200 mbar



- Filter Regeneration



**• FILTER-BACKPRESSURE**

# Fuel Consumption increase $\Delta be$

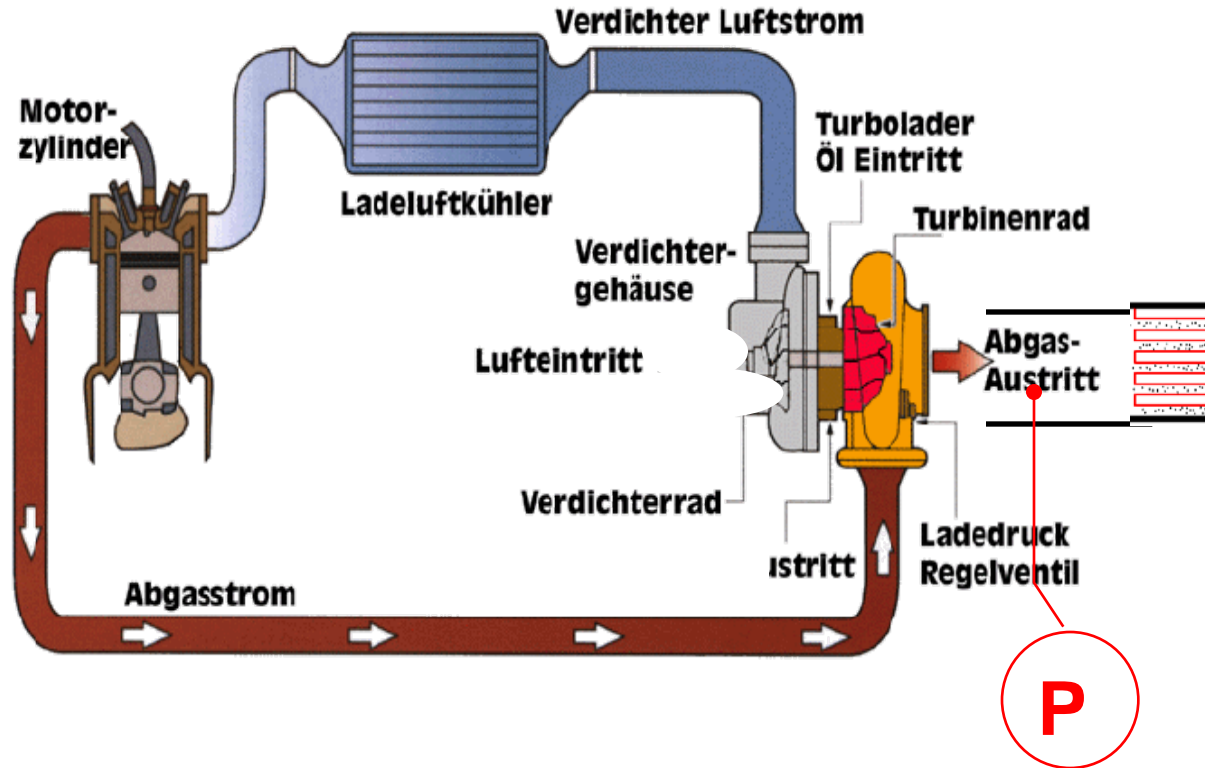
$$\frac{\Delta be}{be} = \frac{\Delta p}{pe + pr}$$

		Bus	Truck	Construction Machine	Passenger Car
$\Delta p$	mbar	100	100	100	100
$pe + pi$	bar	6	8	10	3
$\Delta be/be$	%	1.6	1.2	1.0	3.3

acc. to VERT-Rules

- backpressure of the new filter shall be < 50 mbar
- max backpressure must be < 200 mbar
- average backpressre will be in the range of 100 mbar

# Turbocharged Engines are more sensitive



If Backpressure increases



Charging Pressure  
Air Excess and  
Performance  
Decrease



Soot Generation  
Increases



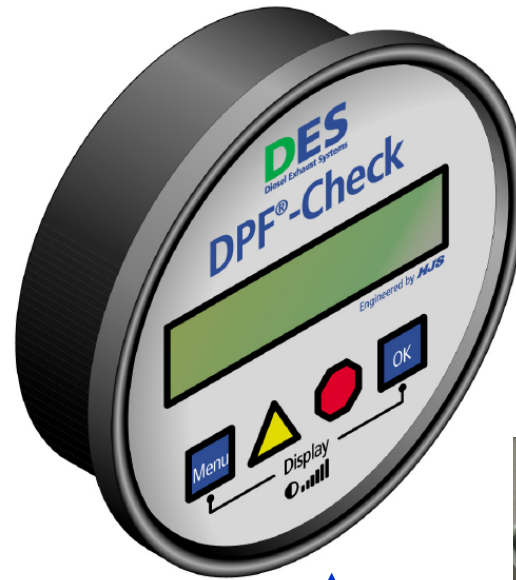


# Backpressure must be under Control

## Electronic Datalogging



## Sensors for Backpressure and Temperatures



### Anzeige von Messwerten der ECU, z. B.

- Gegendruck
- Temperaturen
- Betriebsspannung
- Drehzahl
- Kraftstofftankinhalt
- Additivtankentnahmemenge

### Auslesemöglichkeit aktive Fehlerliste

### Warnung des Fahrers bei

- Zu hohem Gegendruck (VERT)
- Additivreserve ...

Alarm Indicator  
at the Drivers  
Seat

or remotely  
controlled



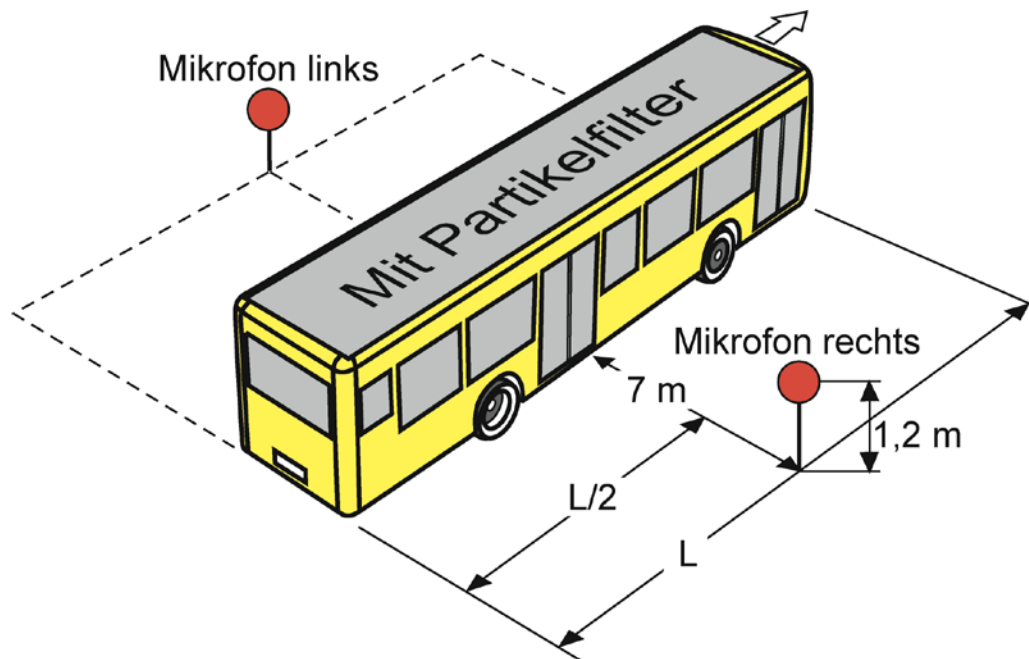


# Noise

**Filter is replacing Silencer**

**Noise must be controlled for each Retrofit Case**

**Noise usually 1-2 dB(A) lower**



Drehzahl [rpm]	Ohne Filter		Mit Filter	
	links [dB]	rechts [dB]	links [dB]	rechts [dB]
600	63	65	62	62
1000	66	70	66	65
1500	74	78	69	69
1700	77	81	71	71
Mittelwert	71,7		66,8	

A scenic landscape featuring a calm lake in the foreground, surrounded by lush green vegetation. In the background, there are majestic mountains with patches of snow under a soft, overcast sky. The overall scene is peaceful and natural.

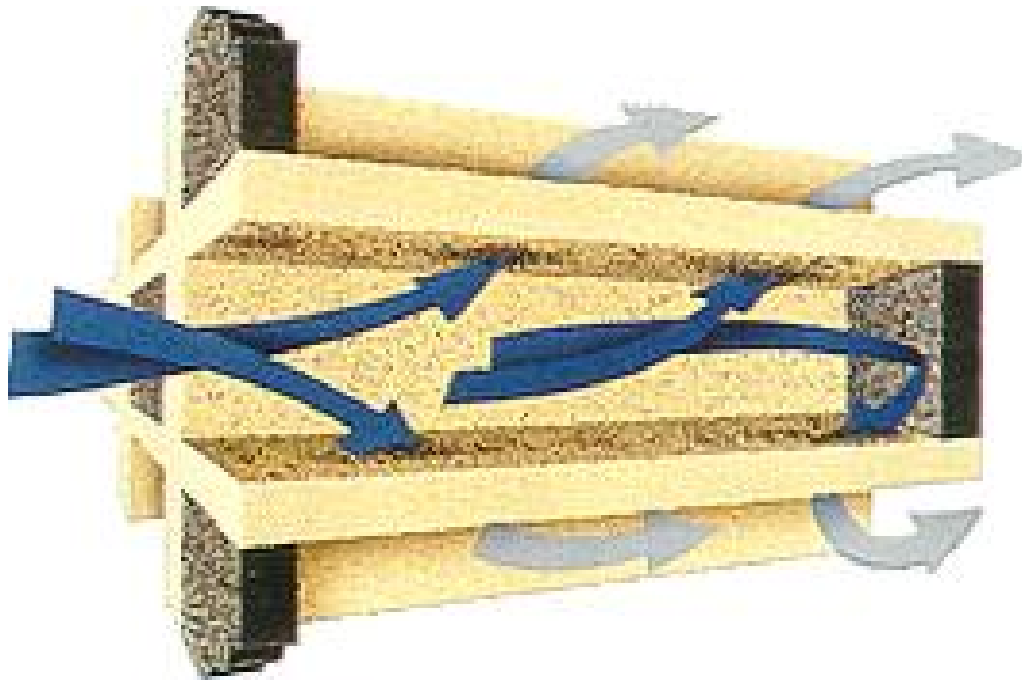
# ***Typical Failures Origins and Solutions***

