7th International ETH-Conference on Combustion Generated Particles
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Recent Trends for Filter Development for Diesel Particulate Aftertreatment

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Abstract:

This paper will give an overview about the recent trend filter development for diesel particulate aftertreatment for passenger cars and heavy duty vehicles. The material development for passenger car diesel particulate filters lead to new materials like silicon carbide while for heavy duty applications still Cordierite plays a major role. However in the future Cordierite might also be used for passenger cars in 4 way catalyst system applications This paper will show the basic difference between both applications and describe the materials in terms of properties (material, back pressure aspects, filtration efficiency) and application on vehicles. Furthermore an outlook will be given on catalysed soot filters.

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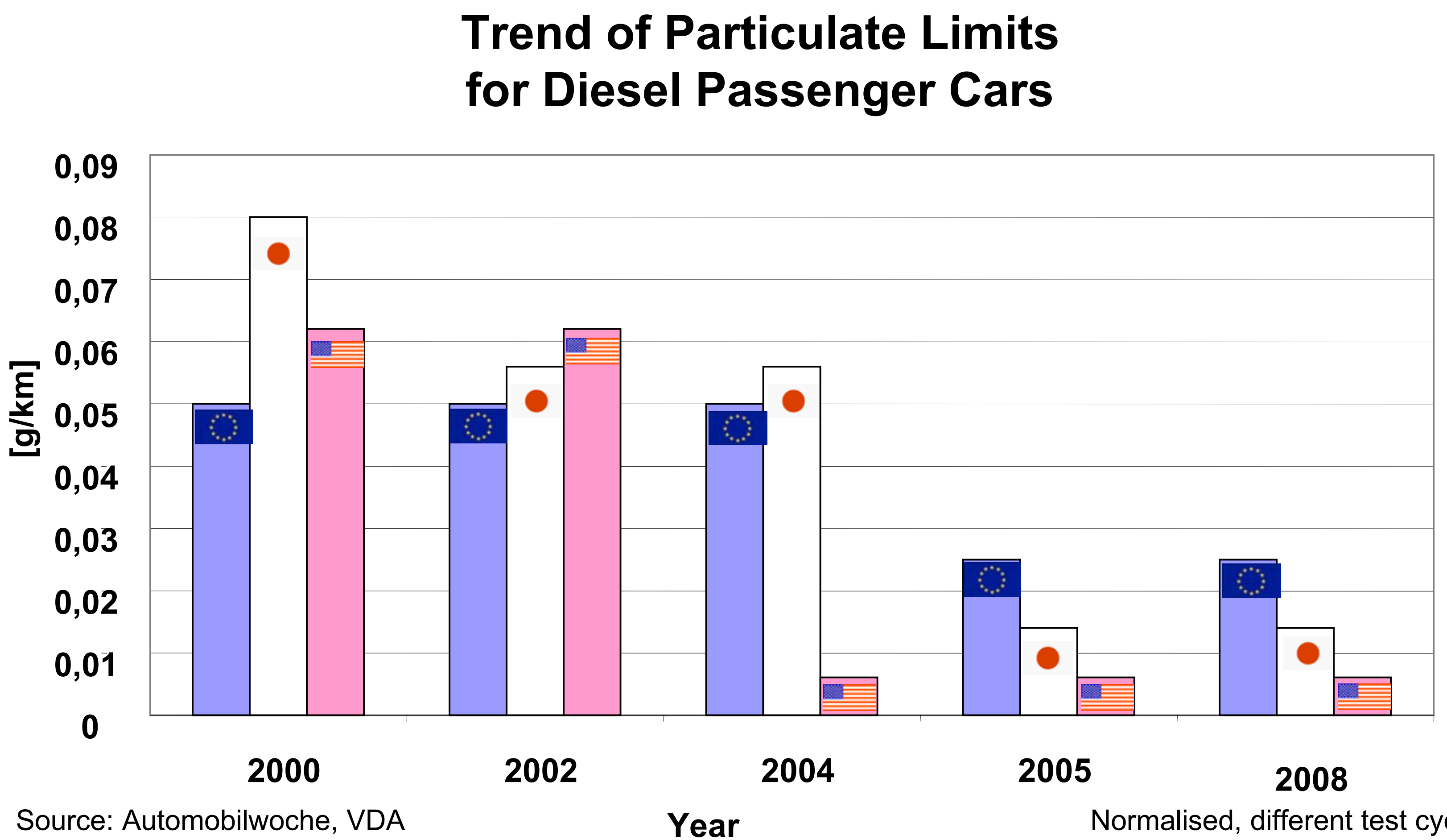
Introduction

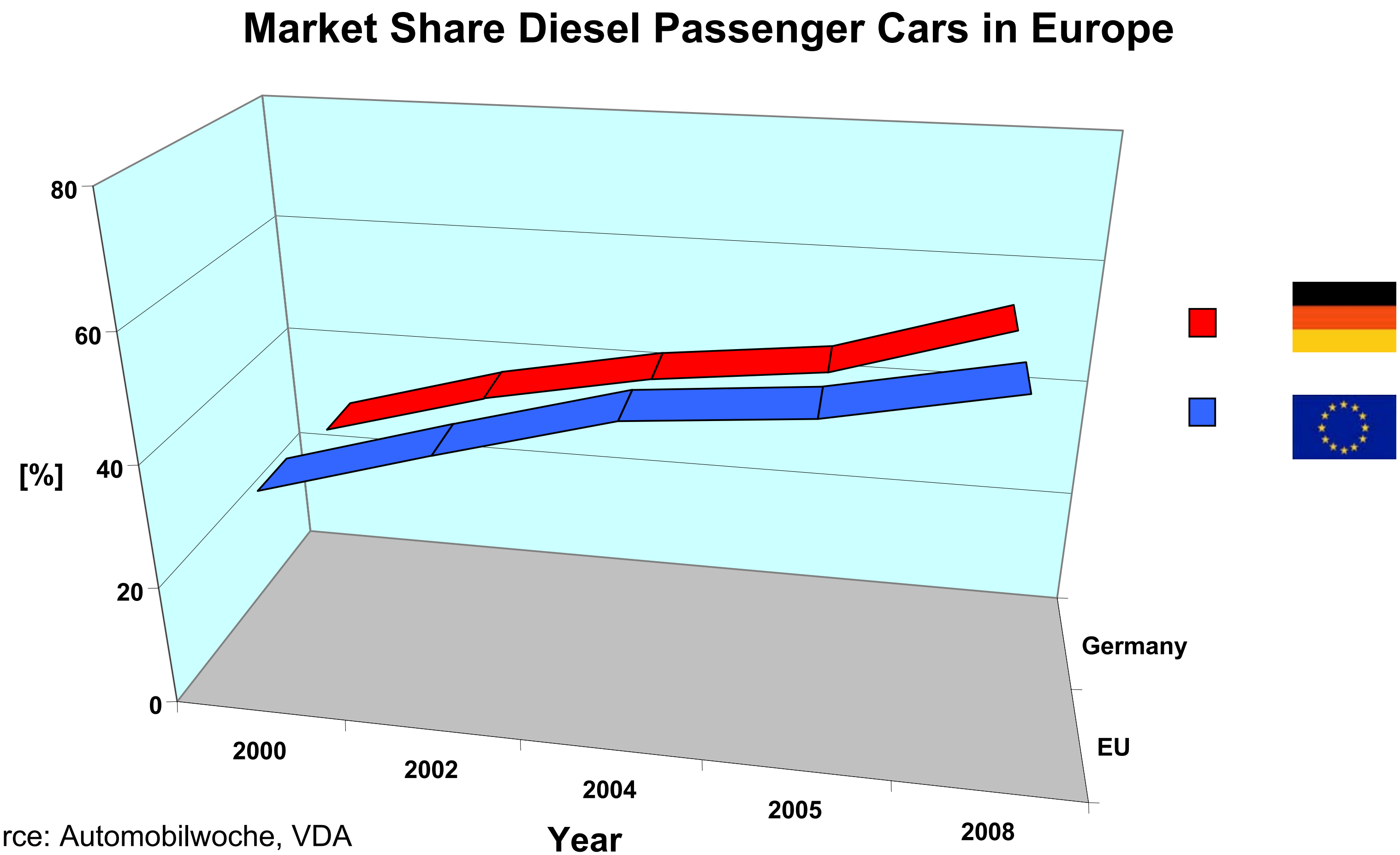


Source: Automobilwoche, VDA

Normalised, different test cycles

➡ Particulate limits tighten globally

Introduction



Source: Automobilwoche, VDA

➡ Growing market share for diesel vehicles in EU

Particulate Filter Applications

Passenger Cars	Heavy Duty Vehicles
- Higher SOF content	- Lower SOF content
- Max. back pressure high	- Max. back pressure low
- Temperature level: 150 - 300 °C	- Temperature level: 200 - 500 °C
- Lower NO content	- Higher NO content
- Discont. regeneration	- Cont. regeneration targeted

