

**ECT-2022**  
**Session 5**  
**Heavy Duty – Automotive**  
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# **New Cordierite Diesel Particulate Filter for Tight PM/PN Regulations**

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Background

Design Concept

Performance

- PM/PN Filtration Performance
- Pressure Drop / Pressure Drop Hysteresis

Summary

## Background

## Design Concept





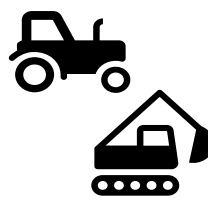



## Performance

- PM/PN Filtration Performance
- Pressure Drop / Pressure Drop Hysteresis

## Summary

# HDV/NRMM Regulation



		2021	2022	2023	2024	2025	2026	2027	2028~	
 HDV		Euro VI step E				Euro VII (Timing is TBD)				
		<b>ISC PEMS CF=1.63 (CF1.0=6.0 x 10<sup>11</sup> #/kWh)</b>				<b>Stricter PN</b> , NO <sub>x</sub> &CO <sub>2</sub>				
		US10			ARB2024			EPA/ARB2027		
		No PN, PM 10 mg/bhp-hr			<b>PM 5 mg/bhp-hr</b> / Tighter NO <sub>x</sub> &CO <sub>2</sub> / Extended Warranty					
		BS VI stage I		BS VI stage II				BS VII?		
		6E+11#/kWh(WHTC), 8E+11#/kWh(WHSC)						<b>Stricter PN?</b> <b>ISC PEMS CF?</b>		
 NRMM		Stage V							Stage VI?	
		<b>PN 1.0x10<sup>12</sup> #/kWh(NRTC/NRSC)</b> , NTE with CF=2.0 for <560kW							<b>PEMS?</b>	
		Tier4 Final								Tier5?
		No PN, PM 0.02 g/kWh, NTE with CF=1.5 for <560kW								<b>PM 5mg/kWh</b>
		TREM III		TREM IV		TREM V				
		CEV IV			CEV V					
		No PN, PM 0.025 g/kWh				<b>PN 1E+12#/kWh(NRTC/NRSC)</b>				

Regulation Key Words	Requirement for DPF
Tighter PN emission	Higher Filtration Performance
Decrease CO <sub>2</sub>	Lower Pressure Drop
	Smaller Pressure Drop Hysteresis (for effective regeneration)
Ultra Low NOx	Lower Heat Mass (Improve Light Off )
Extended Warranty	Higher Ash Capacity



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## Requirements for DPF

## Idea

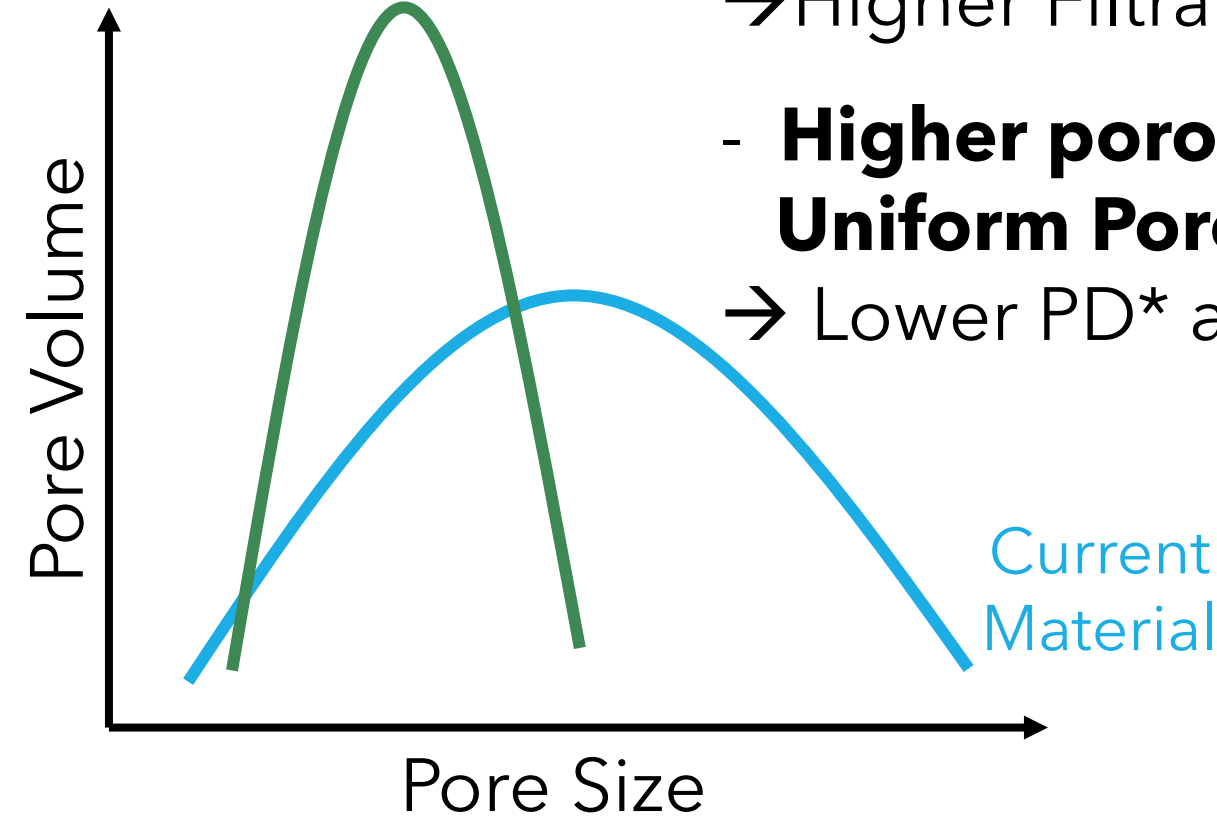
- High Filtration Performance
  - Low Pressure Drop
  - Small Hysteresis
  - Low Heat Mass
  - High Ash Capacity
- Smaller Pore Size
  - Higher Porosity  
+Uniform Pore Size Distribution
  - Cordierite Material
  - Thin wall + Asymmetric cell