# Categories of Failures

1. Thermal and thermomechanical stress
2. Canning Failures
3. Vibration Failures
4. Result of engine and turbo failures
5. Failures due to ash deposits and ash sintering
6. FBC-dosing mistakes
7. Overheating during cleaning
8. Maintenance mistakes
9. Quality of fuels and lubrication oils
10. Short term and long term failures
11. Risks for the environment and people
12. Failure statistics
13. Trouble-Shooting

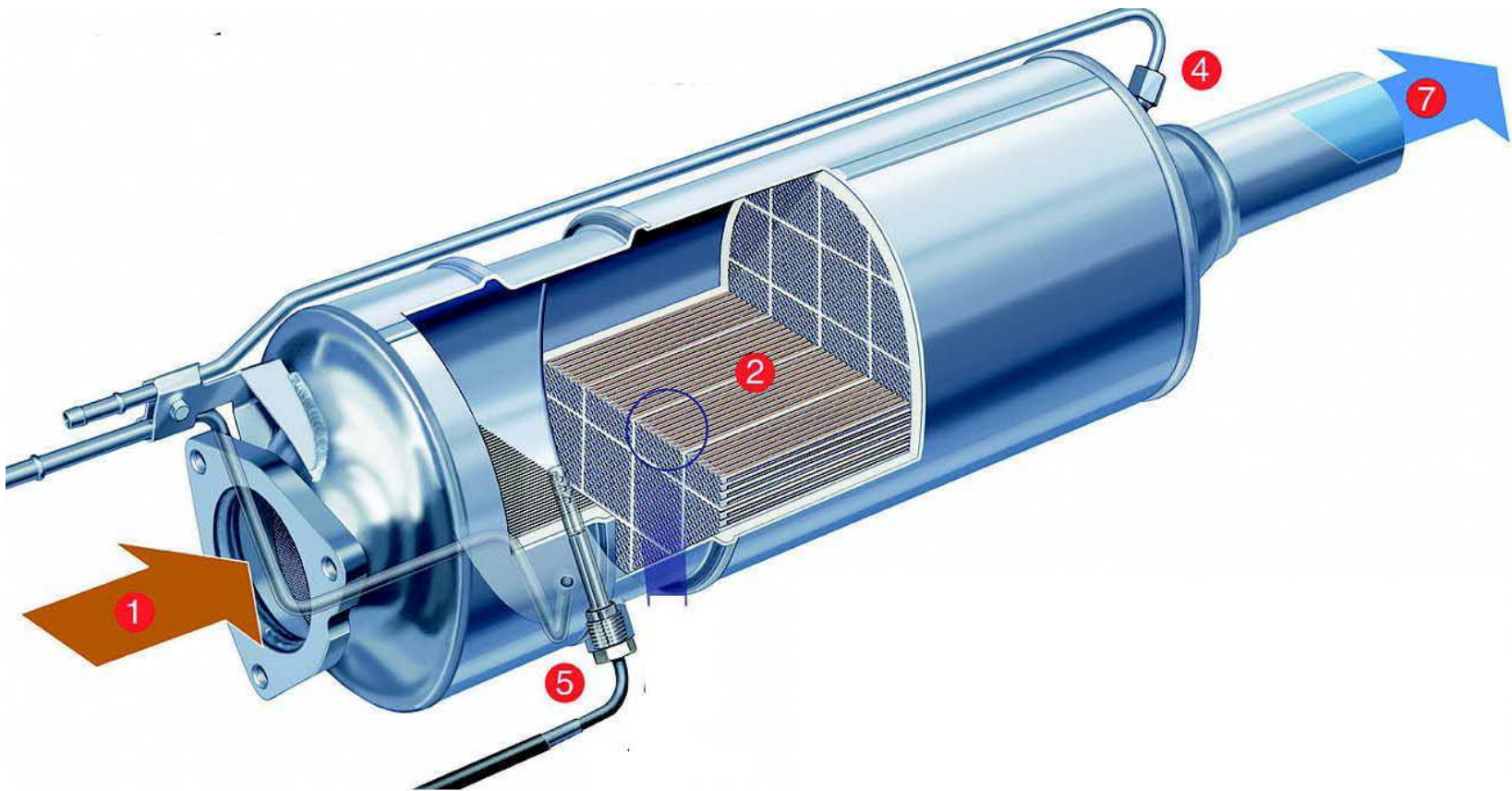
# DPF : Wall-Flow Particle Filters

available since 1982



- - Filtration Effectiveness  $> 99.9\%$  if pore size  $< 15\ \mu\text{m}$
- can be used for all Diesel Engines – new and in-use

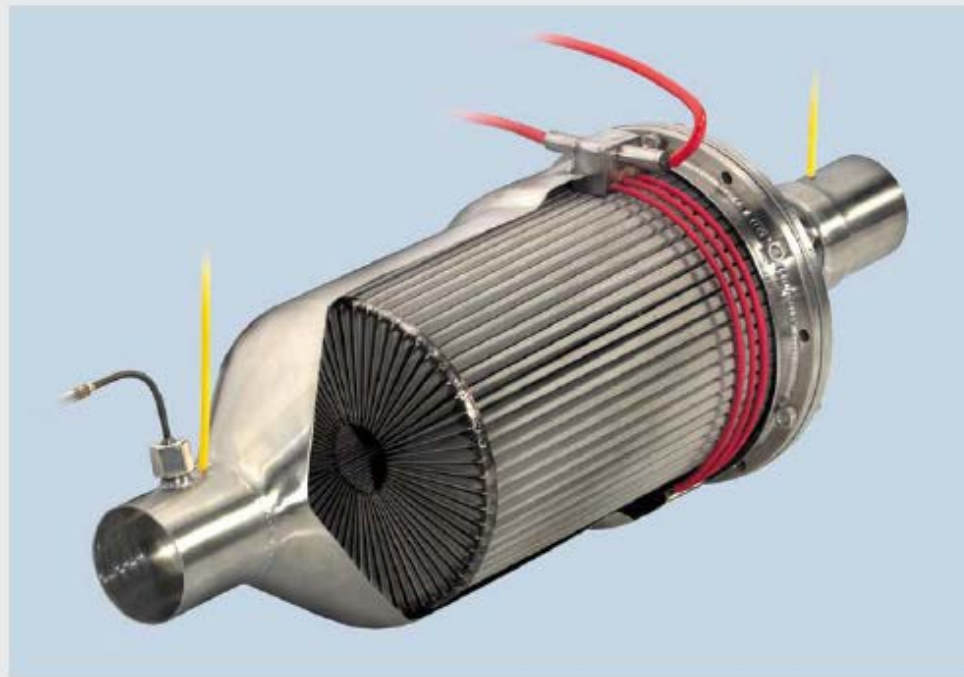
# Ceramic Particle Filter Systems require careful shock absorbing canning and insulation



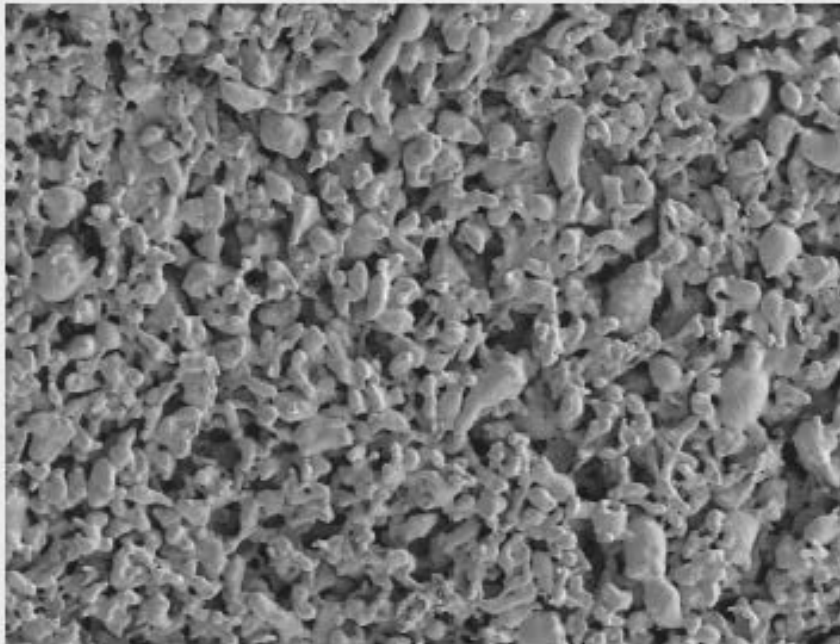
# Also Sinter metal substrate undergo high vibrational stress

HJS Fahrzeugtechnik GmbH & Co KG

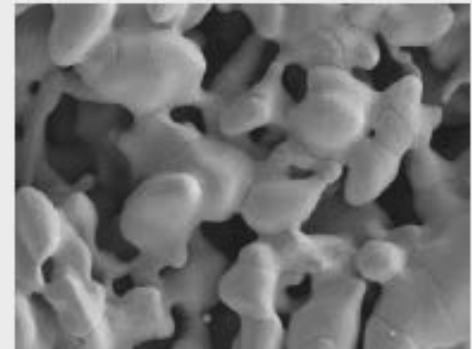
## HJS SMF® – System mit autarker Regeneration



## Filter-Material



REM-Bild, Anströmseite



REM-Bild, Detail

A scenic landscape featuring a calm lake in the foreground, surrounded by lush green vegetation. In the background, there are majestic mountains with significant snow cover under a clear blue sky. The overall scene is peaceful and natural.