➡ **NO_2 regeneration possible with Heavy Duty Vehicles**

Particulate Filter Applications

Fuel Additive Systems

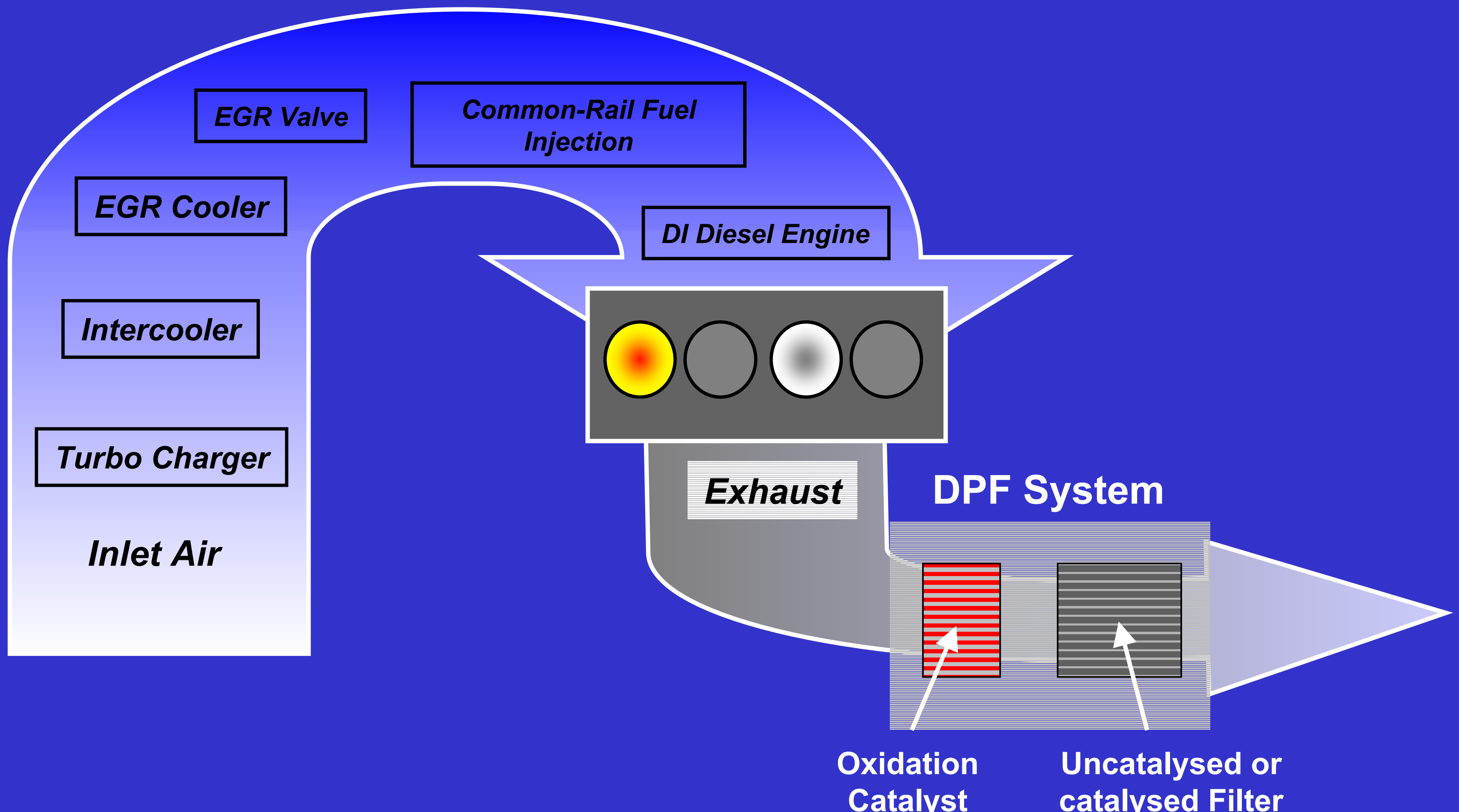
- Fast regeneration
- High exotherm
- High ash deposition
- High pressure drop
- Filter cleaning necessary

Catalysed Soot Filter (CSF)

- „Softer regeneration“
- No CO and HC peaks
- Only oil ash deposition
- Lower pressure drop over service life
- No Filter cleaning needed

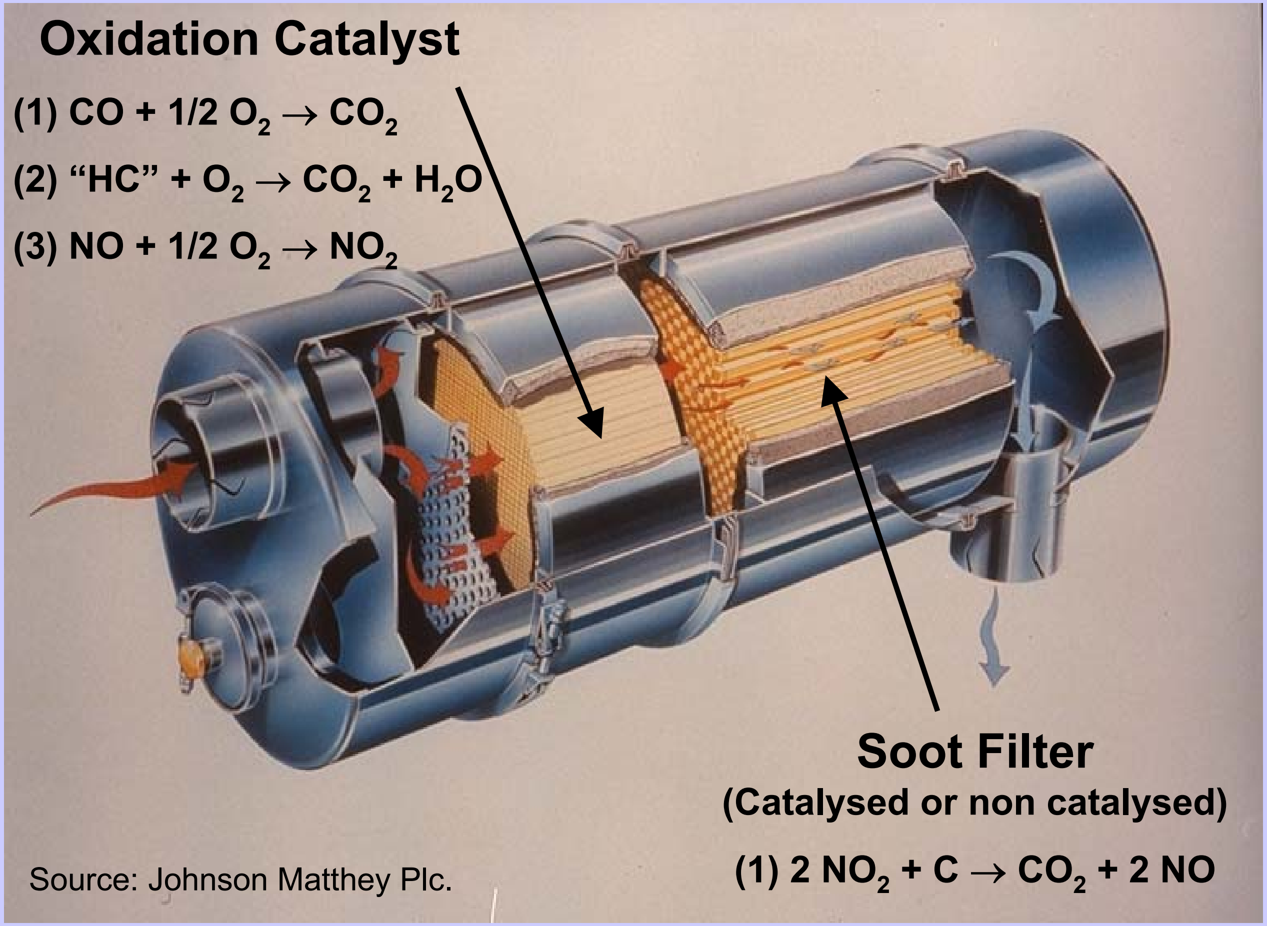
➡ **CSF should reduce ash and back pressure**

Passenger Car Soot Filter System



➡ Possible diesel passenger car aftertreatment system

Heavy Duty Aftertreatment System



➡ **Heavy duty application maybe combined with SCR**

Cordierite and Si-SiC Filters

Cd-DPF ⇨ Monolithic

SiC-DPF ⇨ Segmented

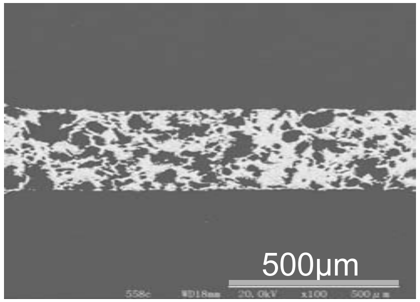
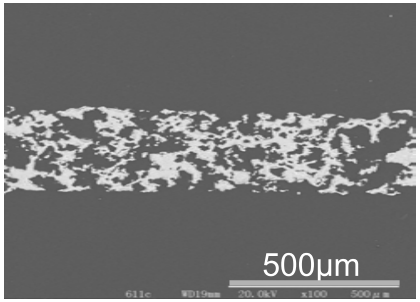
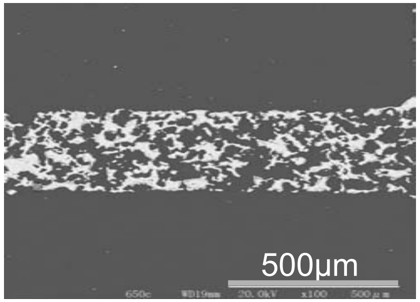
Cordierite (Cd)-DPF