*Optimization challenges*

Challenge: Improve filtration performance with decreasing pressure drop  
Developed DPF: **Cordierite new material + thin wall + asymmetric cell**

## New Material Idea

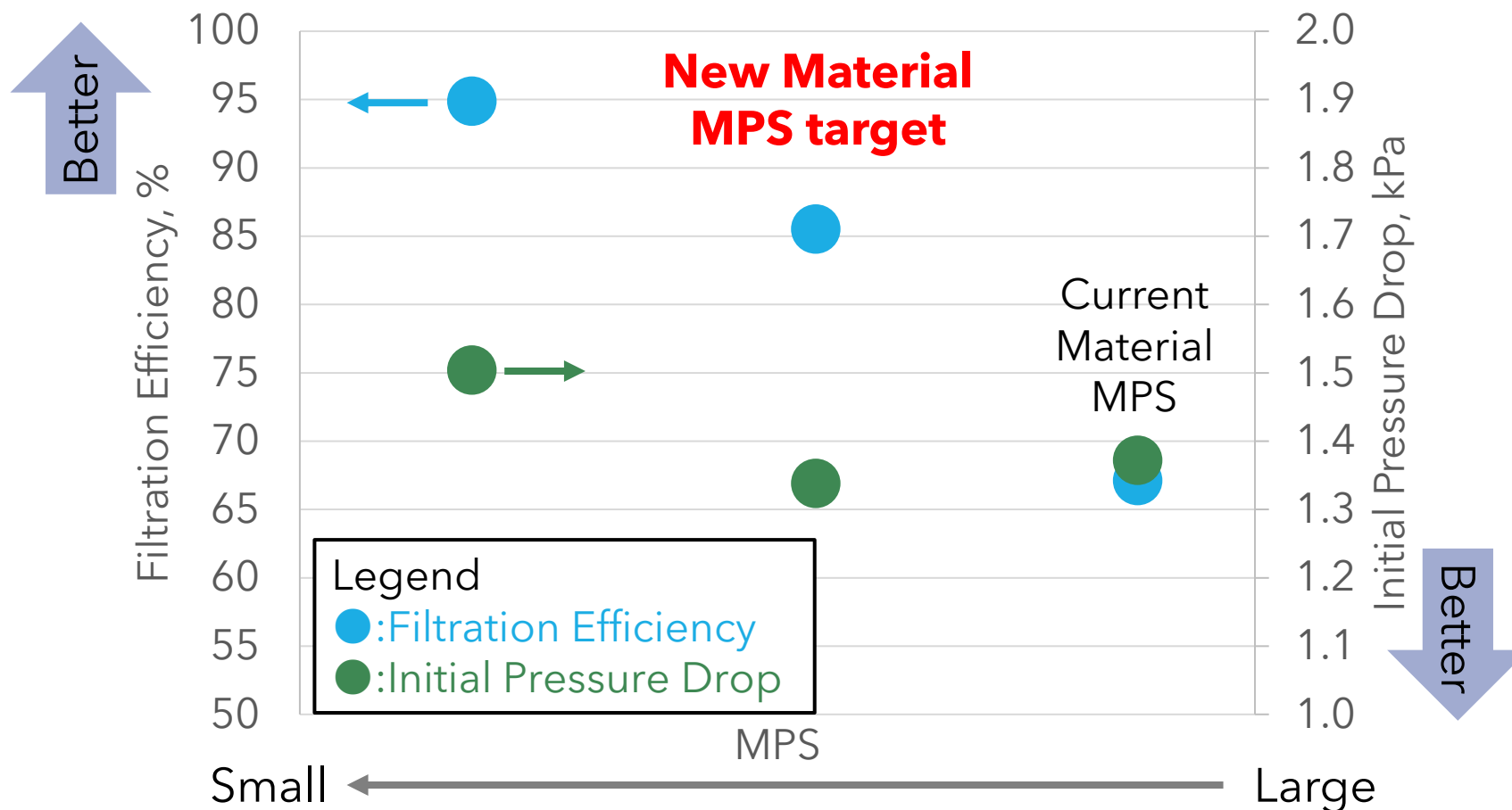
- **Smaller MPS\***  
→ Higher Filtration Performance
- **Higher porosity, Uniform Pore Size Distribution**  
→ Lower PD\* and smaller PD hysteresis