*Typical Failures*  
***Thermal Stress during  
Regeneration***

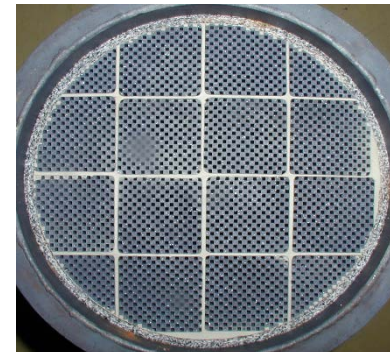
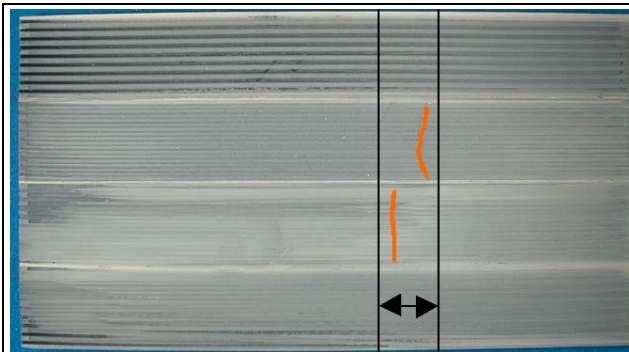
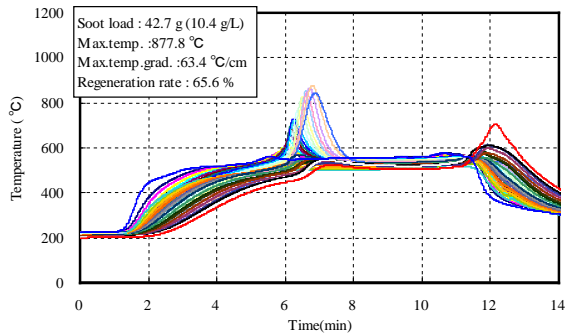


### Regeneration chart

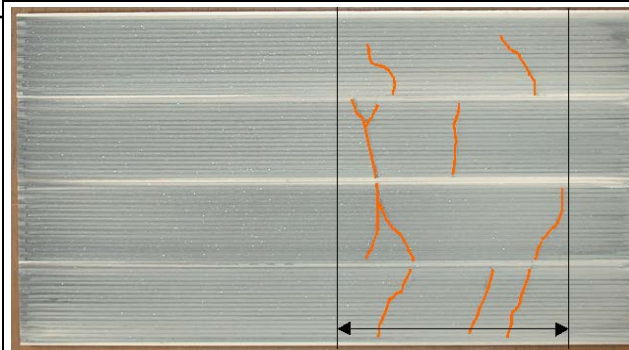
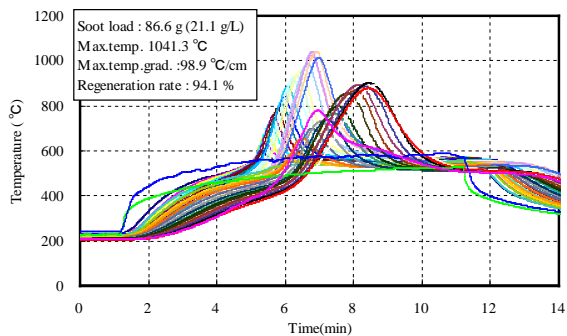
### Cross section photo

### Outlet surface photo

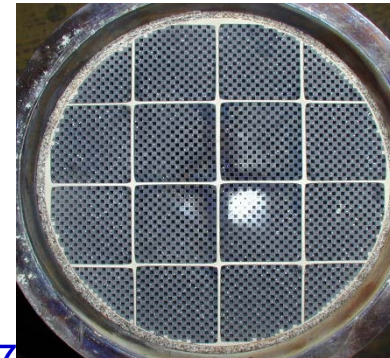
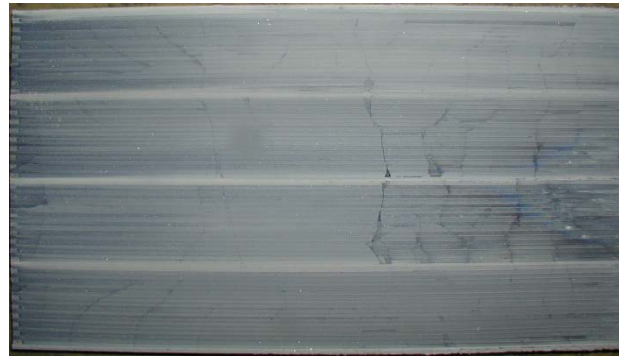
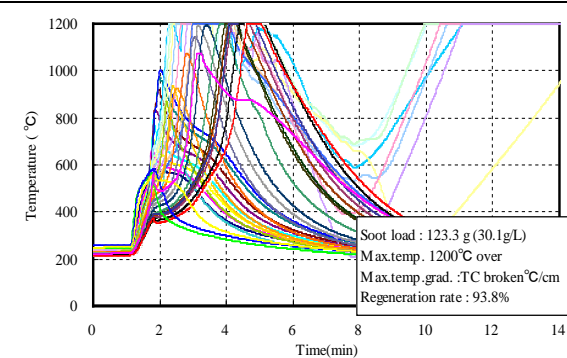
•10 g/L



•20 g/L



•30 g/L



# Repair Small Failures by ceramic cement

W.Haldenwanger  
Technische Keramik GmbH  
Teplitzer Strasse 27  
D-84478 Waldkraiburg  
WH Feuerfestkitt Teil A und B  
*[www.haldenwanger.de](http://www.haldenwanger.de)*



A scenic landscape featuring snow-capped mountains in the background, a dense forest of evergreen trees in the middle ground, and a calm lake in the foreground reflecting the sky and mountains. The text is overlaid on this background.

## *Typical Failures*

*Canning problems due to wrong materials, excessive thermal expansion or humidity*

**Canning-Gap leaking due to low cycle fatigue (thermomechanic, vibrations, design mistake, manufacturing defect )**



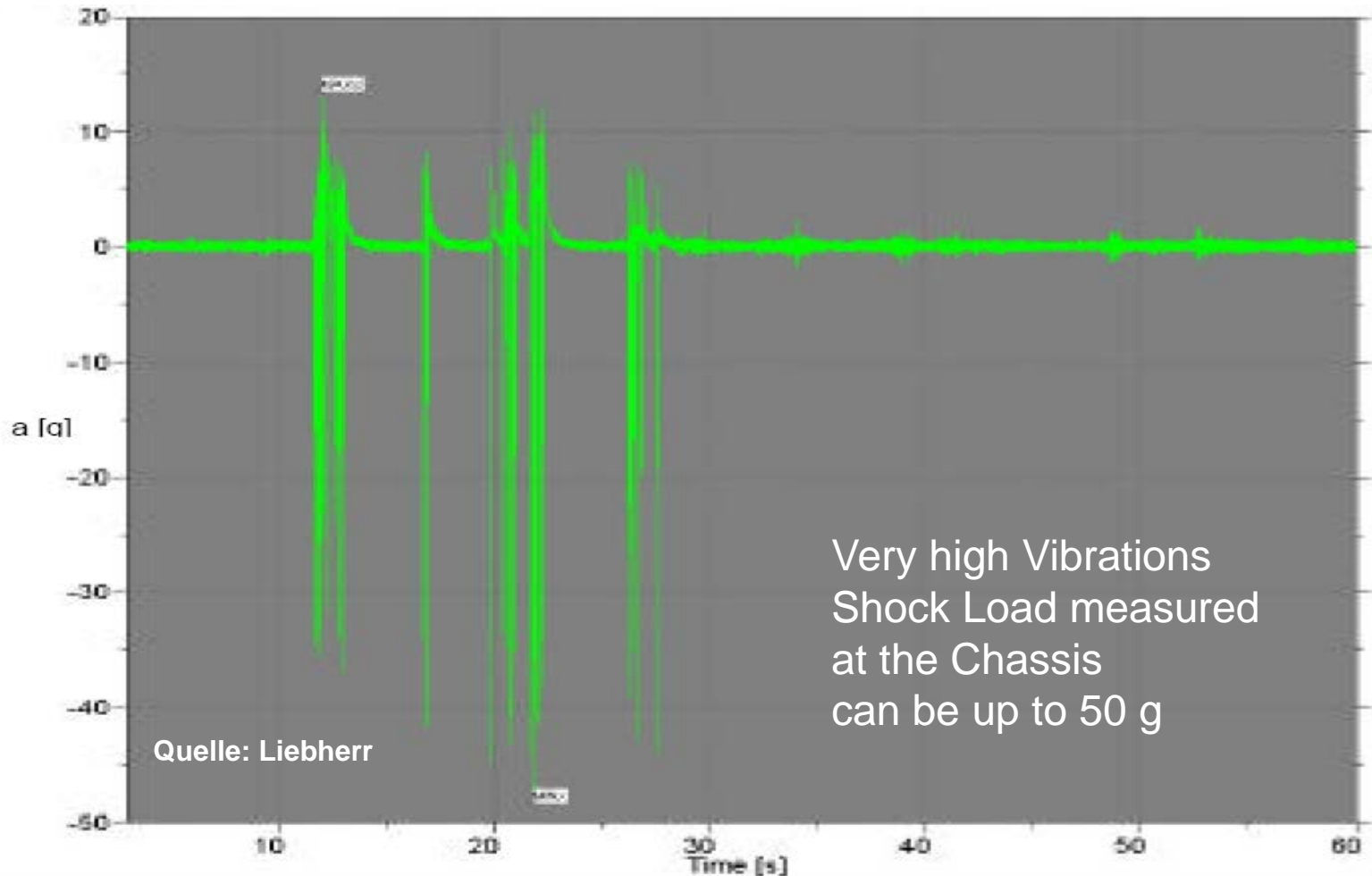
# Double-Wall-Insulation without Pressure Release



A scenic landscape featuring a range of snow-capped mountains in the background, a dense forest of evergreen trees on a ridge to the right, and a calm lake in the foreground that reflects the mountains and sky. The overall scene is peaceful and natural.

