

ECT-2023
Session 2
Light Duty Applications
2nd November 2023



Gasoline Particulate Filter (GPF) for Indian Market

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Background

GPF challenge to BS7

- GPF necessity with PFI engine?**
- Any concern with ash and/or under real driving?**
- Sub23nm PN?**

Summary

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PC/LDV PM/PN Regulation



		2021	2022	2023	2024	2025	2026	2027	2028~	
<u>PC/LDV</u>		Euro6d			Euro6e		Euro7 (Timing is TBD)			
		WLTC, RDE 6E+11#/km, CF=1.5			WLTC, RDE 6E+11#/km, CF=1.34		Same as Euro6e?		RDE 6E+11#/km (>10nm) ?	
		Tier3				Tier4				
		FTP/US06 3mg/mi				FTP/US06 0.5mg/mi (-7deg.C)				
		LEV III				LEV IV				
		FTP/US06, 3mg/mi				FTP/US06, 1mg/mi				
		BS6 stage I			BS6 stage II			BS7?		
		MIDC 6E+11#/km			MIDC, RDE 6E+11#/km, CF=1.5			WLTC?, RDE Stricter PN?		

NGK GPF Development Roadmap



Uncoated Type

Coated Type

Gen. 1
Porosity: low, MPS: mid.

Gen. 2
Porosity: mid, MPS: small

Gen. 3
Porosity: mid, MPS: small
or **Gen. 2 with MT**

Gen. 4 Gen. 3 with MT
Membrane Technology

For 17MY
EU6d

For 20MY
EU6d RDE

For 20-23MY
EU6d RDE

For 23-25MY
EU6e RDE

For 26MY~
EU7

FE
50-60

FE
60-70

FE
90

FE
95

Almost
ambient air

FE
99-

Gen.1
Porosity: large, MPS: big

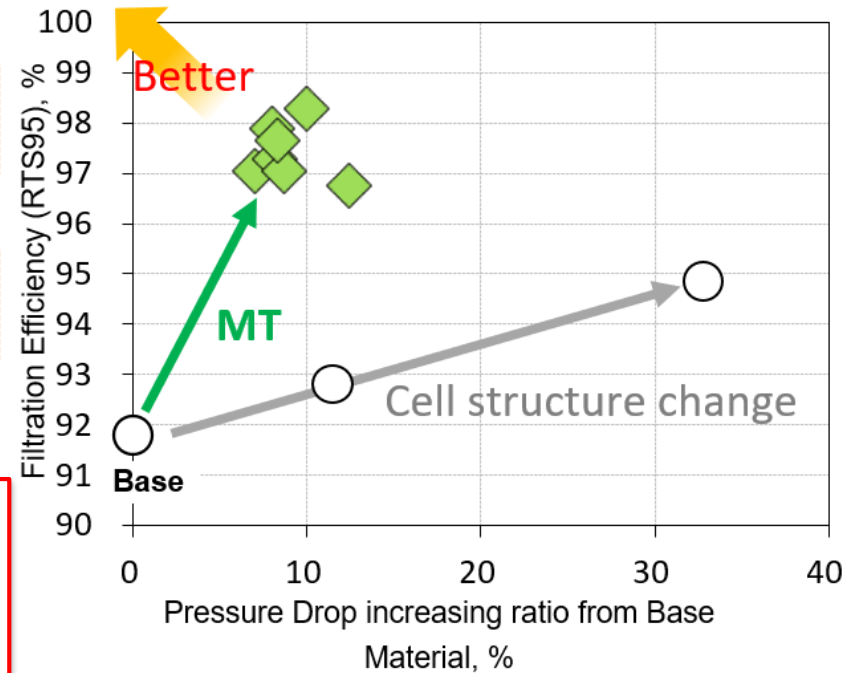
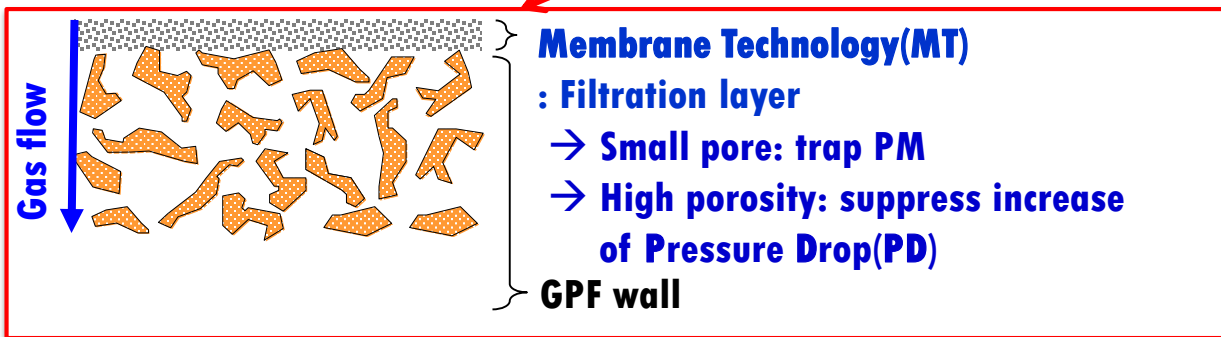
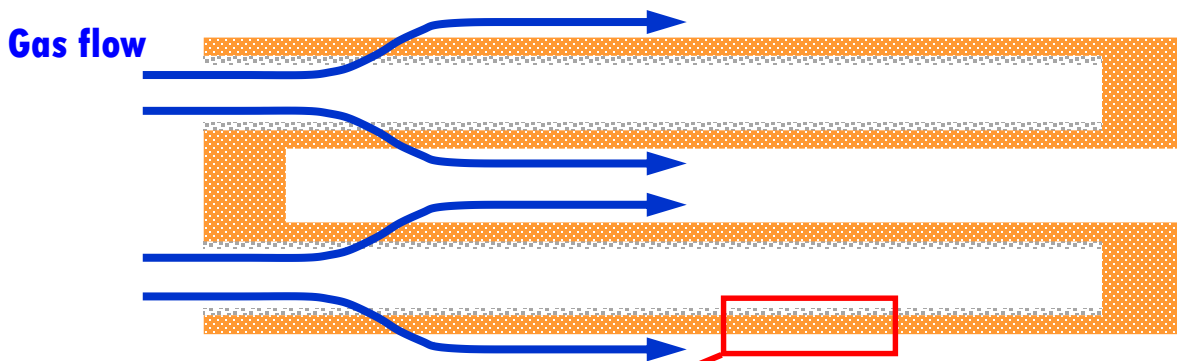
Gen.2
Porosity: large, MPS: mid.

Gen.3
Porosity: large, MPS: mid.
with sharp pore size distribution
(=reduce both big and small pores)

FE: PN Filtration Efficiency, NGK conditions: UF GPF, RTS95 after precond. 3xEUDC

MPS: Mean Pore Size

What is Membrane Technology (MT)