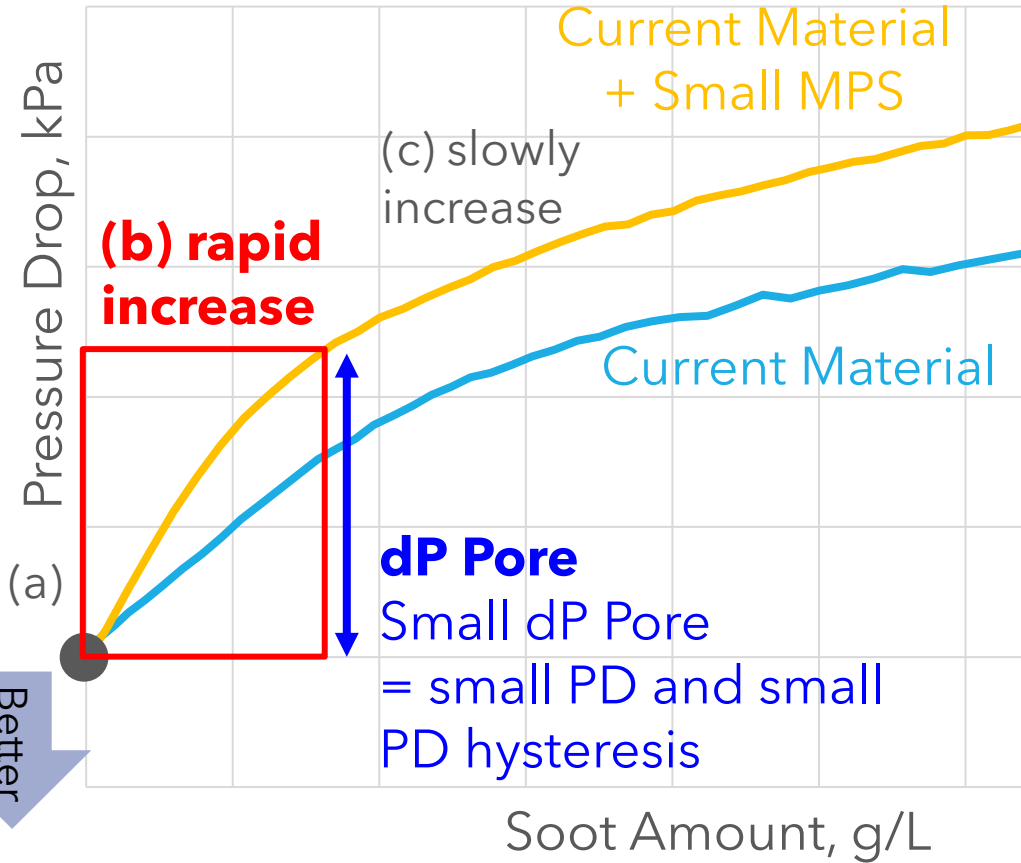
MPS\*: Mean Pore Size  
PD\*: Pressure Drop



# New Material Design / Set MPS target



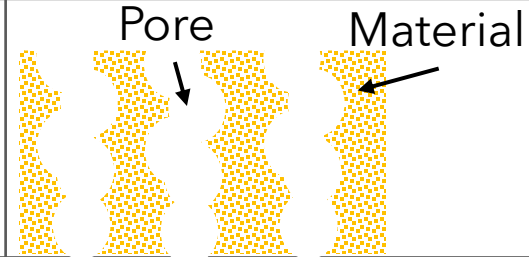
Decreasing MPS improves filtration efficiency, but simultaneously increases pressure drop as a result of higher DPF-wall permeability. MPS target was optimized by balancing the initial pressure drop with required PN filtration efficiency.



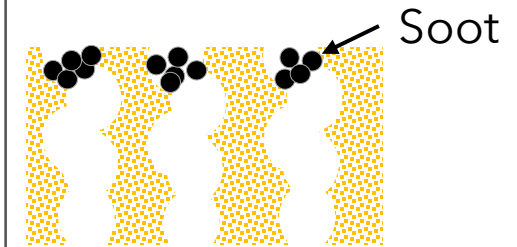
## Phase and Phenomenon

## Image

(a) Without soot



**(b) Soot penetration into material**



(c) Forming soot layer

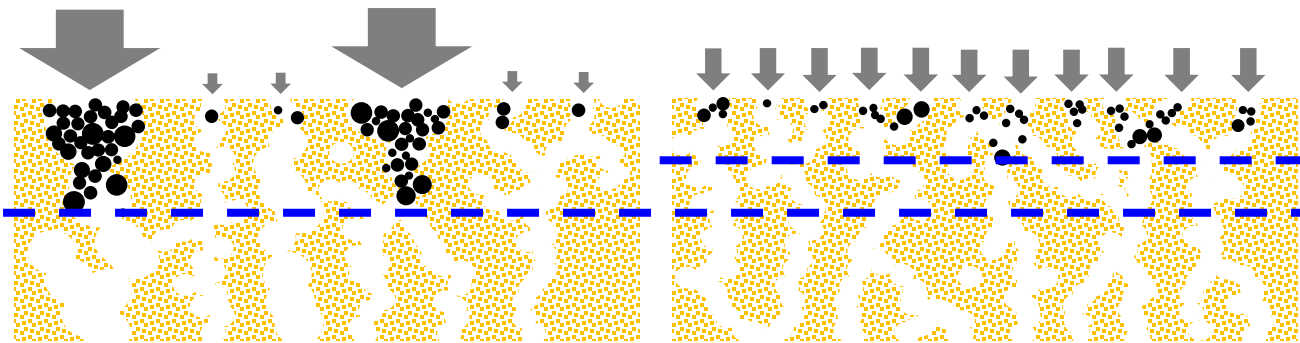


Smaller MPS shows higher pressure drop with soot due to inferior dP pore performance.