SiC-DPF

Material Properties	Cd-DPF	SiC-DPF
Coefficient of Thermal Expansion A-axis ($x10^{-6}/^{o}C$: 40 - 800°C)	0.4 - 1.0	4
Thermal Conductivity (W/m·K)	1	12

➡ **Major difference in design and material properties**

NGK Material Properties of Cordierite Filters

Material	C 558 Std. Cordierite Filter (w/o coating)	C 611 High Porosity Filter for CSF	High Porosity Filter for CSF (high loading)
			
Porosity [%]	52	59	65
Mean Pore Size [μm]	15	20 - 25	22
Therm. Conductivity [W/mK]	1	1	1
CTE, A Axis [x 10^6/°C]	1,0	1,0	1,0

NGK Material Properties of Si-SiC Filters

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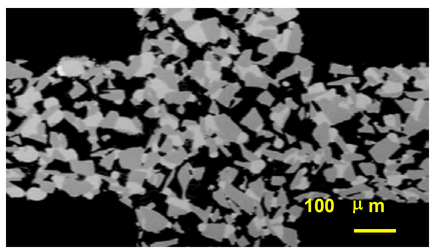
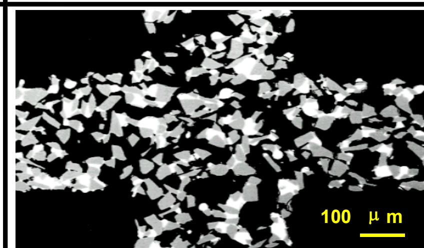
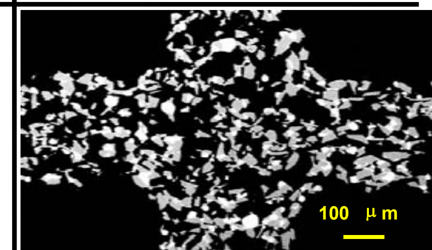
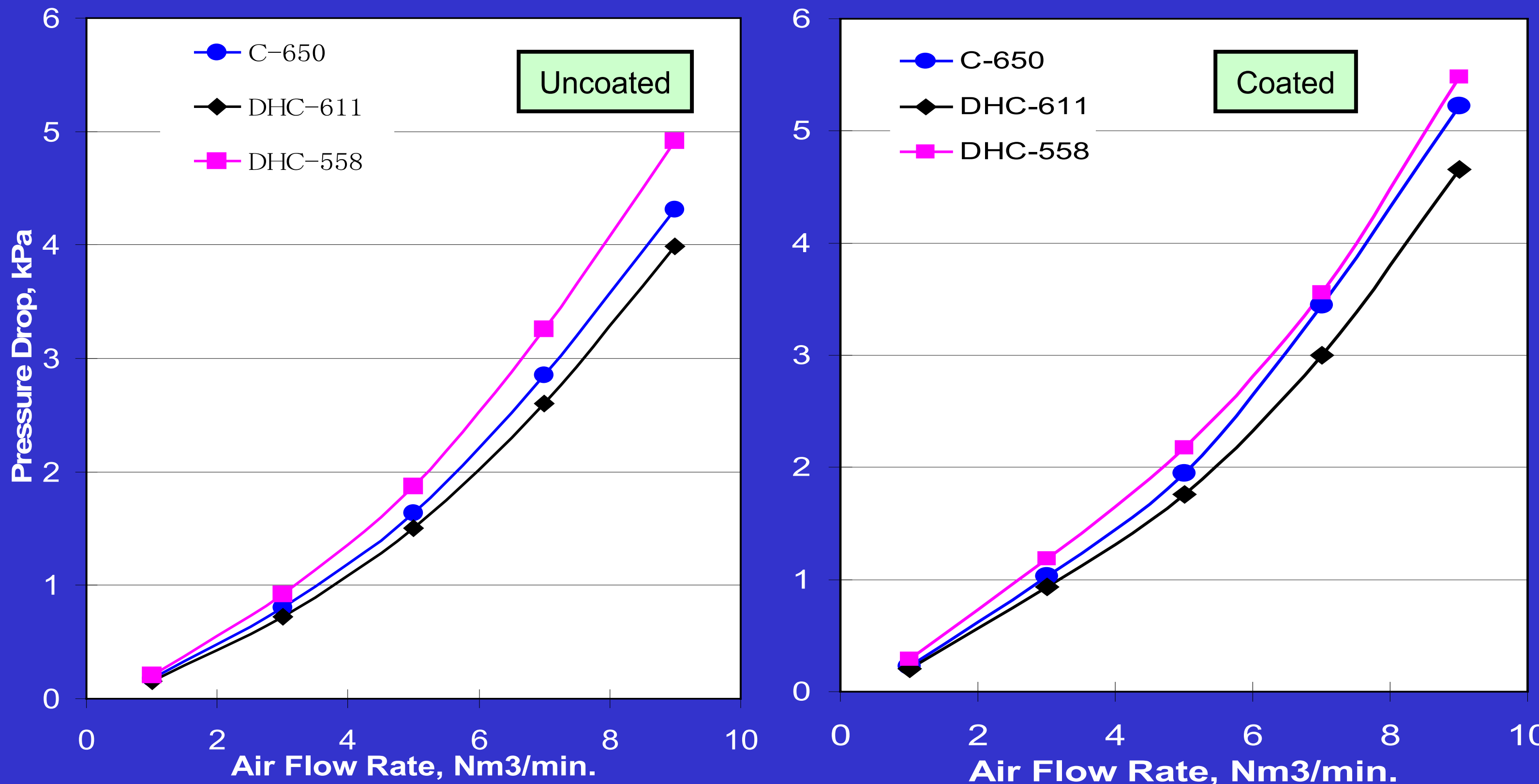
NGK Materials	Si-SiC Material for Fuel Additive Systems	Si-SiC Material for Catalysed Filters (CSF)	Si-SiC Material for Catal. Filters (CSF) (High Porosity)
			
Porosity [%]	46	52	60
Mean Pore Size [μm]	20	20	20
Therm. Conductivity [W/mK]	30	18	11
CTE, A Axis [x 10^6/°C]	4,0	4	4

Cordierite Filters

Impact of Coating on Initial Pressure Drop



➡ Coating increases initial back pressure by ~ 10 %

Cordierite Filters

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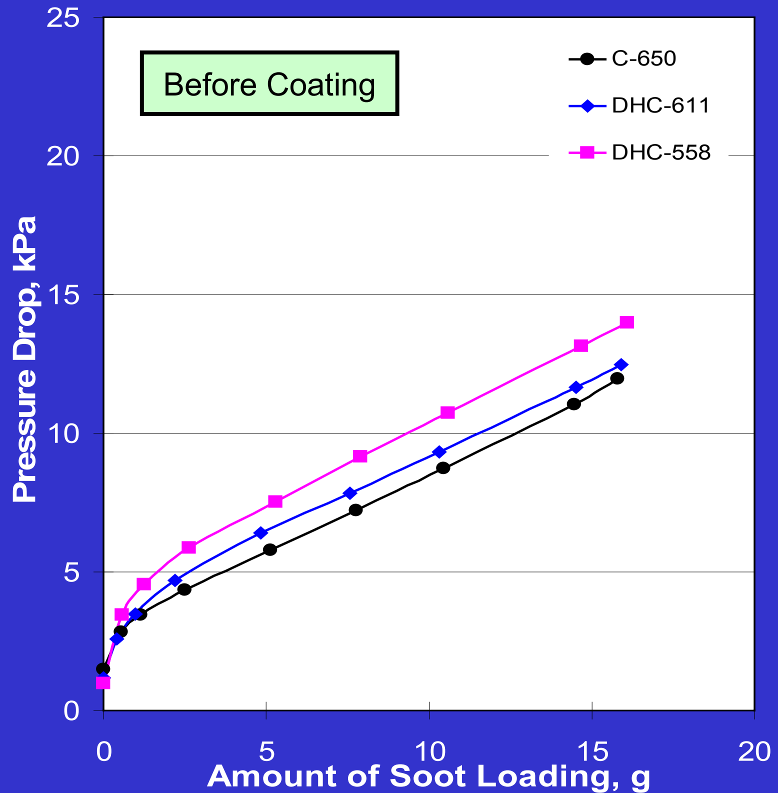
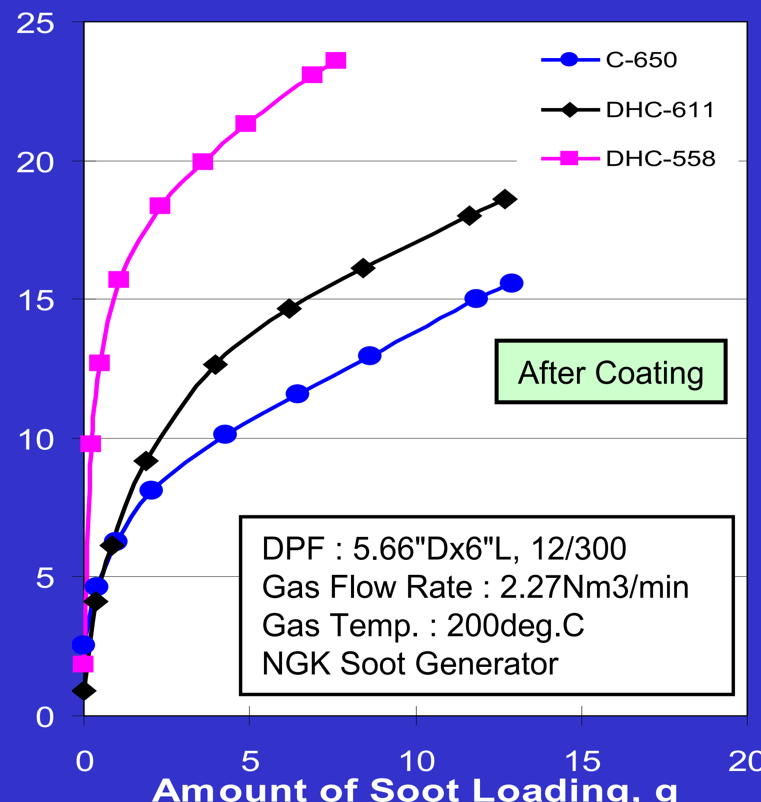
Impact of Porosity on Pressure Drop with Soot