***Typical Failures  
due to Vibrations***

# Vibration up to 50 g

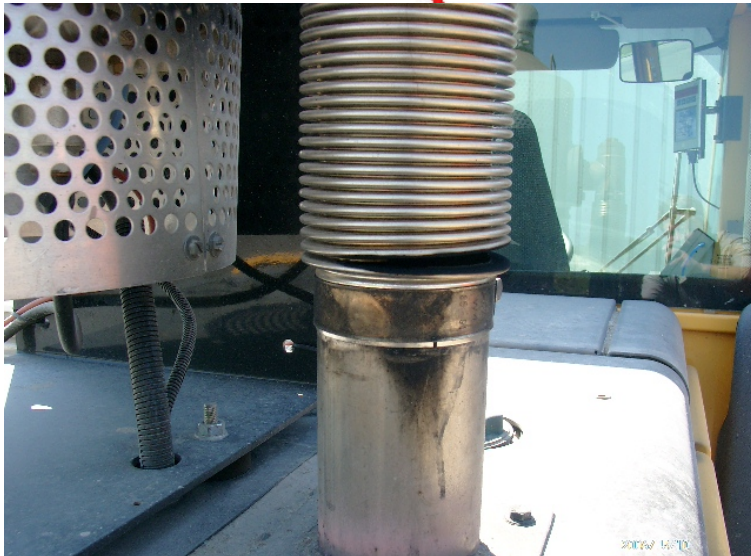


# Lose Catalysts and Filter Substrates





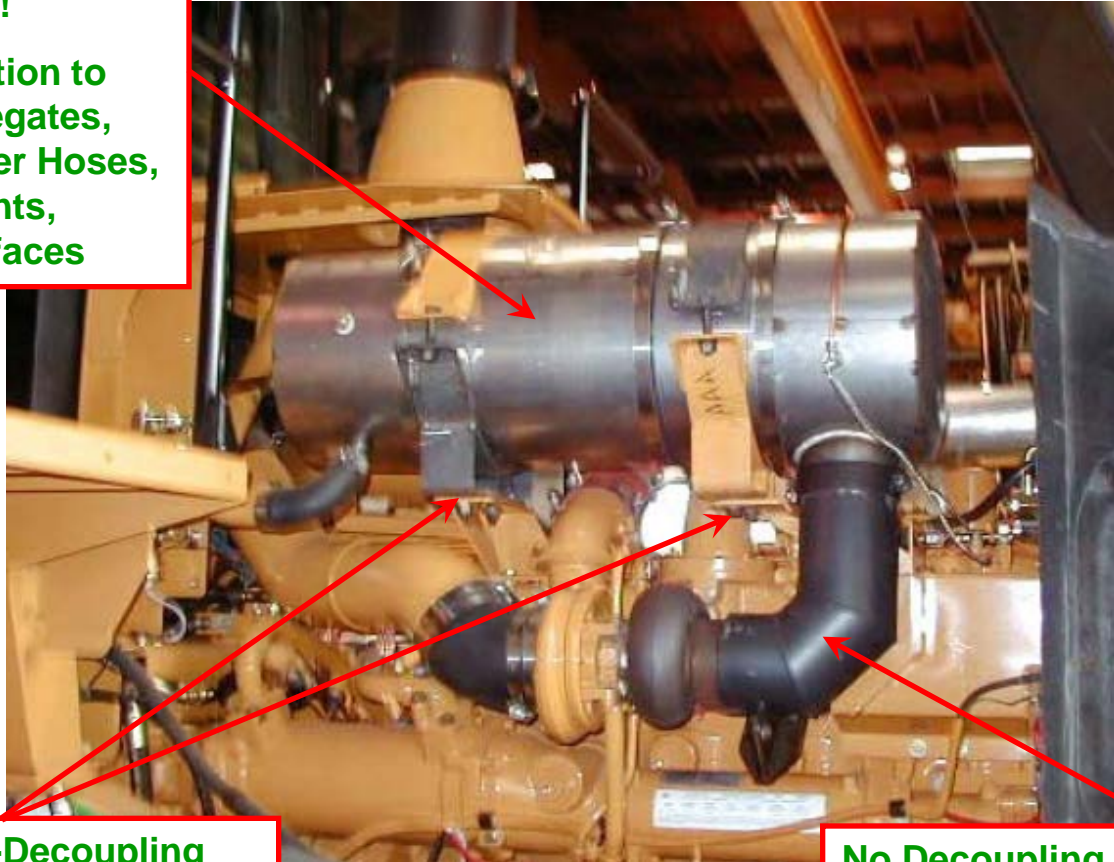
# Vibration finds every weak Point of a Design



# Mechanical Problems to be Expected ?

**No Insulation !**

→ Heat Radiation to  
Engine, Aggregates,  
Cables, Rubber Hoses,  
Plastic elements,  
Coloured Surfaces



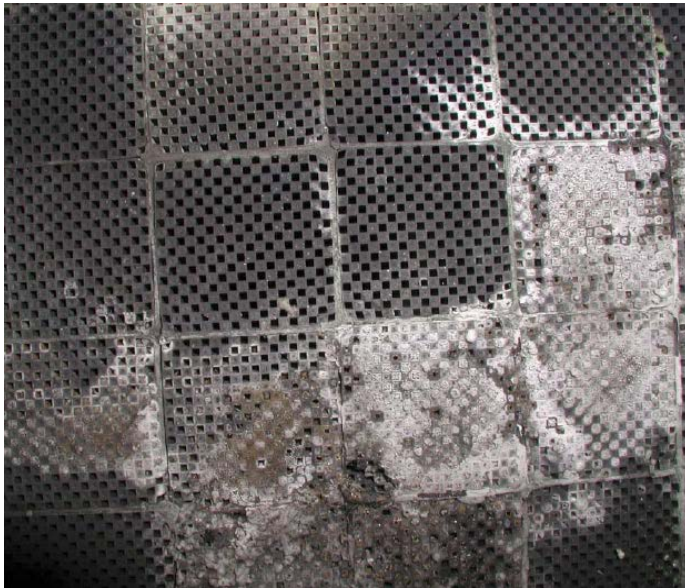
**No Vibration-Decoupling  
angainst an Engine Aerea  
where 30- 50 g is a normal  
Vibration Level**

**No Decoupling against Vibration  
and Thermal Expansion**

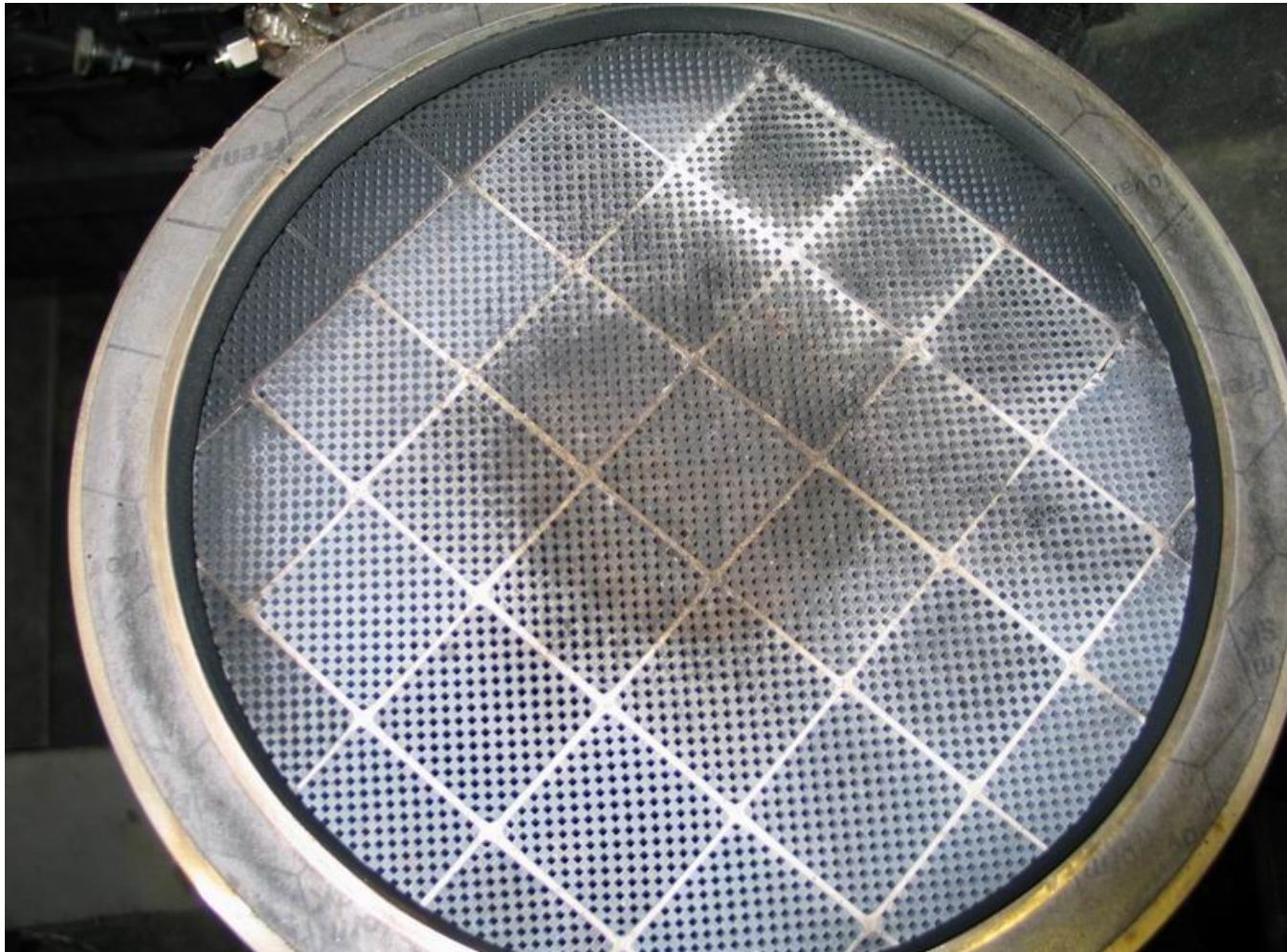
A scenic landscape featuring a range of snow-capped mountains in the background, a dense forest of evergreen trees in the middle ground, and a calm lake in the foreground. The lake is surrounded by green reeds and grasses. The sky is a pale blue with light clouds. The overall scene is peaceful and natural.