→: Gas Flow  
●: Material  
●: Soot

Non-uniform Gas Flow

Uniform Gas Flow



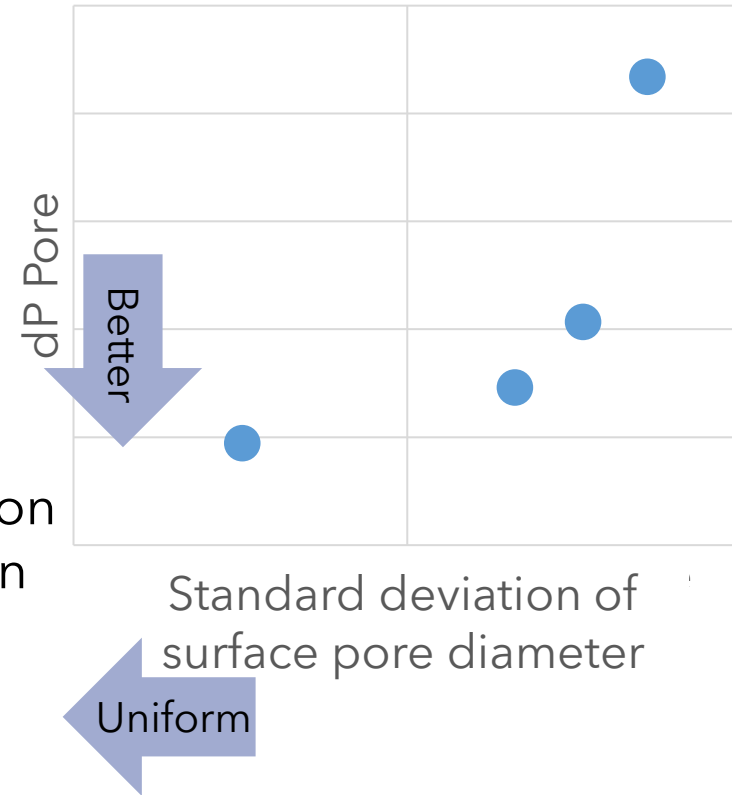
**Non-uniform pore size**

- Faster Gas flow at large pore
  - Deep soot penetration
- **Worse dP Pore**

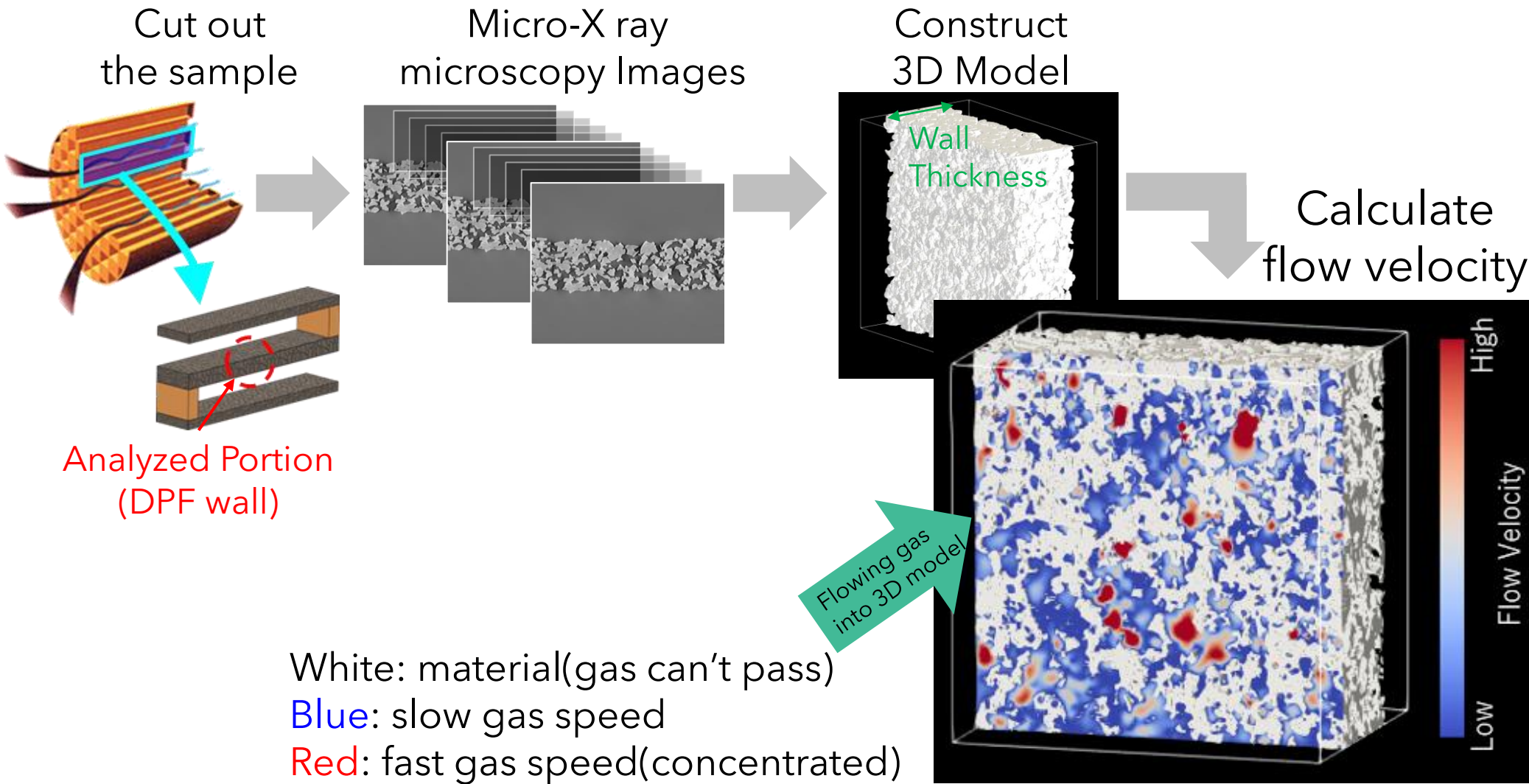
**Uniform pore size**

- Even Gas flow distribution
  - Shallow soot penetration
- **Better dP Pore**

**Wall Surface Pore Uniformity vs dP Pore**

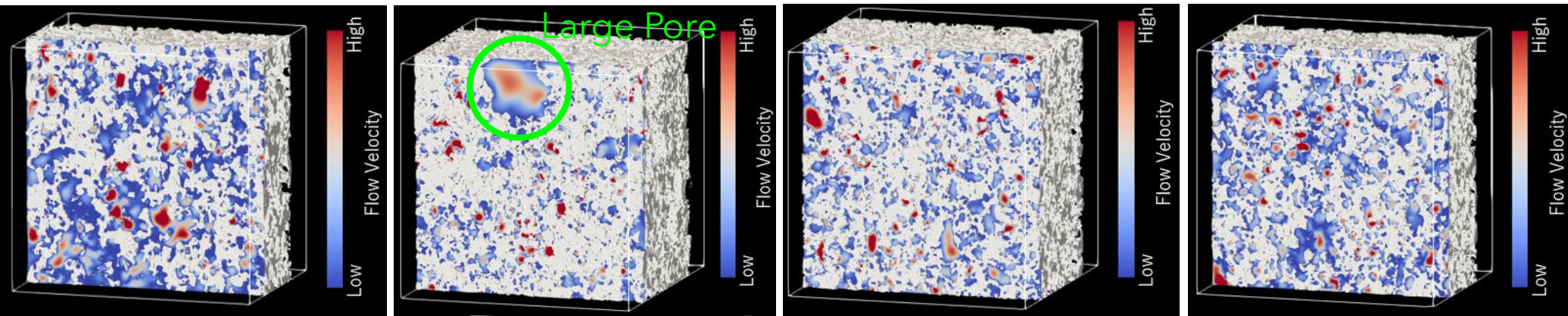


Uniform gas flow (=uniform pore) will be key to improve dP Pore performance.



Evaluate the flow velocity distribution on the surface of the substrate by flowing gas into the 3D model computationally.

Ref: Current Material → **1: Small MPS** → **2: Uniform Pore** → **3: High Porosity = New Material**



- 1: In case smaller MPS with current material, higher flow velocity at large pore area
- 2: In case small MPS with modified material, less large pore and uniform flow velocity
- 3: With high porosity, the flow path can be increased (blue color in flow velocity)