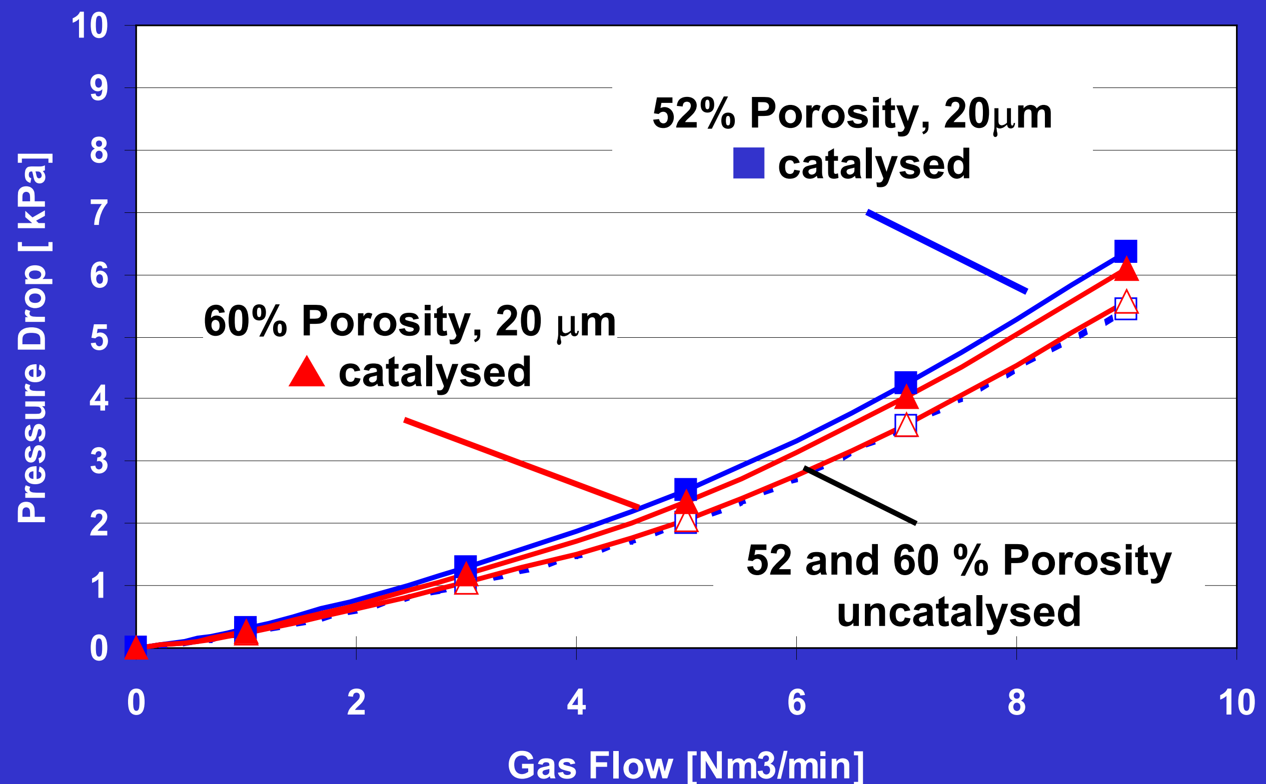




➡ High porosity filters provide lowest pressure drop

Si-SiC Filters

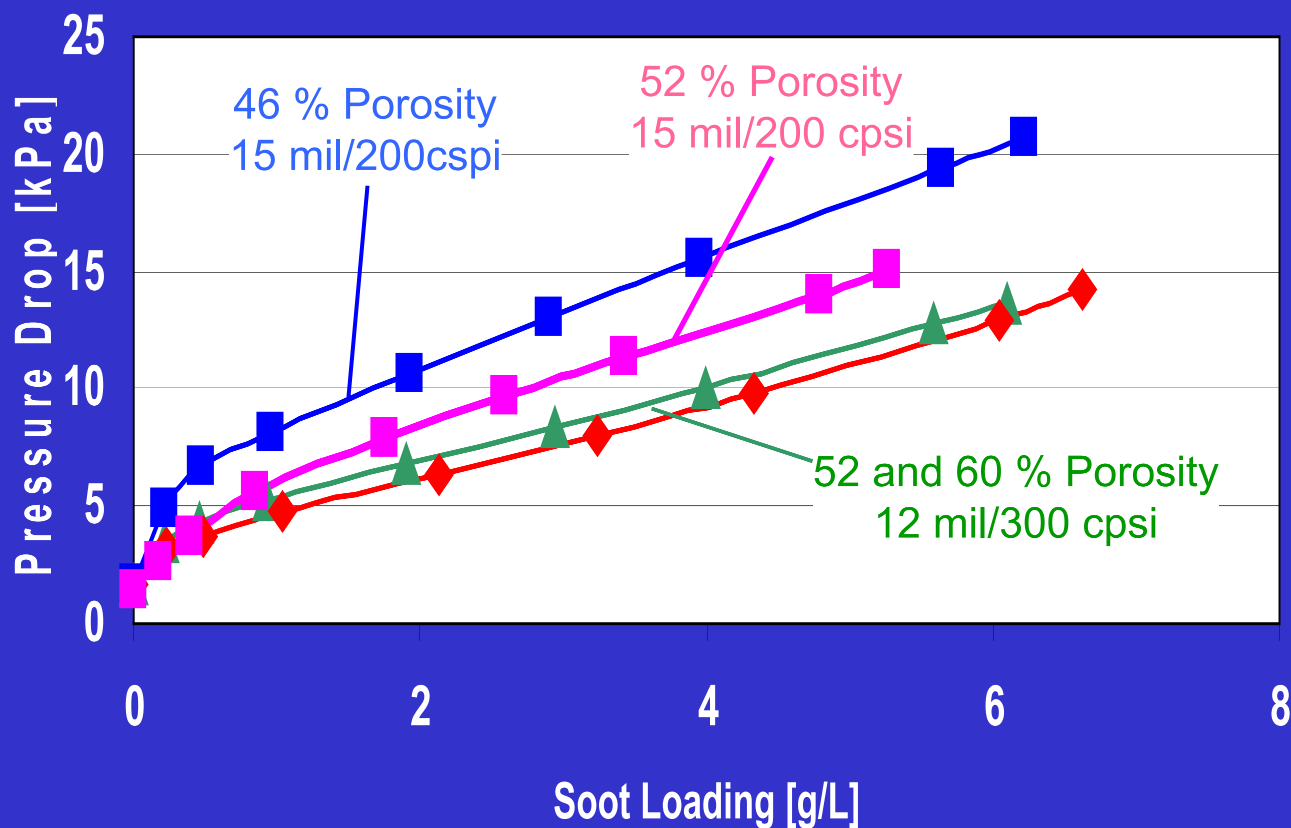
Impact of Porosity on Initial Pressure Drop