***Typical Failures  
due to Deposits***

# Deposits lead to fast Plugging and rapid Increase of Back Pressure

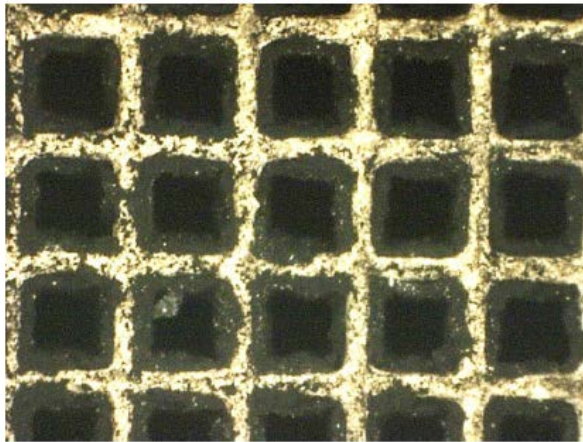


# High Lube Oil Consumption (due to Turbo Failure ?)

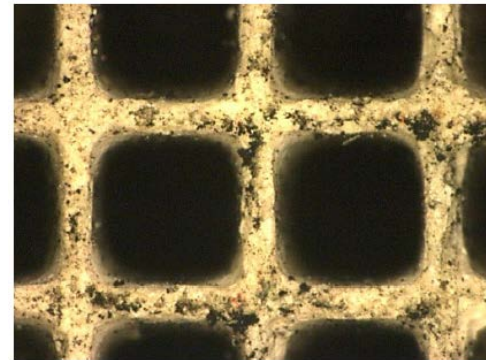
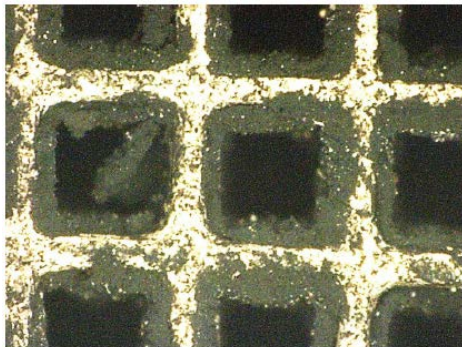
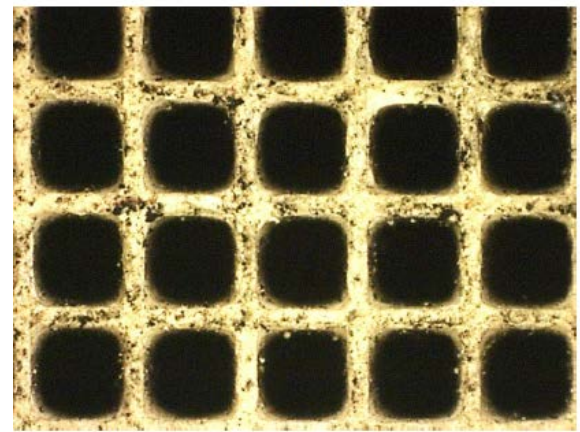


DOC might be covered by soot  
or poisoned or destroyed or aged  
or just not adequately coated

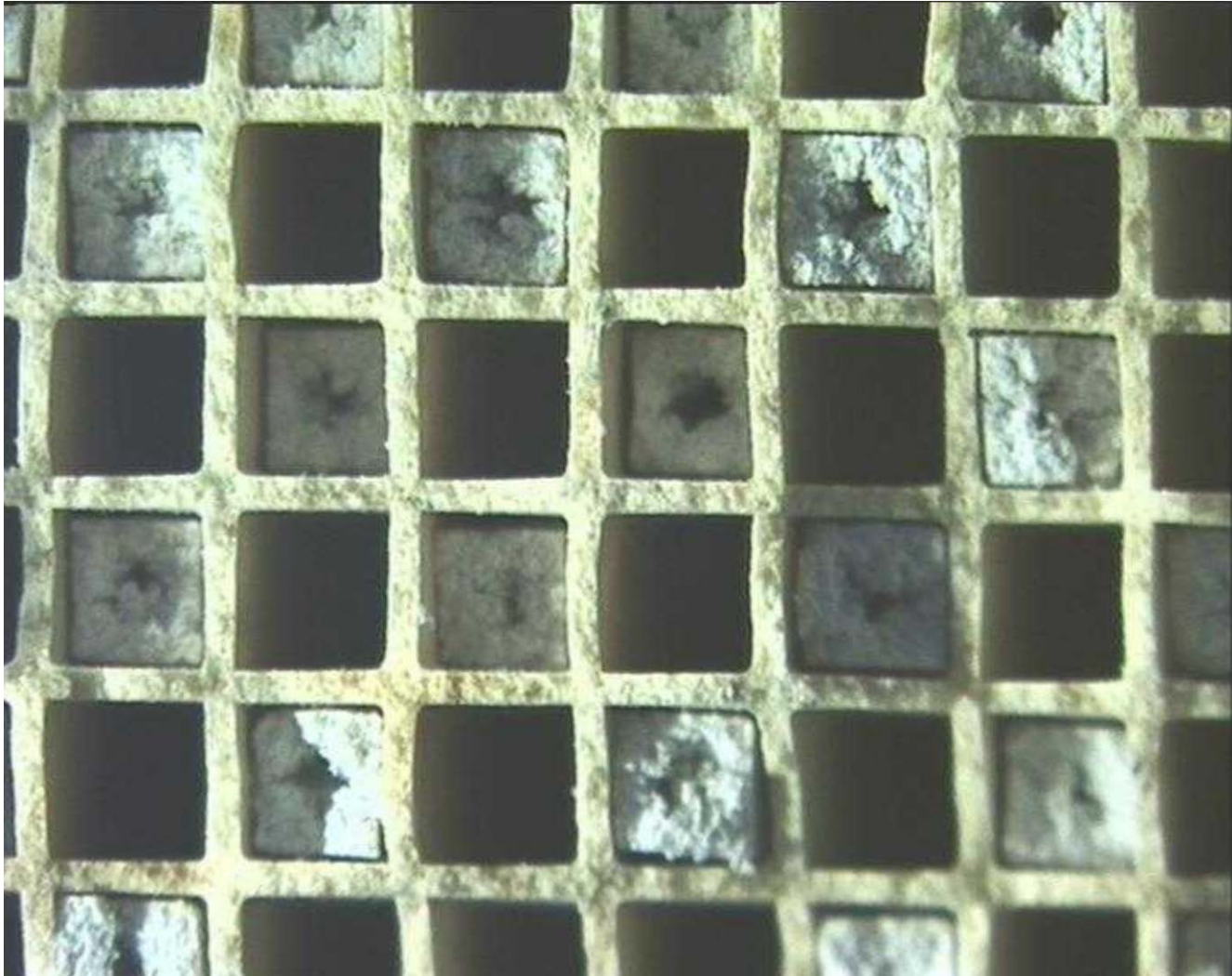
Inlet



Outlet



**Too late - No Cleaning possible anymore !**



# Iron-Additive (FBC) – normal, no worry







***Typical Failures  
due to unprofessionel  
Installations***

# Installation too tight (close to plastic wall)



# Trouble Shooting (1) → see VERT-Guidelines

Disorder	Cause	Remedy
Pressure indicated persistently and unexpectedly low.	Connection or pipe is clogged, iced or leaky; Pipe diameter too small.	Clean pipe and connection. Verify leak tight.
		Fit larger pipe sloping down. Condensate trap. Condensate filtration.
	Defective pressure sensor.	Compressed air test with reduction valve at 500 mbar.
Pressure indicated high. Does not revert to zero at standstill.	Connection or pipe is clogged.	Clean pipe and connection. Verify leak tight
		Pipe sloping down. Condensate trap.
	Defective pressure sensor.	Compressed air test with reduction valve at 500 mbar.
Black smoke emission visible and high back-pressure.	Filter extremely overburdened.	Regenerate filter through full load operation. .
		Adapt regeneration procedure to deployment.
	Regeneration ineffective.	Clean filter (burn-off residues externally).



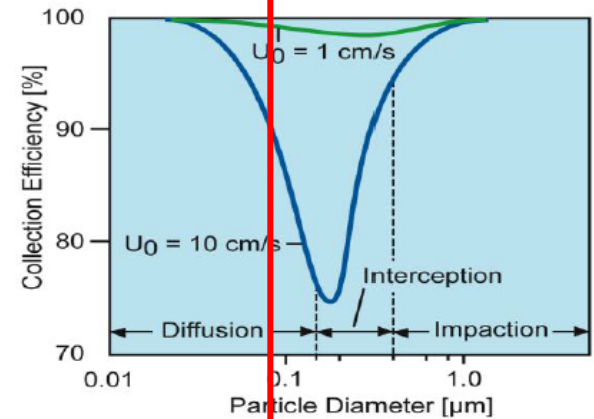
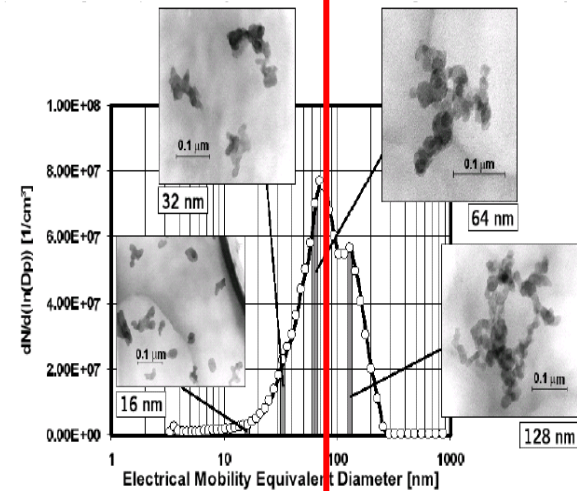
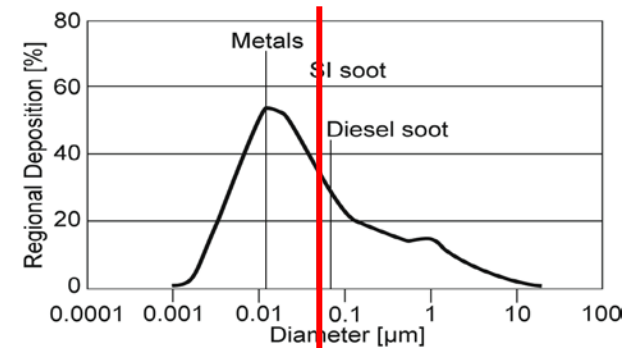
**Not all DPF offered  
on the market  
are good filter**