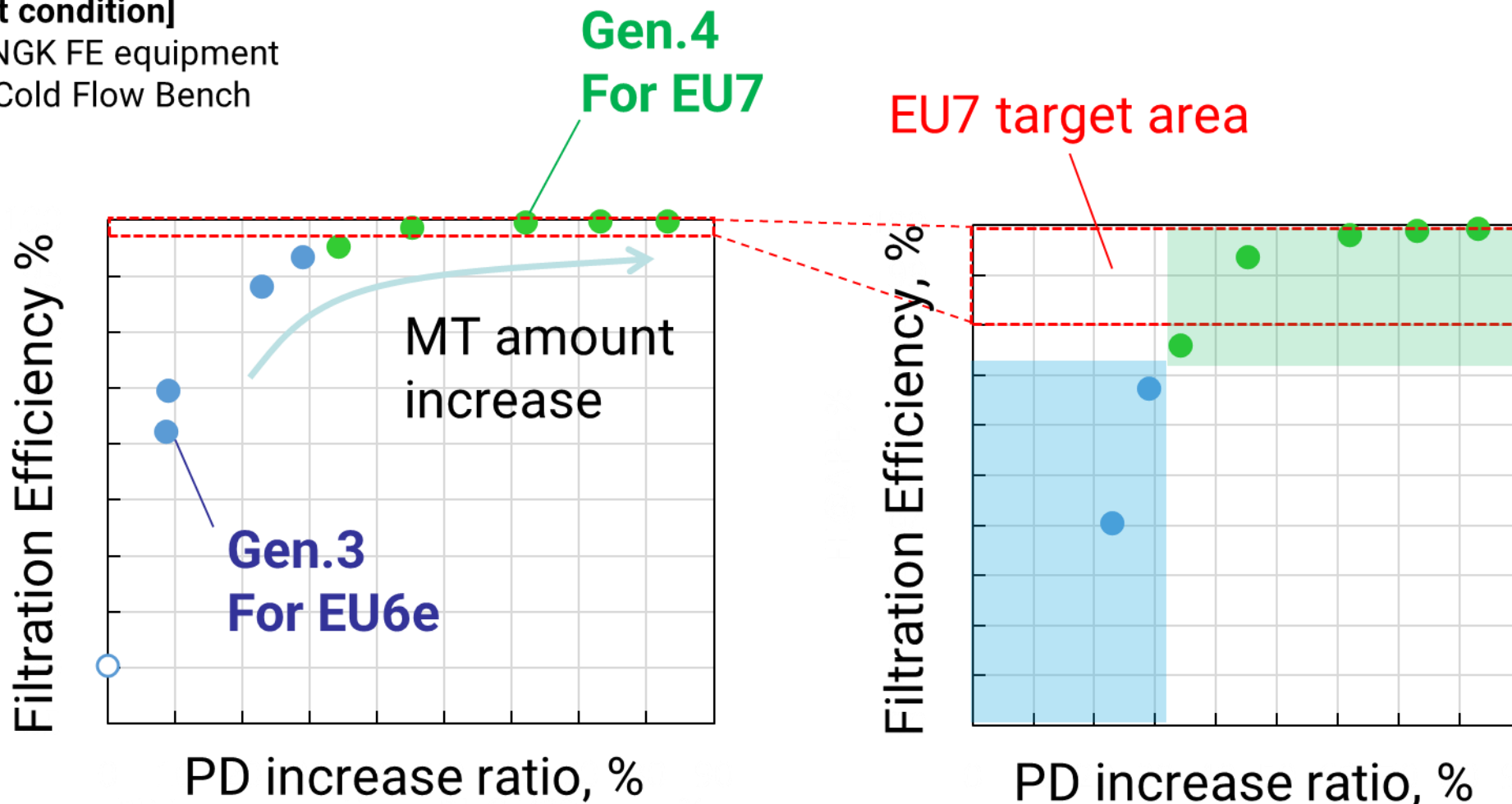
GPF base design change for high FE requirement causes pressure drop increase drastically.
MT improves FE with minimum pressure drop increase.

NGK GPF Development for Euro7

[Test condition]




FE: NGK FE equipment

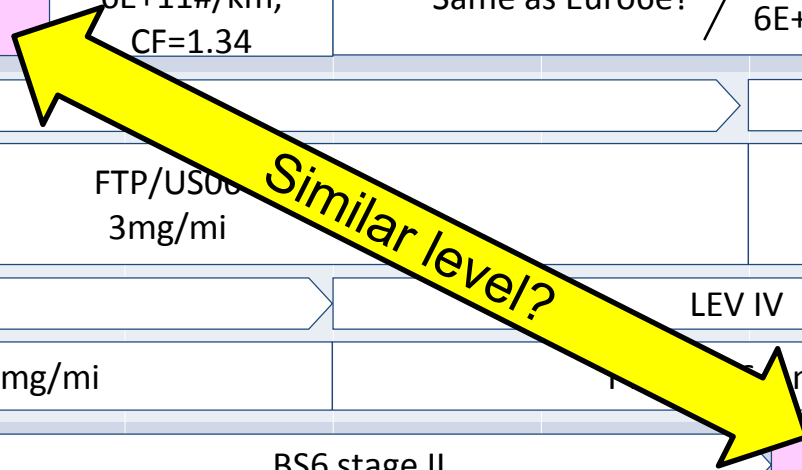
PD: Cold Flow Bench



Applying optimized MT condition, MT GPF can achieve EU7 FE target.