Almost no impact with high porosity filters

Non Coated Si-SiC Filters

Cell Structure, Porosity and Pressure Drop



With soot cell structure has an impact

Si-SiC Filters

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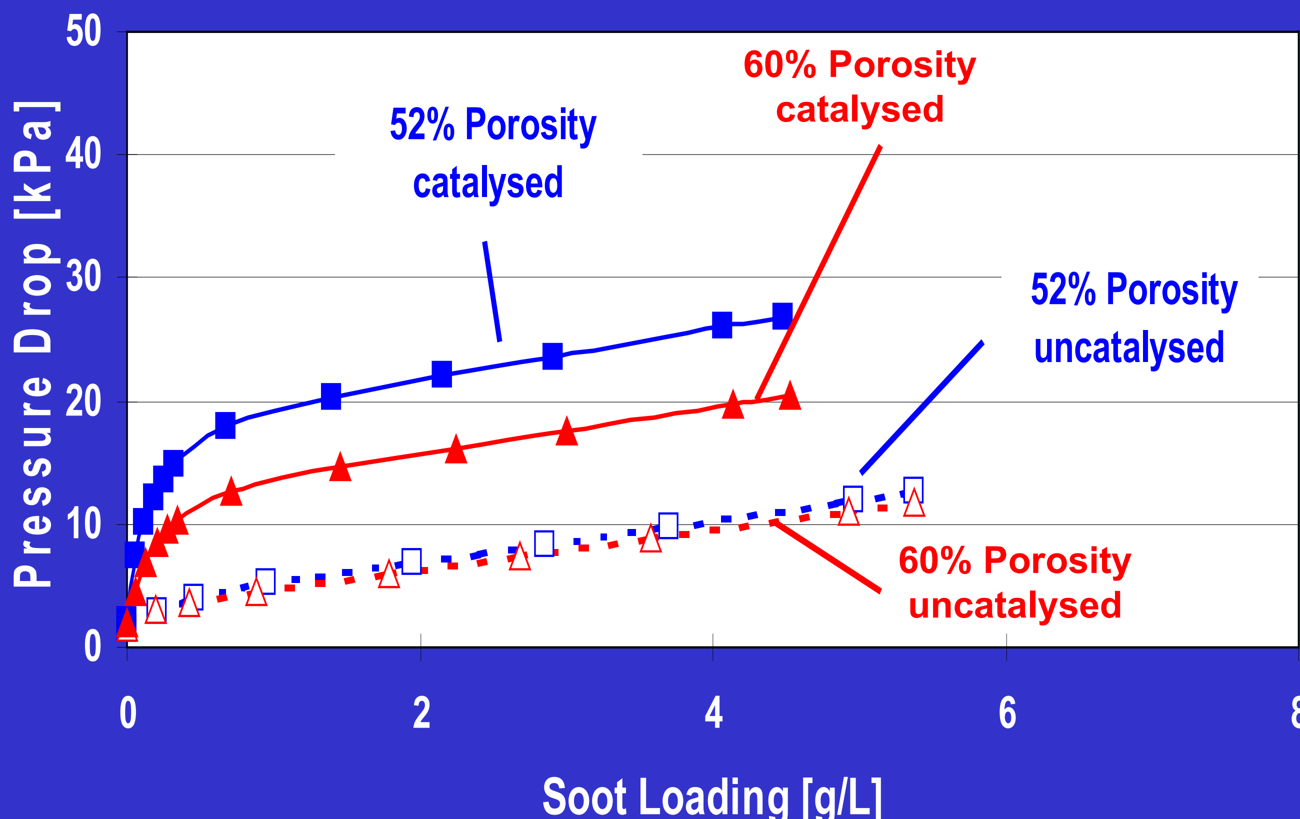
CSF Impact of Porosity on Pressure Drop with Soot



➡ **High porosity filters advantageous for CSF**

Engine Bench Pressure Drop Evaluation

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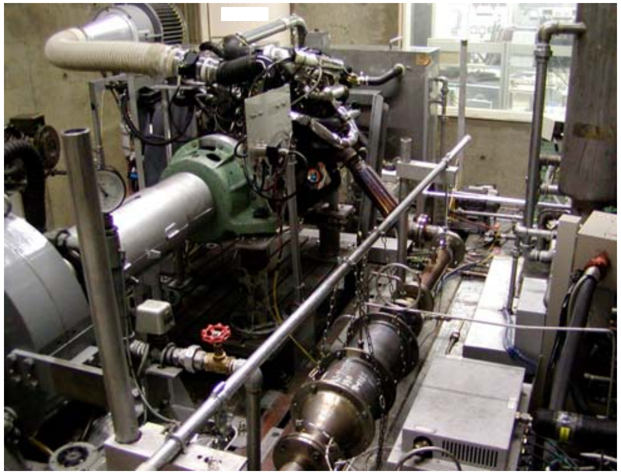
Experimental Conditions

Engine and particulate filter

Engine Type	Common Rail Direct Injection
Engine Displacement [L]	2,0
Filter size [inch]	5,66“ x 6“
Filter volume [L]	2,47

Test procedure

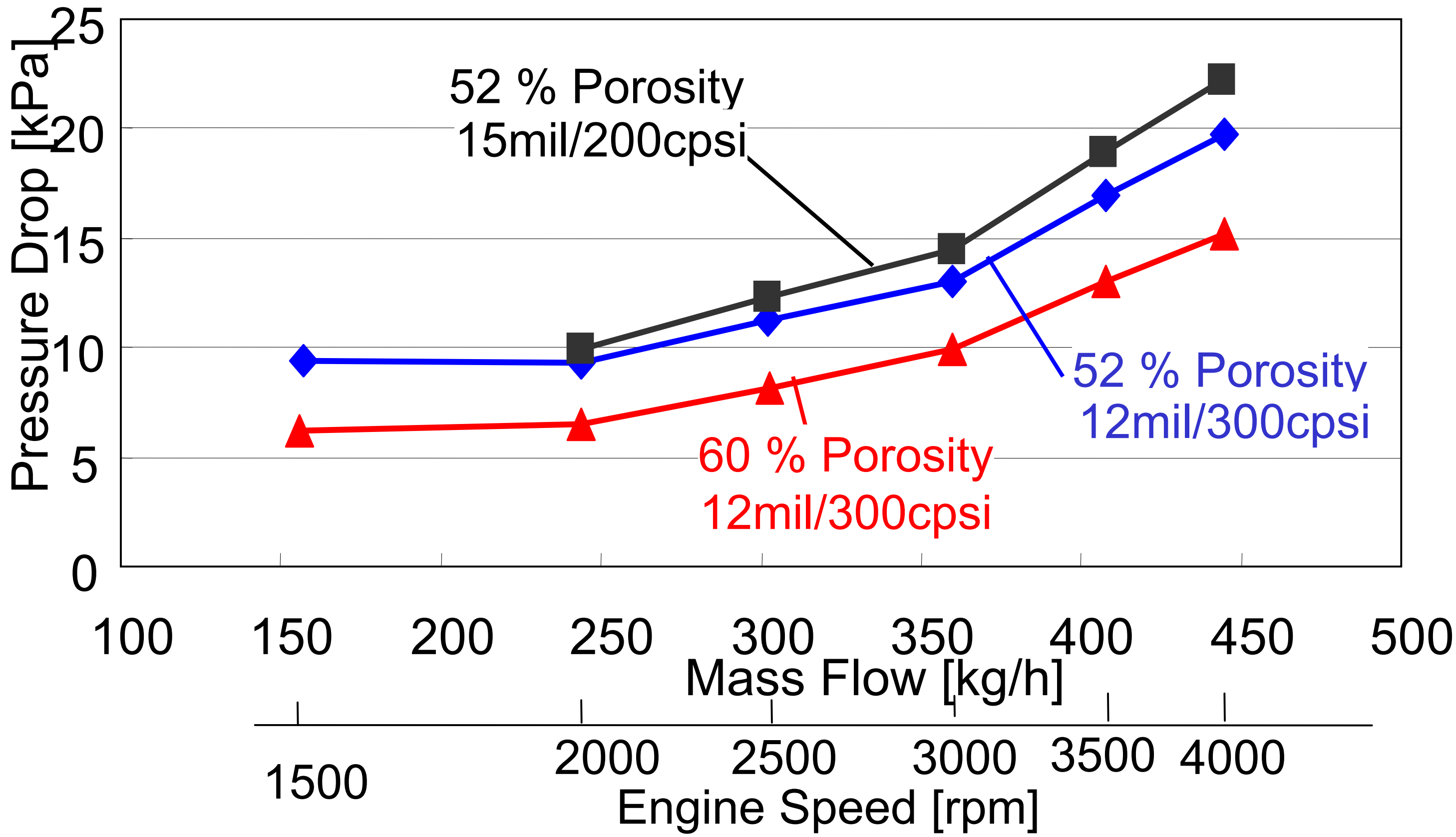
Engine Speed [rpm]	1500 – (500) - 5000
Sampling time per step [min]	6
Load	Up to full load