Background

Design Concept

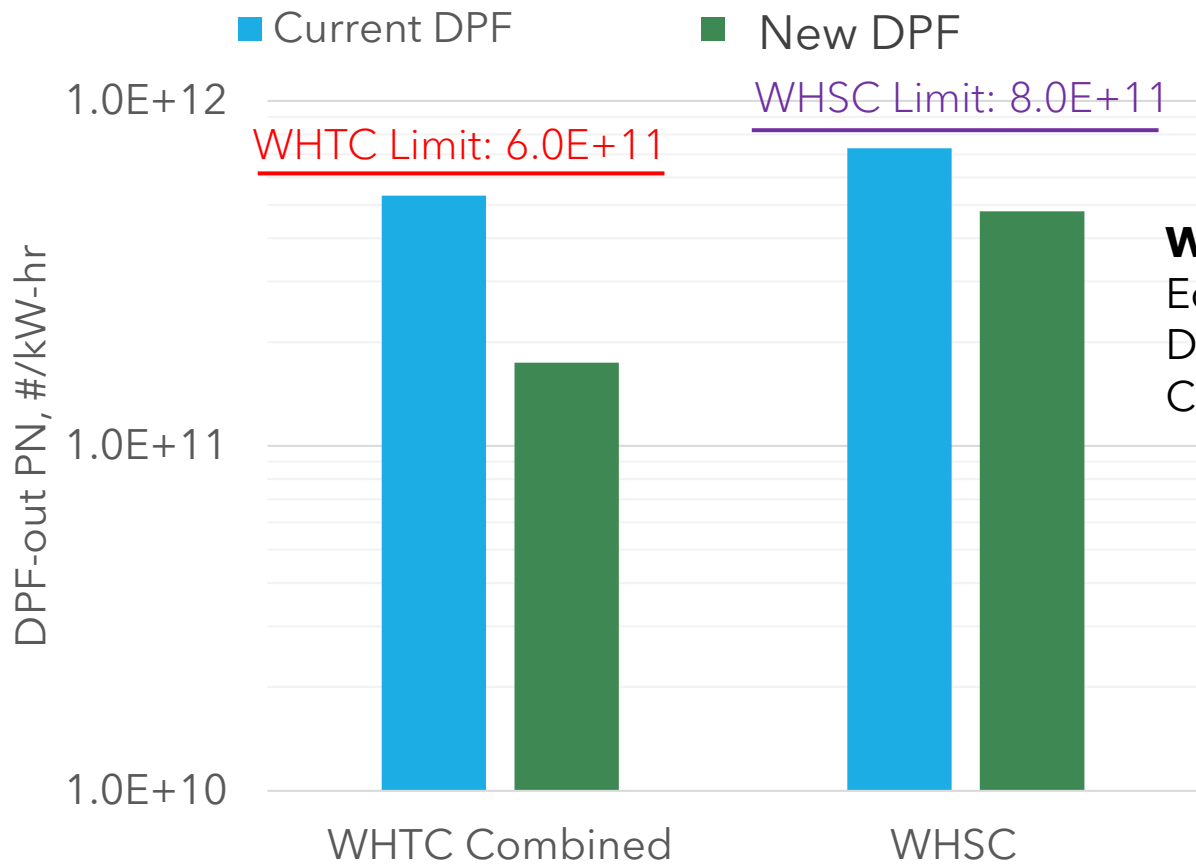
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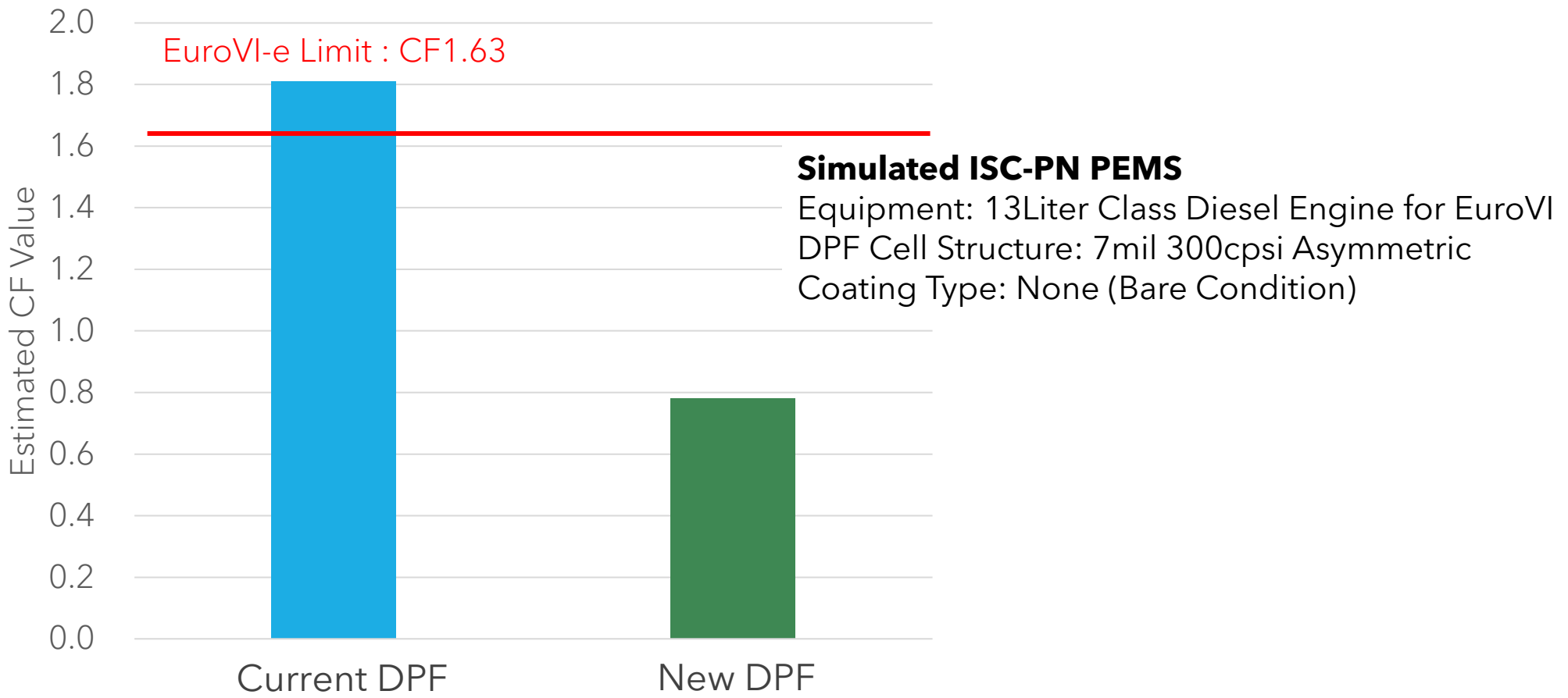
# PN Filtration Performance / WHTC & WHSC