**Many don't fulfil  
the BAT requirements**

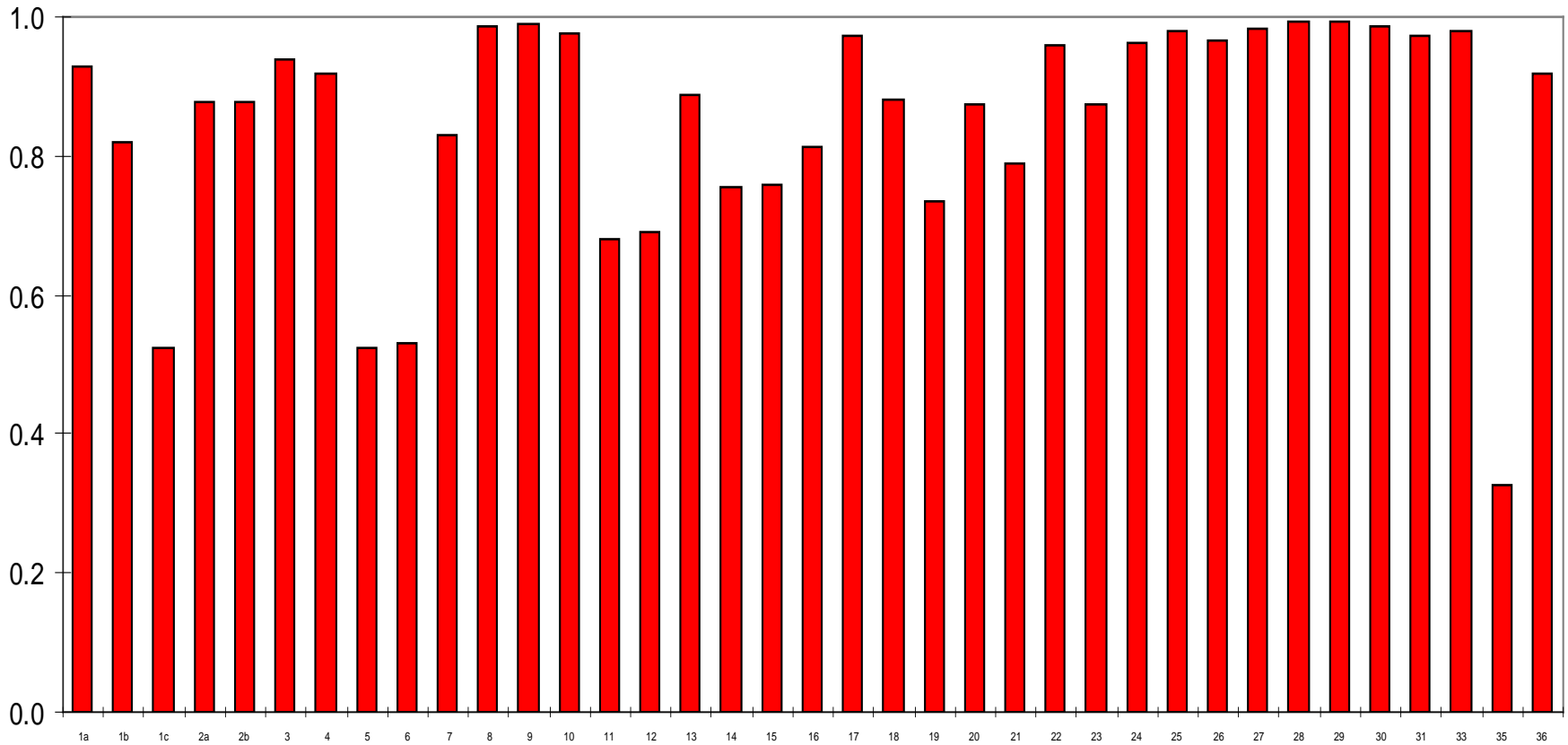
# Strange Coincidence

*The most sensitive size range of the lungs is the most intensive emission range of the engines and the weakest size range of filtration*

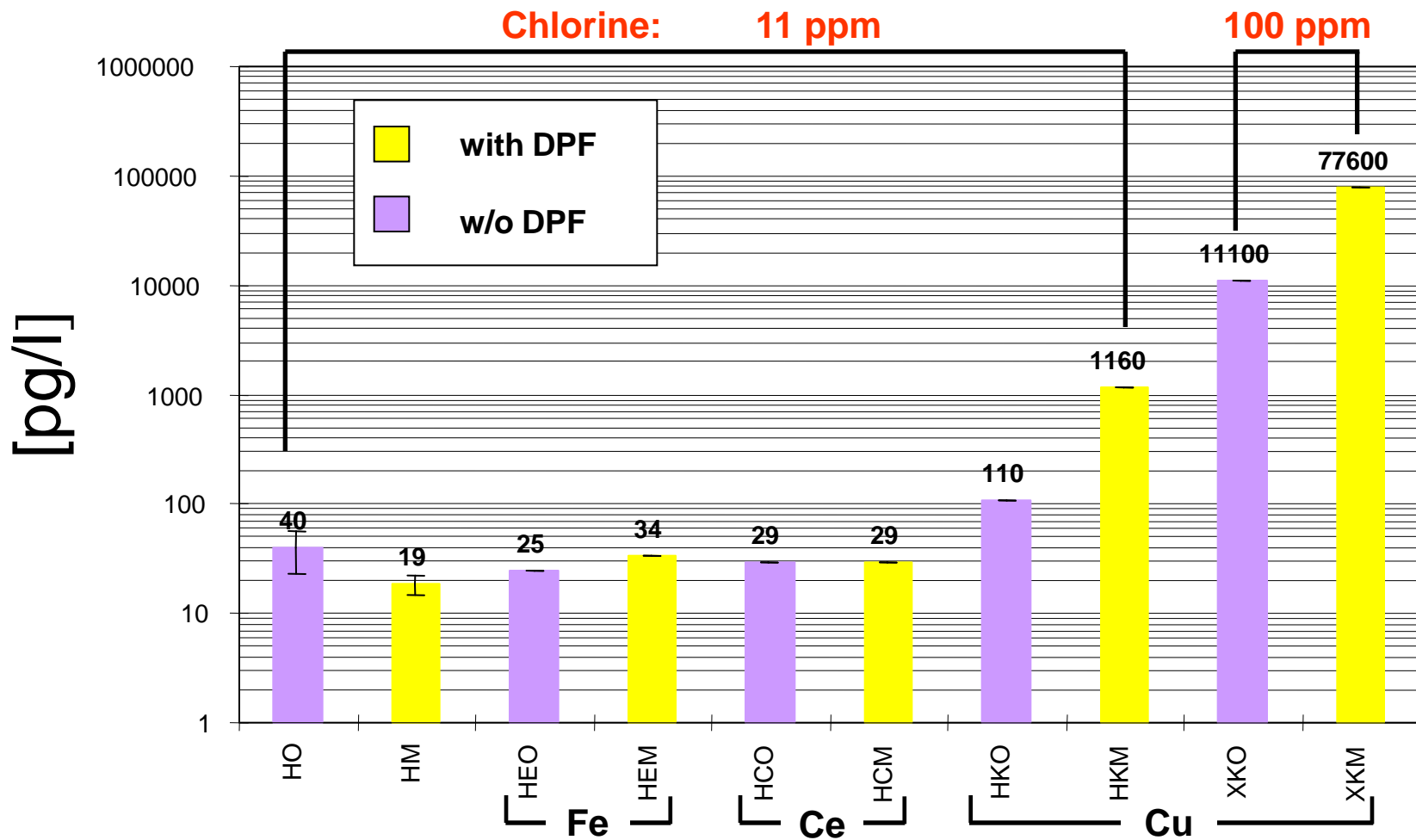
*The lung is an open door for engine emitted ultrafine particles in this size range*



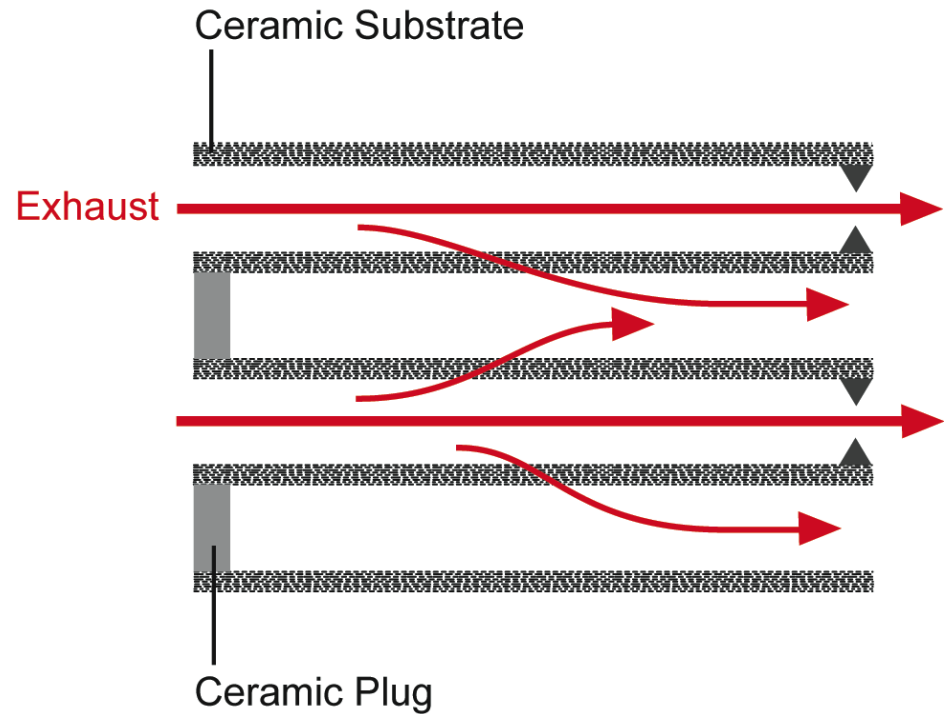
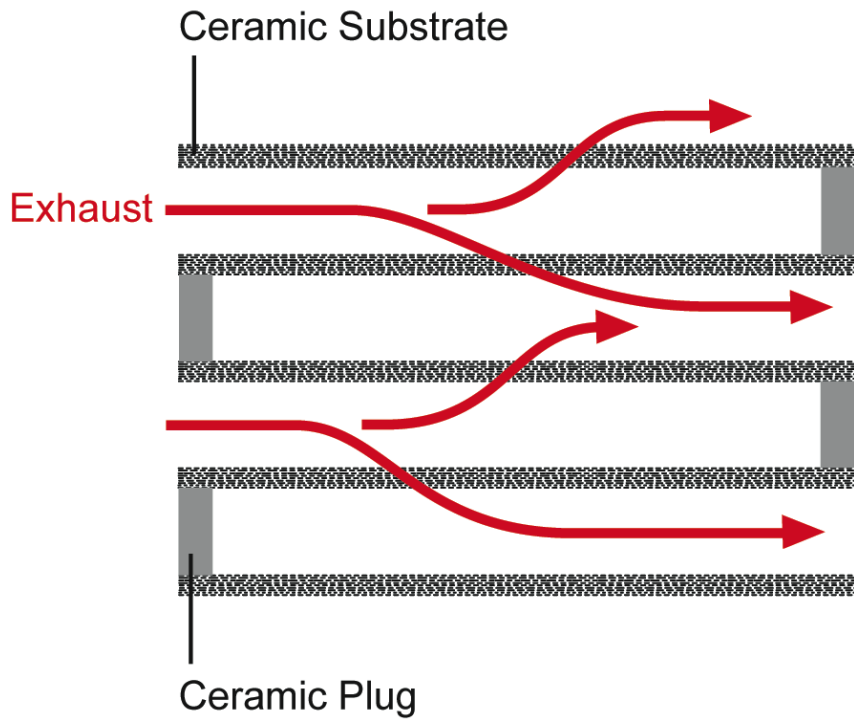
# PAH are very effectively reduced in most filter systems