NGK Engine Bench with 2,0l Common Rail DI Diesel Engine

Engine Bench Pressure Drop Evaluation

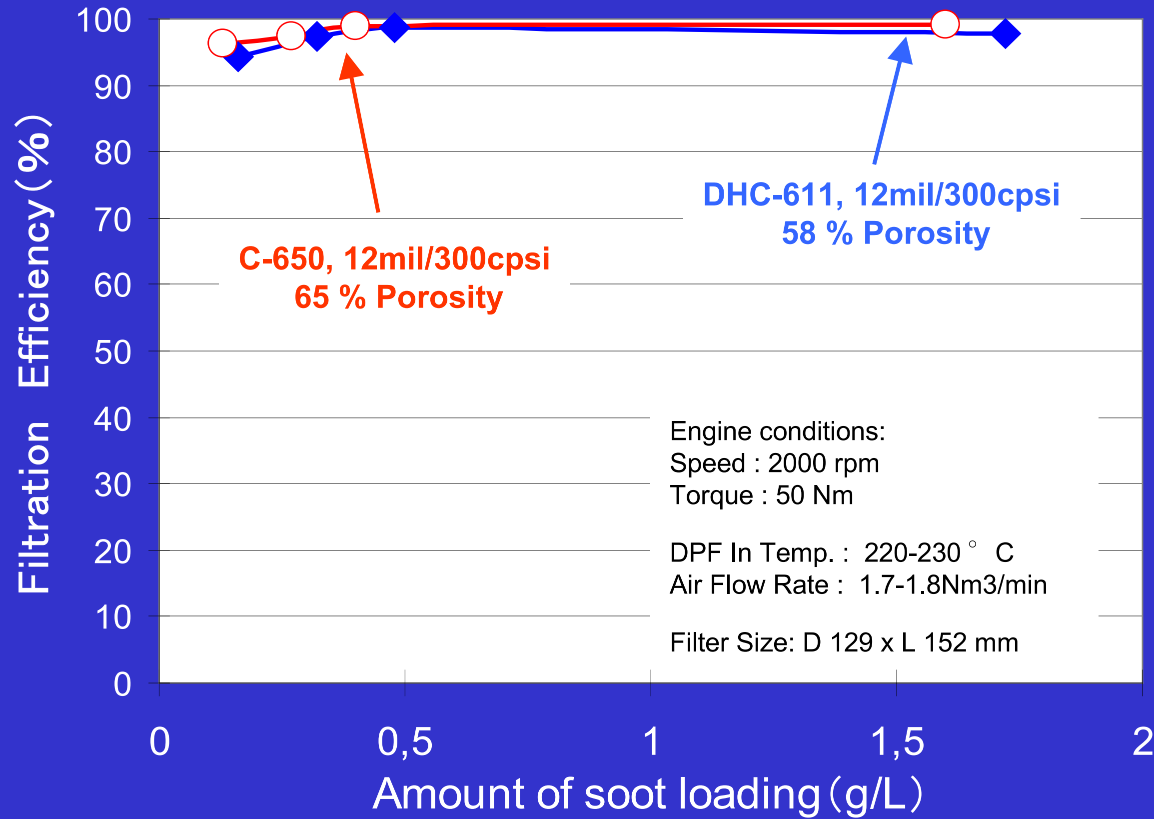
Pressure Drop Test up to Full Load (1 g/L soot loading)



➡ High porosity and high surface filters advantageous

Filtration Efficiency of Cordierite Filters

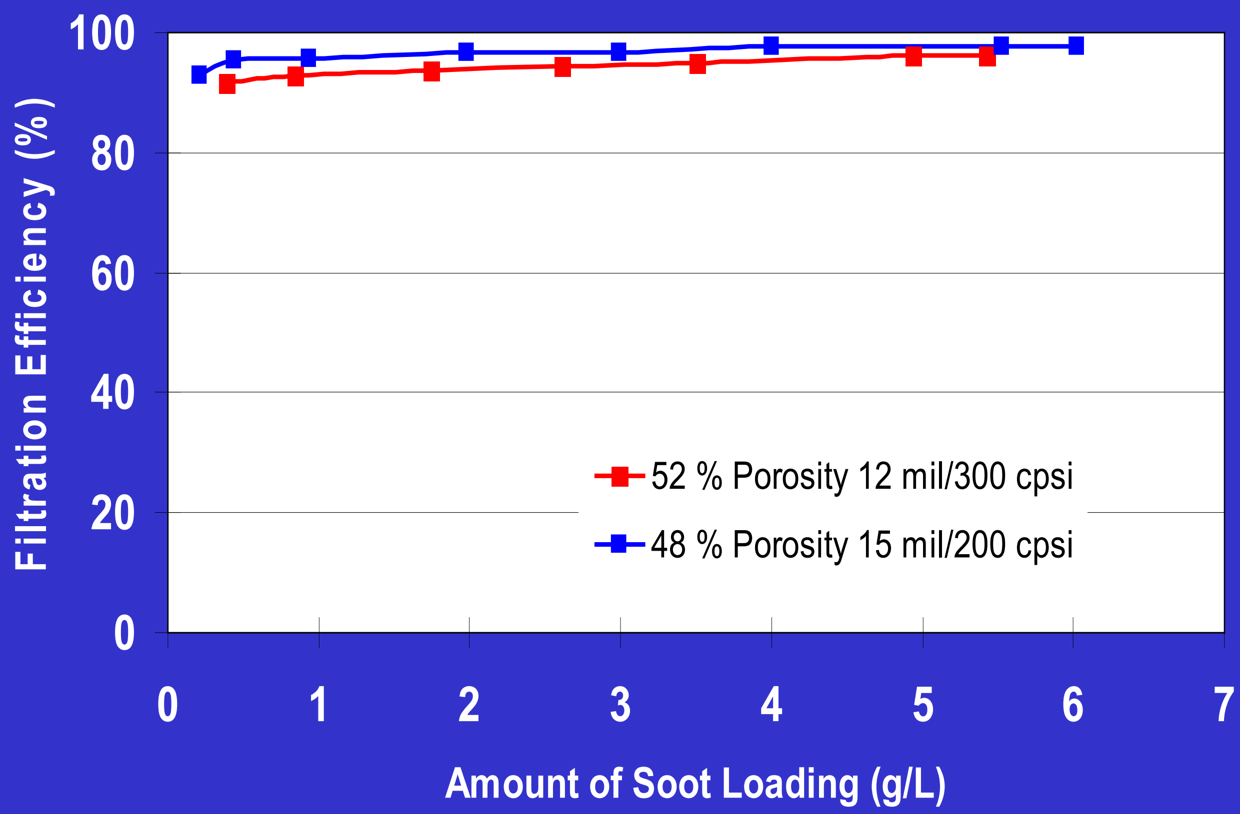
Non coated Cordierite Filters versus Soot Loading