## WHTC&WHSC

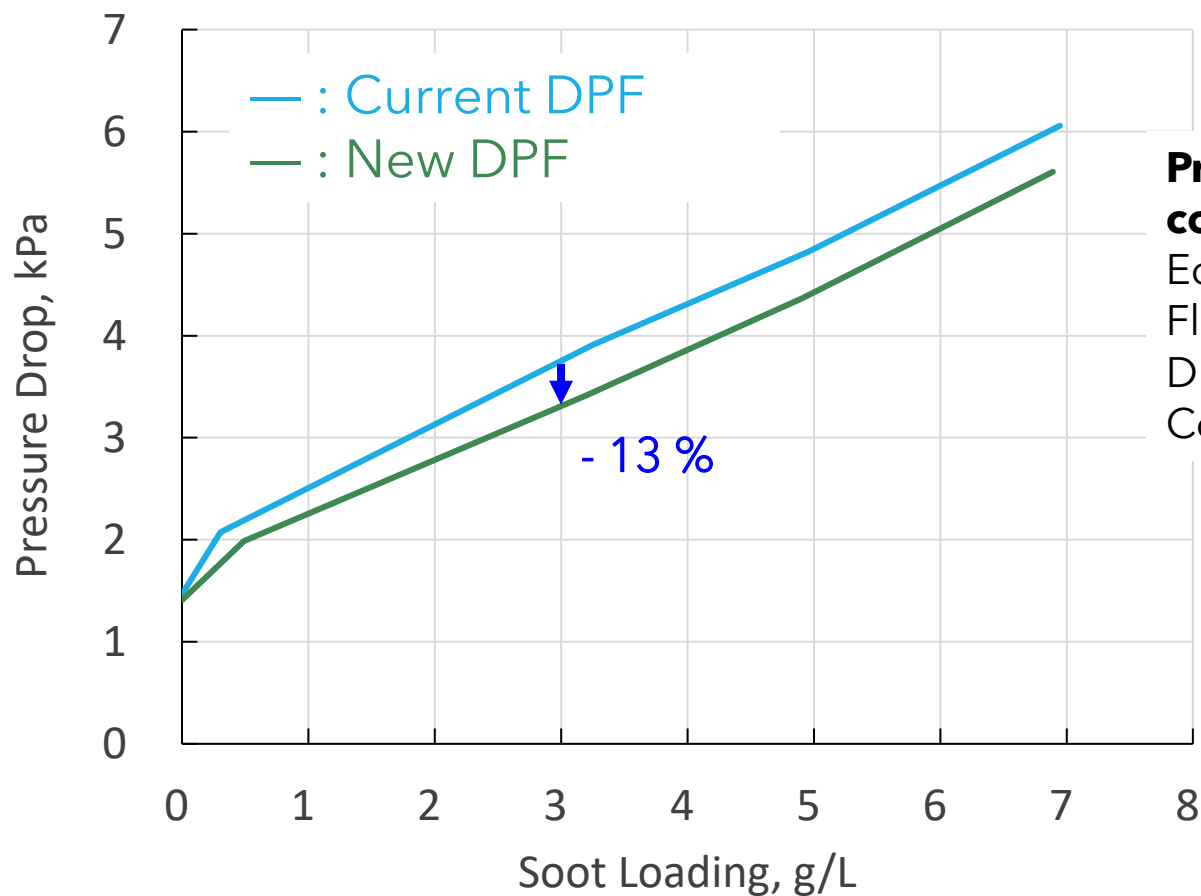
Equipment: 7L Class Diesel Engine for US10  
DPF Cell Structure: 7mil 300cpsi Asymmetric  
Coating Type: CSF

New DPF shows higher PN filtration performance than current DPF because of smaller MPS.  
New DPF has a wider safety margin against EuroVI PN standard.



New DPF shows higher filtration performance than current DPF because of smaller MPS.  
It has strong potential to achieve EuroVI-e ISC-PN PEMS regulation.