# Formation of Dioxins in a Filter System using Cu-FBC



# Schematic of full-flow (closed) filters FFF (left) and partial flow (open) filters PFF (right)

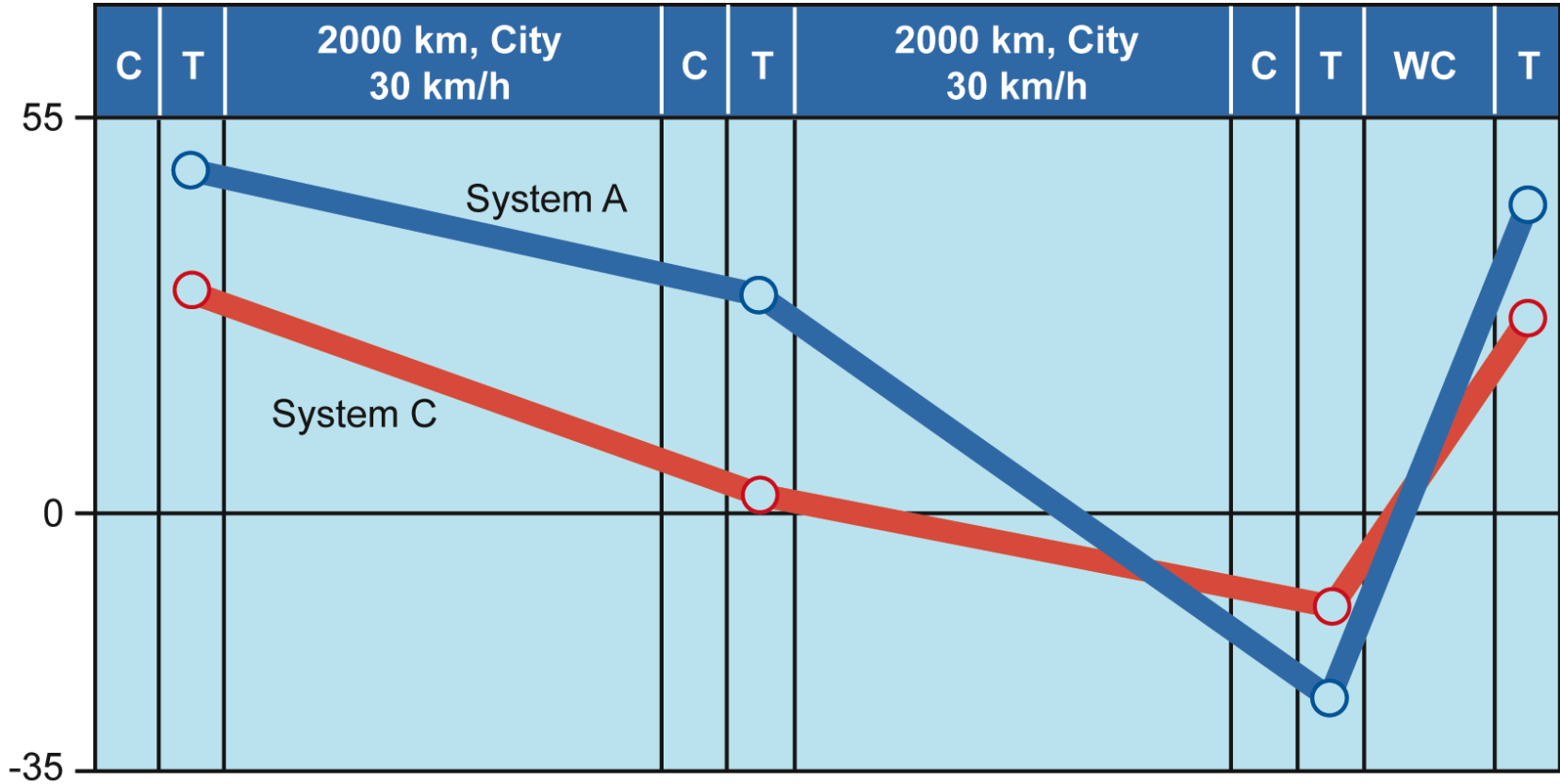




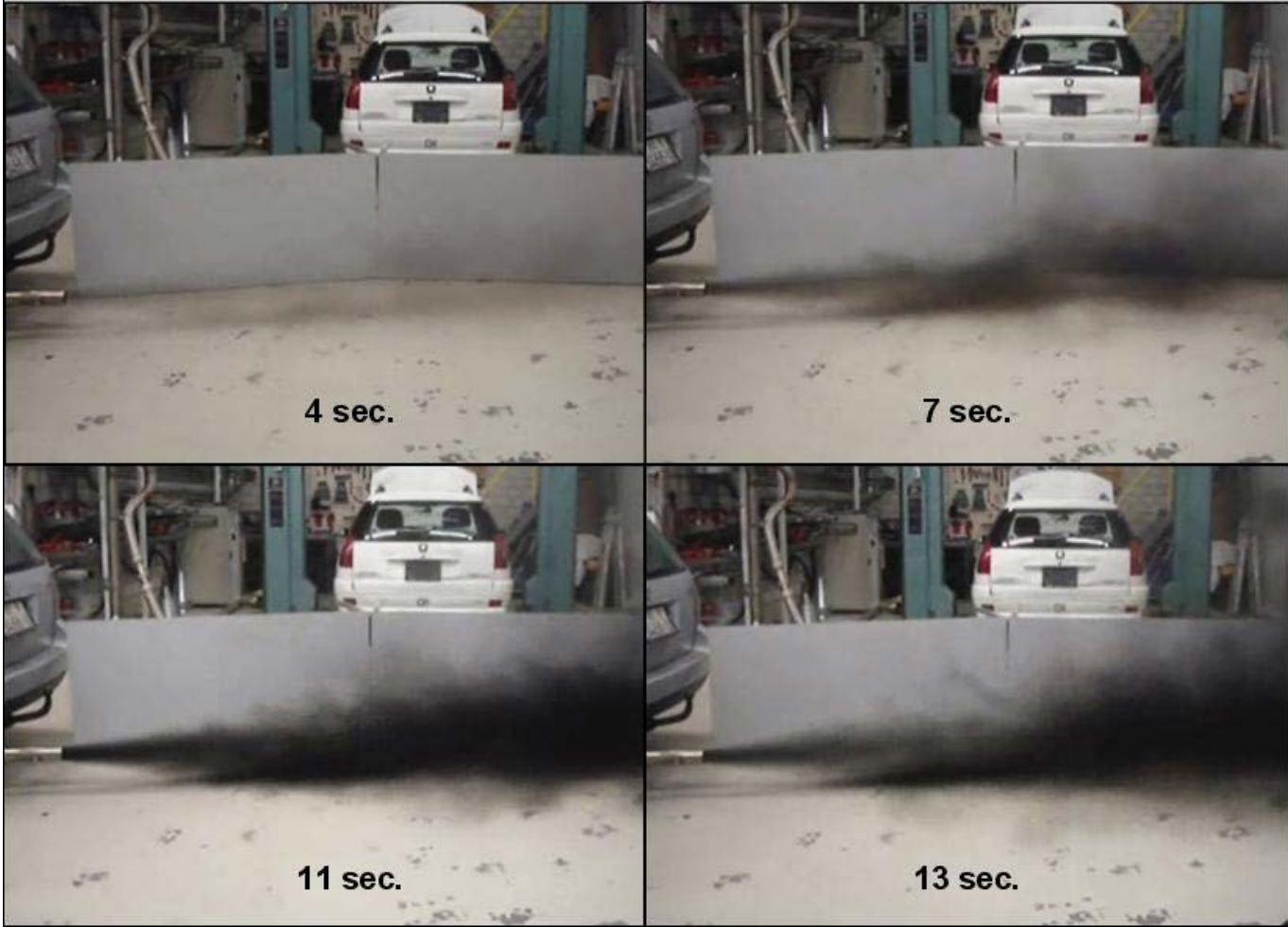
# System A and C during a city driving test of

2 x 2000 km < 70km/h, < 300°C (homologation test App. 26)

„C“ = conditioning= 3x NEDC, „T“= NEDC-test; „WC“= worst case;



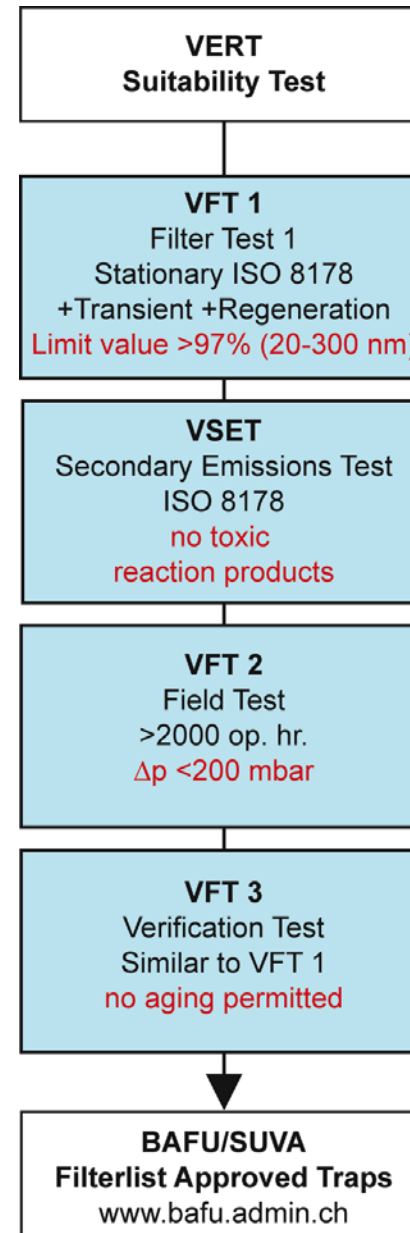
# Typical blow-off during full load acceleration after city driving



A scenic landscape featuring a range of snow-capped mountains in the background, a dense forest of evergreen trees in the middle ground, and a calm lake in the foreground that reflects the mountains and sky. The water is clear, showing some aquatic plants. The overall scene is peaceful and natural.