➡ Already ~ 95 % efficiency at 0.2 g/L soot loading

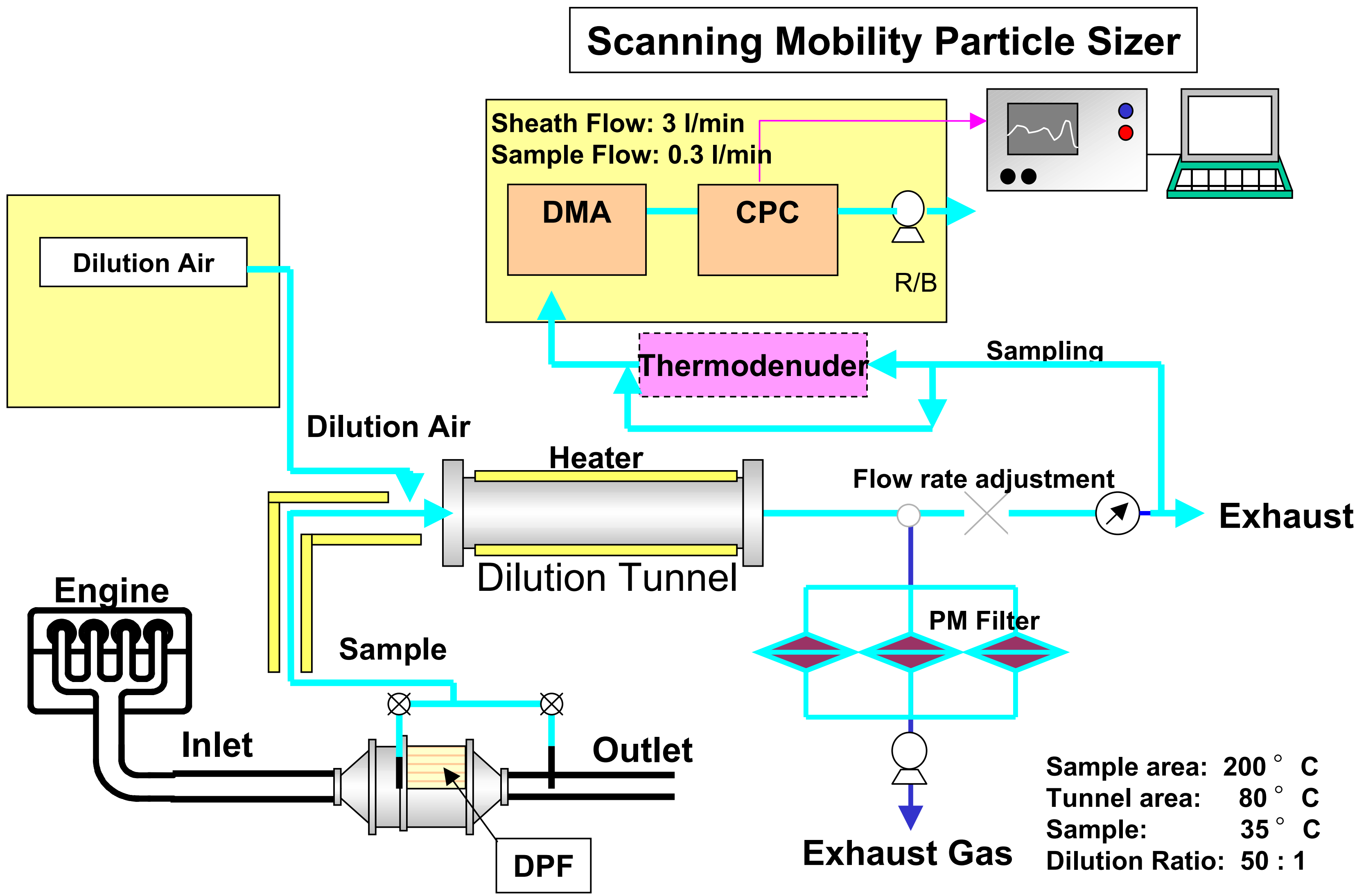
Filtration Efficiency

Non coated Si-SiC Particulate Filters



➡ Filtration efficiency > 90 % at 0,1 - 0,2 g/L soot

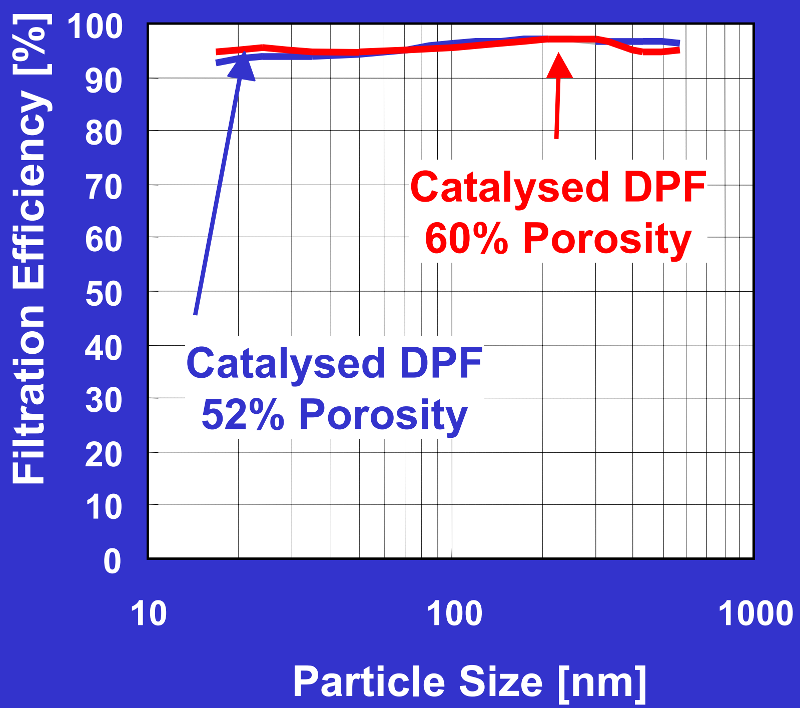
Determination of the Filtration Efficiency



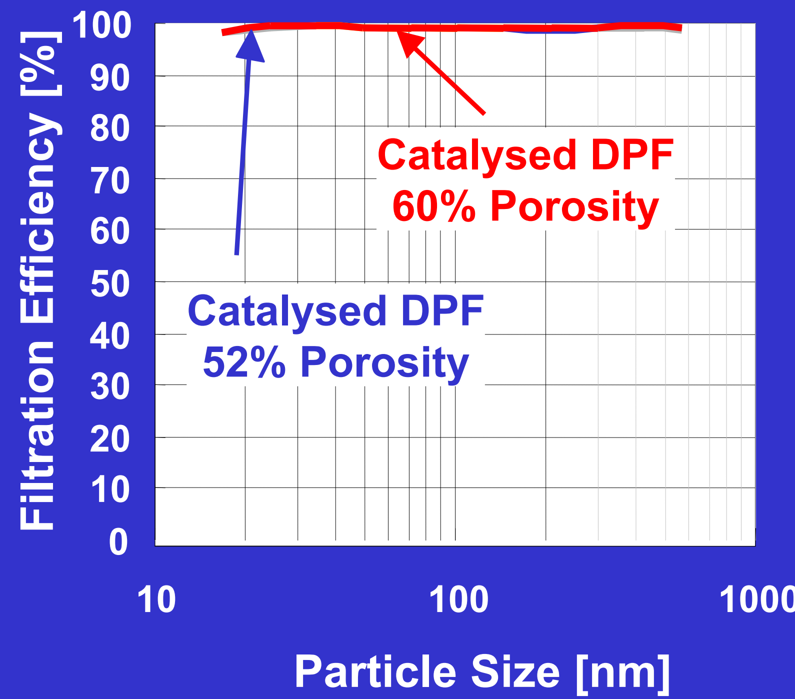
Filtration Efficiency of Catalysed Si-SiC DPF

Comparison of the Filtration Efficiency by SMPS

Soot Loading: 0-0.1 g/L



Soot Loading: 1.6-2.4 g/L

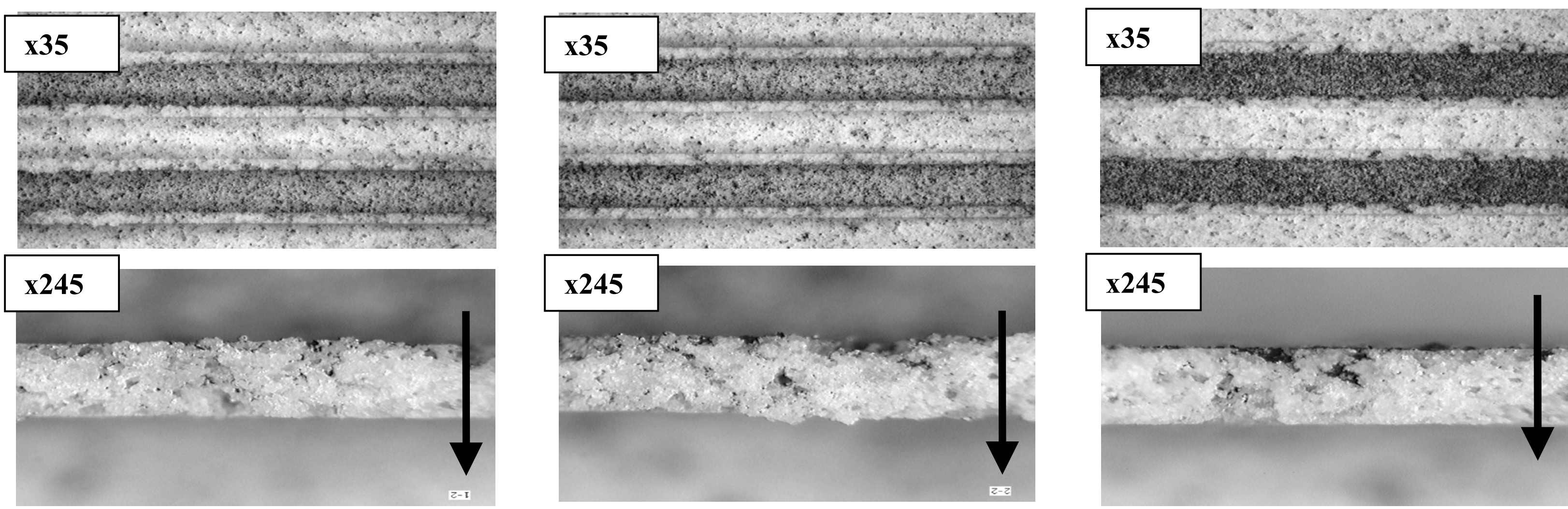


➡ **Already > 90 % efficiency at 0.1 g/L soot loading**

Filtration Efficiency of Cordierite Filters

Impact of Soot Loading

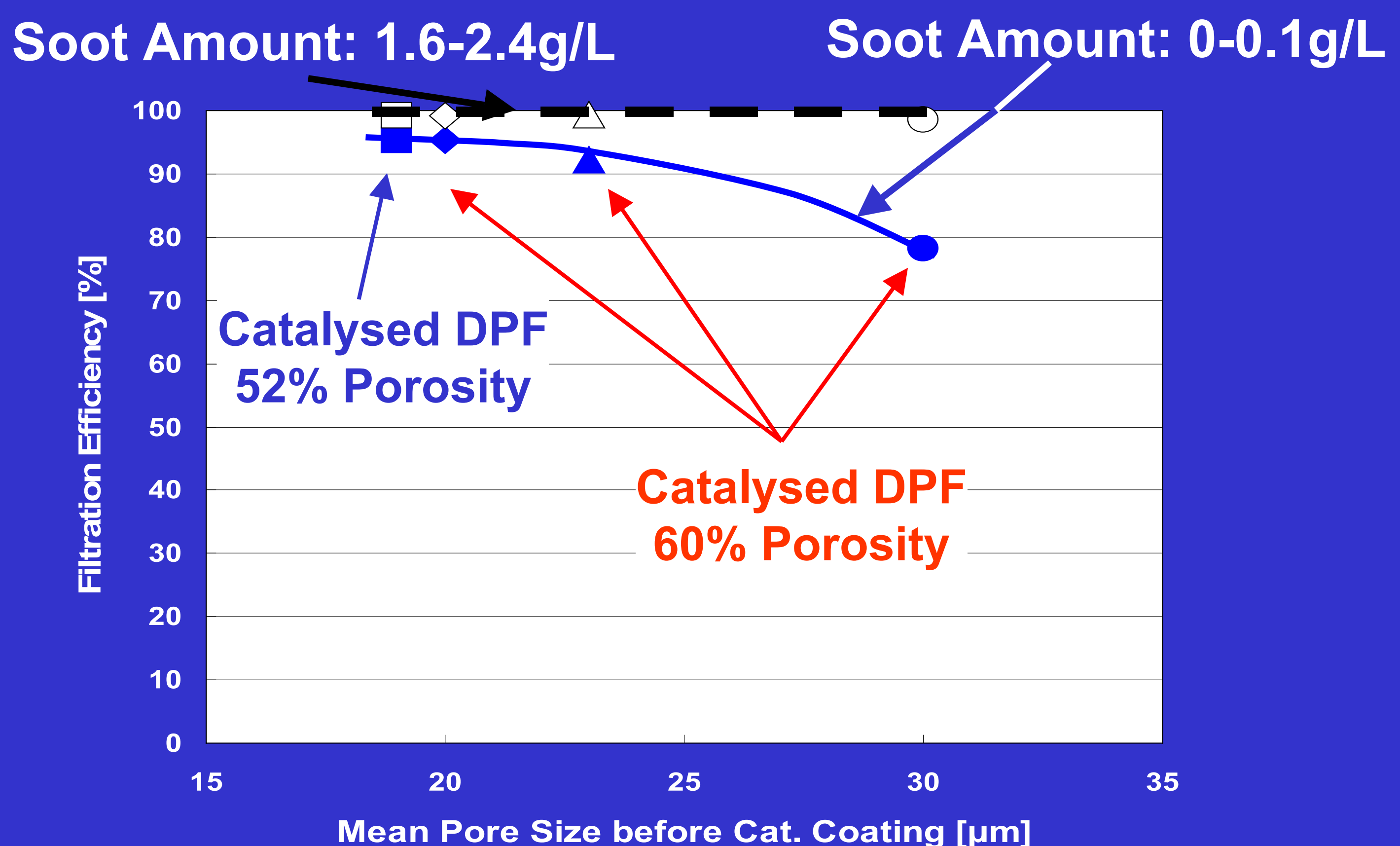
0,1 g/L Soot Loading | **0,3 g/L Soot Loading** | **0,5 g/L Soot Loading**