# Pressure Drop with Soot



## Pressure Drop with soot measurement conditions

Equipment: 7L Class Diesel Engine for US10

Flow Rate: 0.2m<sup>3</sup>/sec

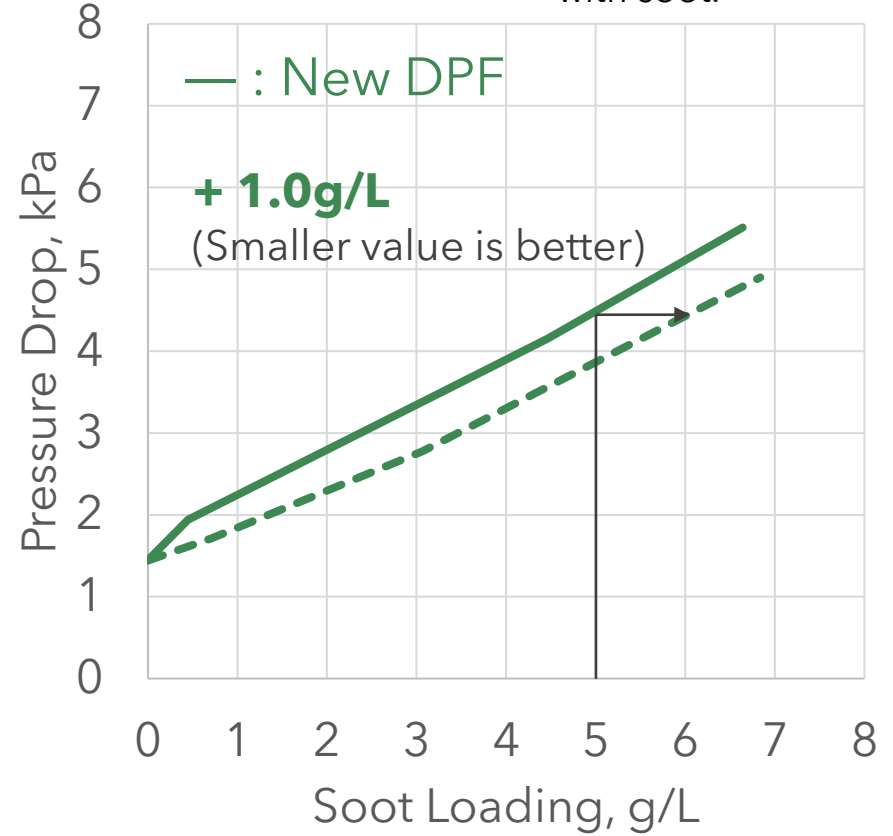
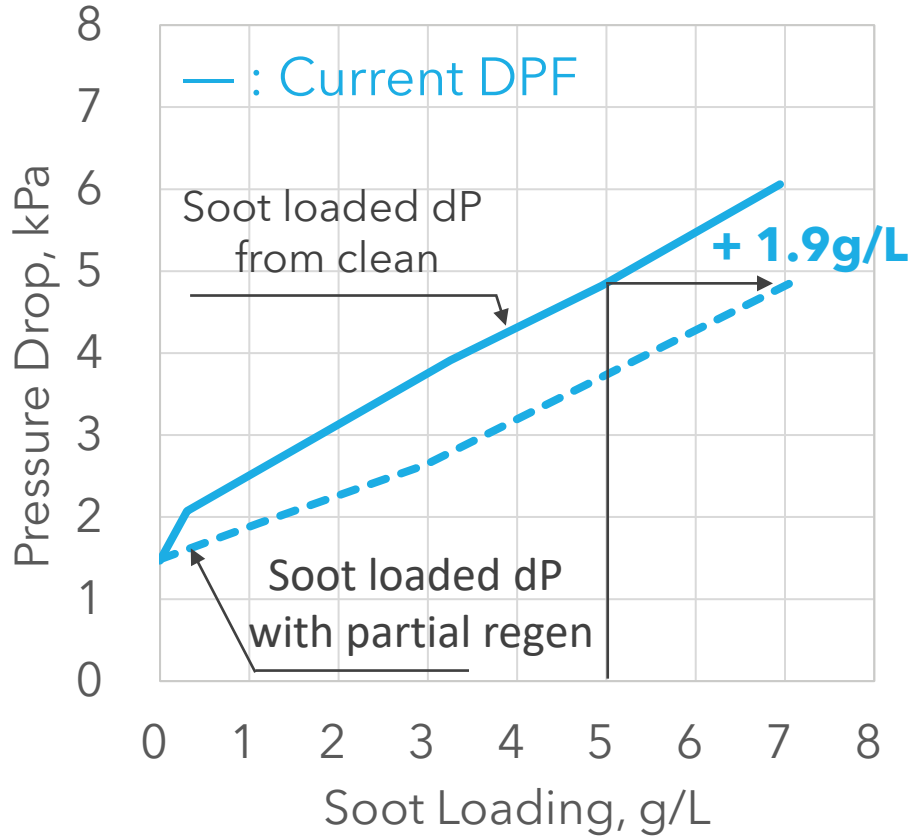
DPF Cell Structure: 7mil 300cpsi Asymmetric

Coating Type: CSF

New DPF shows lower pressure drop because of reduced dP pore.  
→ Uniform pore size distribution and higher porosity contributes.

# Pressure Drop Hysteresis

Measurement condition is same as Pressure Drop with soot.



New DPF shows smaller PD hysteresis due to uniform pore and higher porosity.

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**Summary**

NGK has developed new Cordierite DPF to meet tighter PN/PM regulations.

Higher PN filtration performance with lower pressure drop and smaller pressure drop hysteresis were obtained.

NGK is now developing further advanced DPF material for beyond 2025 regulation based on confirmed design concept.



A large, light blue graphic of a hand with fingers spread, positioned behind the "Thank you" text.

*Thank you*

NGK