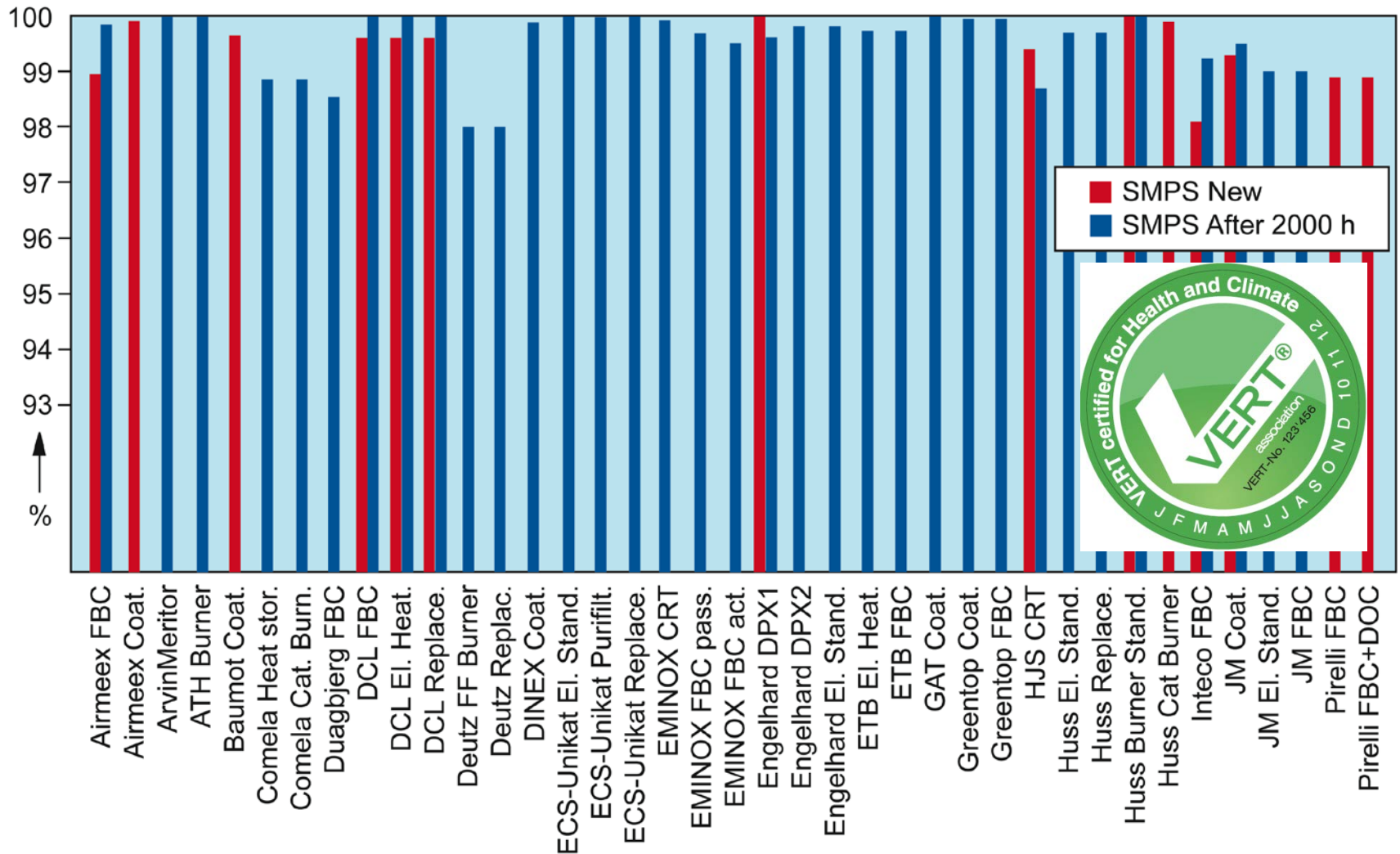
**Suggestion**  
**exclusive use of**  
**VERT certified filters**

# VERT type approval + local approval



# Filtration - 65 DPF VERT tested

25 % > 99.8 % within size range 20-300 nm



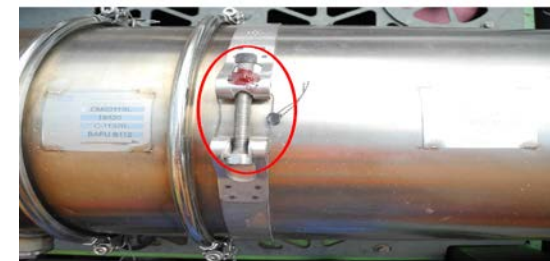
# Durability Test (Field test) **2000 hrs**

VERT approved DPF systems must undergo a field test of **at least 2000 operating hours**

Do be done in a typical application of the specific DPF system (i.e. stationary or mobile application resp.)

With periodic tests of filter performance, back pressure, regeneration, control and alert systems, mechanical construction etc.

Followed by a full filter test on bench VFT3 **no aging or deterioration permitted**



A scenic landscape featuring a calm lake in the foreground, a dense forest of evergreen trees on the right, and a range of rugged, snow-capped mountains in the background under a clear sky. The text 'Reliability Experience' is overlaid in the center in a bold green font.

# Reliability Experience

# Reliability of DPF in Switzerland

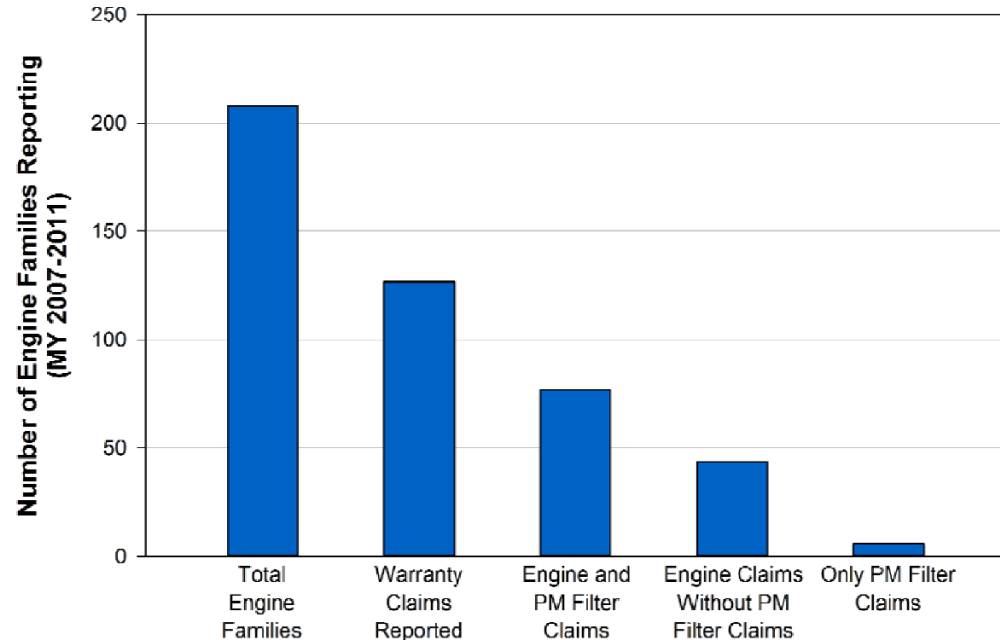
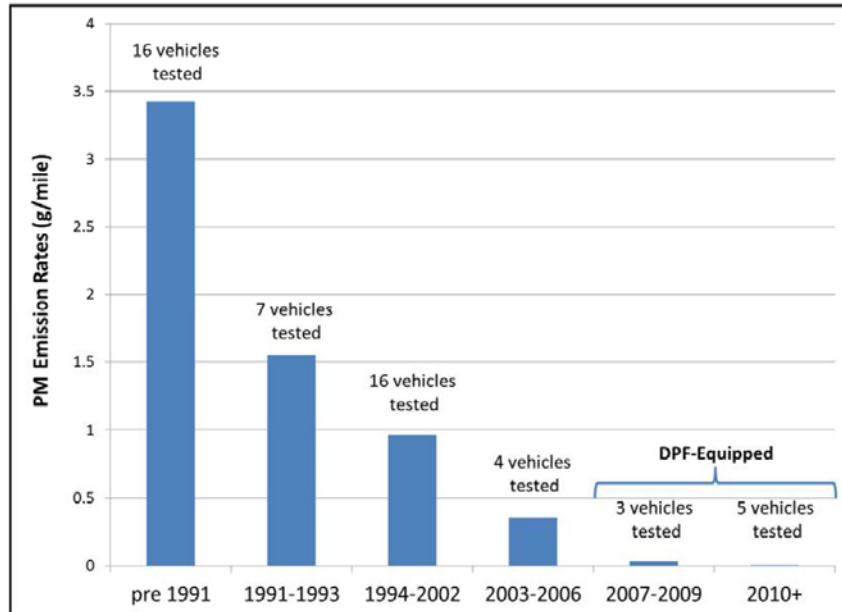
- 1990: 230 Filters installed in Buses (DB/M&H-System)  
1998: still 200 in Operation
- 2000: 2400 PFS in Operation, > 6% Failures per year  
→ too many Failures → VERT-Test 2 introduced
- 2003: > 6500 PFS in Operation  
Failures 2-3 % per year
- PFS > 800'000 km Trucks and Buses
  - PFS > 10'000 op.hrs Construction Machines
  - PFS > 45'000 op.hrs Ferry Boat
  - PFS > 60'000 op.hrs Genset
- 2010 > 25'000 PFS in Operation  
Failures 2-3 % per year; some companies < 1 %
- 2012 < 1 % - some large fleets < 0.3**



# CARB investigated 587 trucks (OE and Retrofit) for engine and DPF problems (report May 2015)

As discussed in Section 3, staff conducted 621 roadside truck inspections, 587 of which were trucks equipped with PM filters. The resulting sample of paired truck inspections and operator surveys was representative of the California fleet. Appendix V provides a table showing the number of trucks inspected by body type relative to statistical sample targets.

Based on responses from truck operators, about 2 percent (11 of 587 trucks) reported a past problem with the PM filter on their truck that required service to resolve the



# Summary - How to avoid Failures

- Use only VERT-certified filters –VERT-Filterlist
- Evaluate vehicle operation → VERT Guide
- Install datalogger and alarms – remote download
- Training for mechanics, drivers and management
- Acceptance test of each retrofit → VERT-Guide
- Control emission once a year → VERT-Guide
- ***Be proud cleaning the air of your environment***

*Bus Fleet of Berlin (1200 vehicles) respecting these rules  
has 1-2 failures per year – 0.1 %*