➡ After soot cake build up filtration efficiency > 95 %

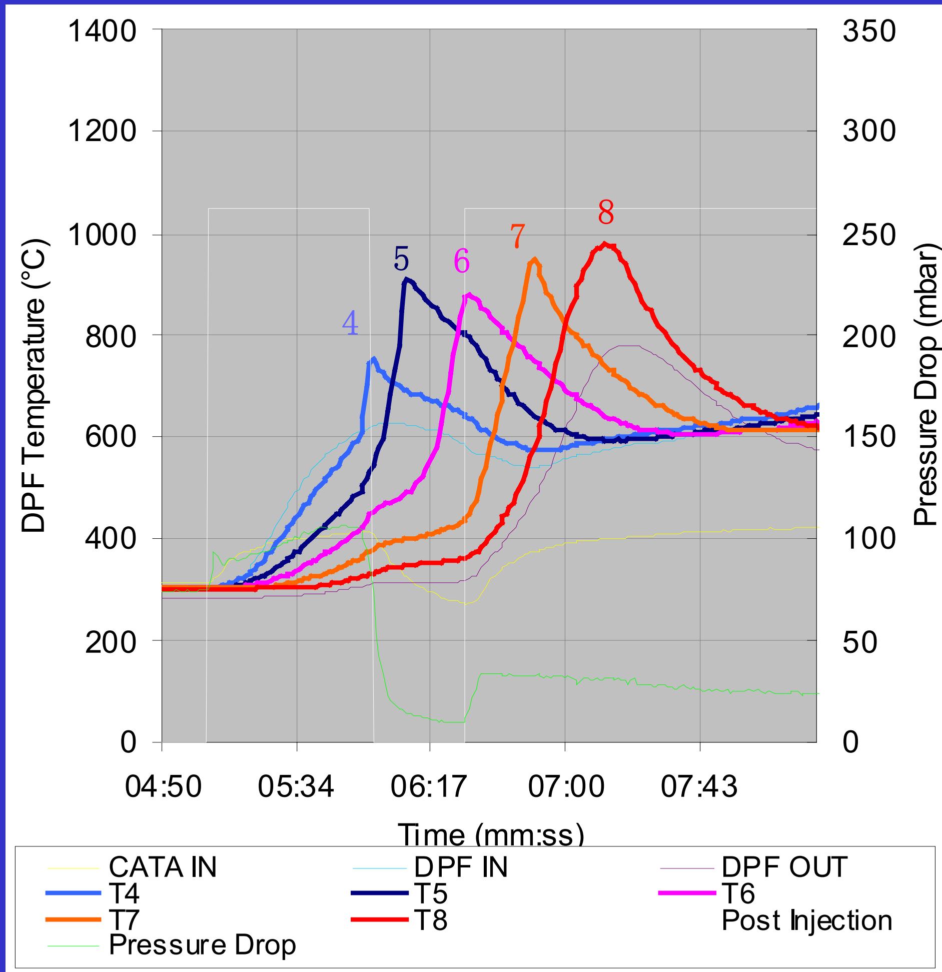
Filtration Efficiency and Porosity

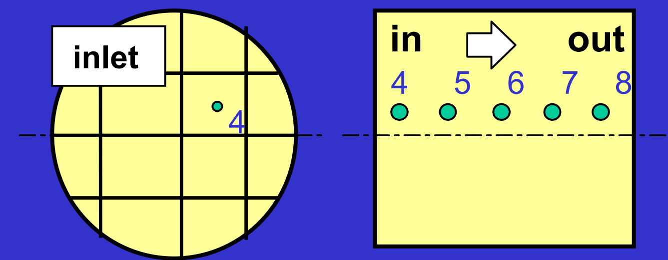
■ Filtration Efficiency of catalysed Si-SiC Filters



➡ Soot loading has an impact on filtration efficiency

Regeneration with Fuel Additives





Sample:
SiC
5.66” Dx10” L,
10g/L soot loading

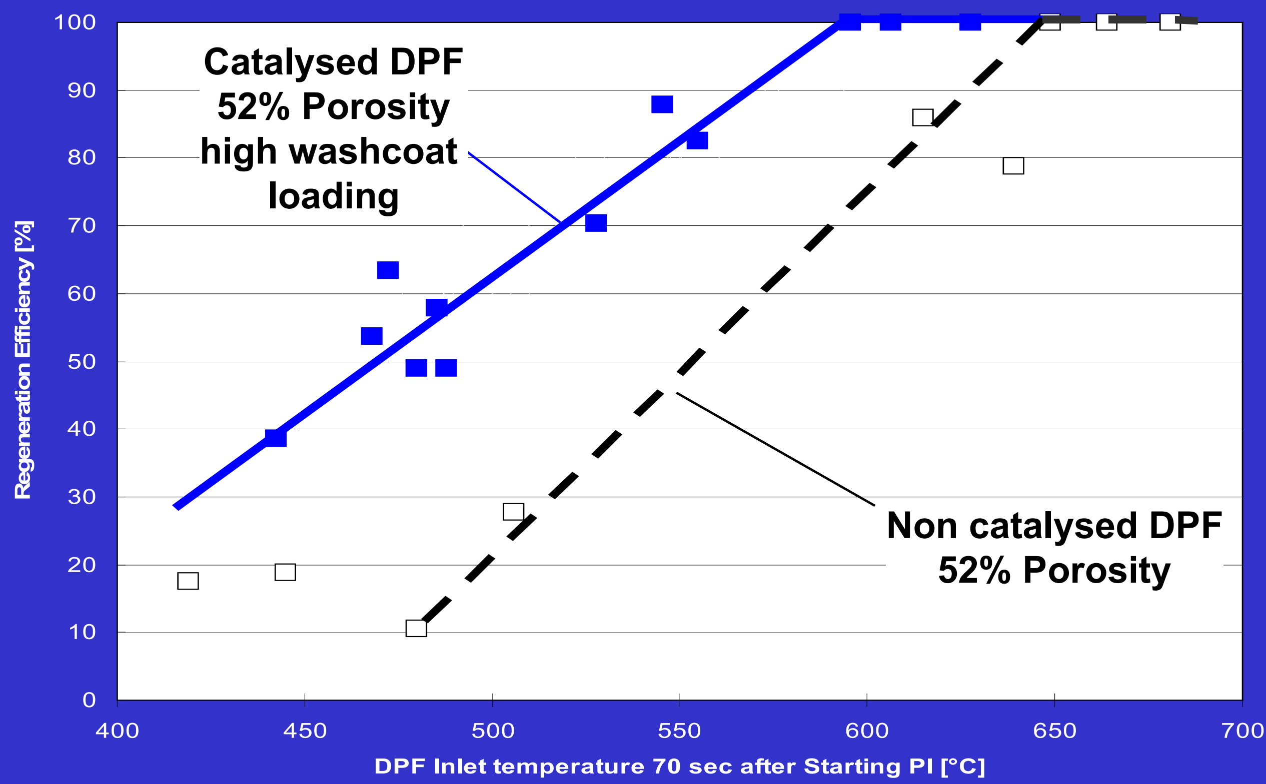
Engine: 2.0L DI,
25ppm Ce additive

➡ **High soot mass limits with Si-SiC materials**

Regeneration with Catalysed Si-SiC Filters

Engine: DI 2.0L (Common Rail)
Conditions: 1700 rpm x 95 Nm
10 min post injection

4 g/L soot



➡ Improved regeneration efficiency with CSF

Summary

- Passenger cars discontinuous regeneration
- CRT and SCRT systems likely for heavy duty
- Low pressure drop with high porosity filters
- Filtration efficiency > 90 % from 0.1 g/L soot
- High heat mass and therm. conductivity favourable
- Good thermal shock resistance with Si-SiC filters
- High soot mass limits for Si-SiC filters
- Improved regeneration efficiency with CSF

Thank you very much for your attention !

The Authors

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wish to thank

ENGELHARD

for submitting catalysts and catalysed soot filters (CSF)

JM

Johnson-Matthey Plc. for providing the cut-away of the CRT

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