PC/LDV PM/PN Regulation

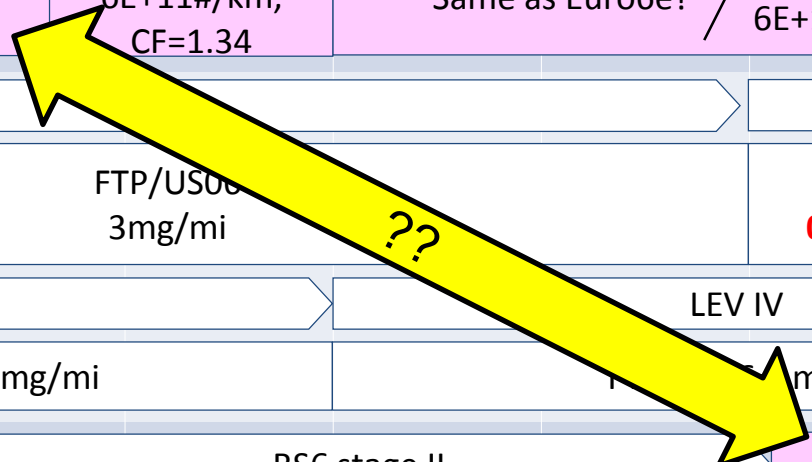
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		LEV III					LEV IV				
		FTP/US06, 3mg/mi					mg/mi				
		BS6 stage I			BS6 stage II					BS7?	
		MIDC 6E+11#/km			MIDC, RDE 6E+11#/km, CF=1.5					WLTC?, RDE Stricter PN?	



Potential BS7 PN regulation is assumed the similar level as Euro6d PN regulation? or somewhere in between Euro6d and Euro7?

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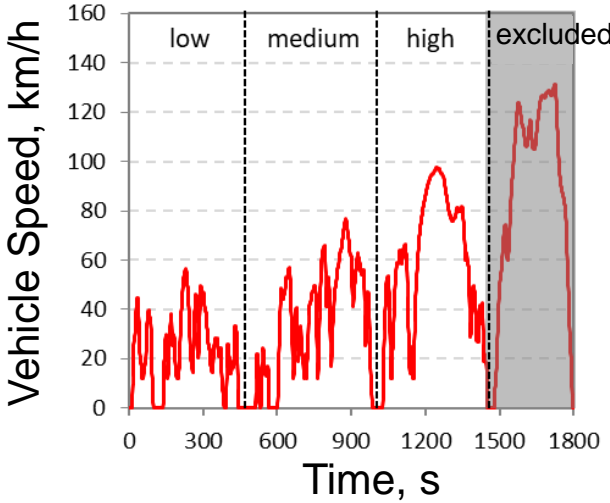
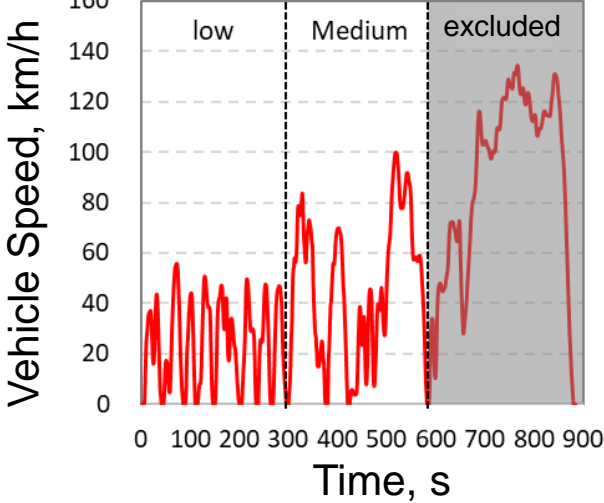
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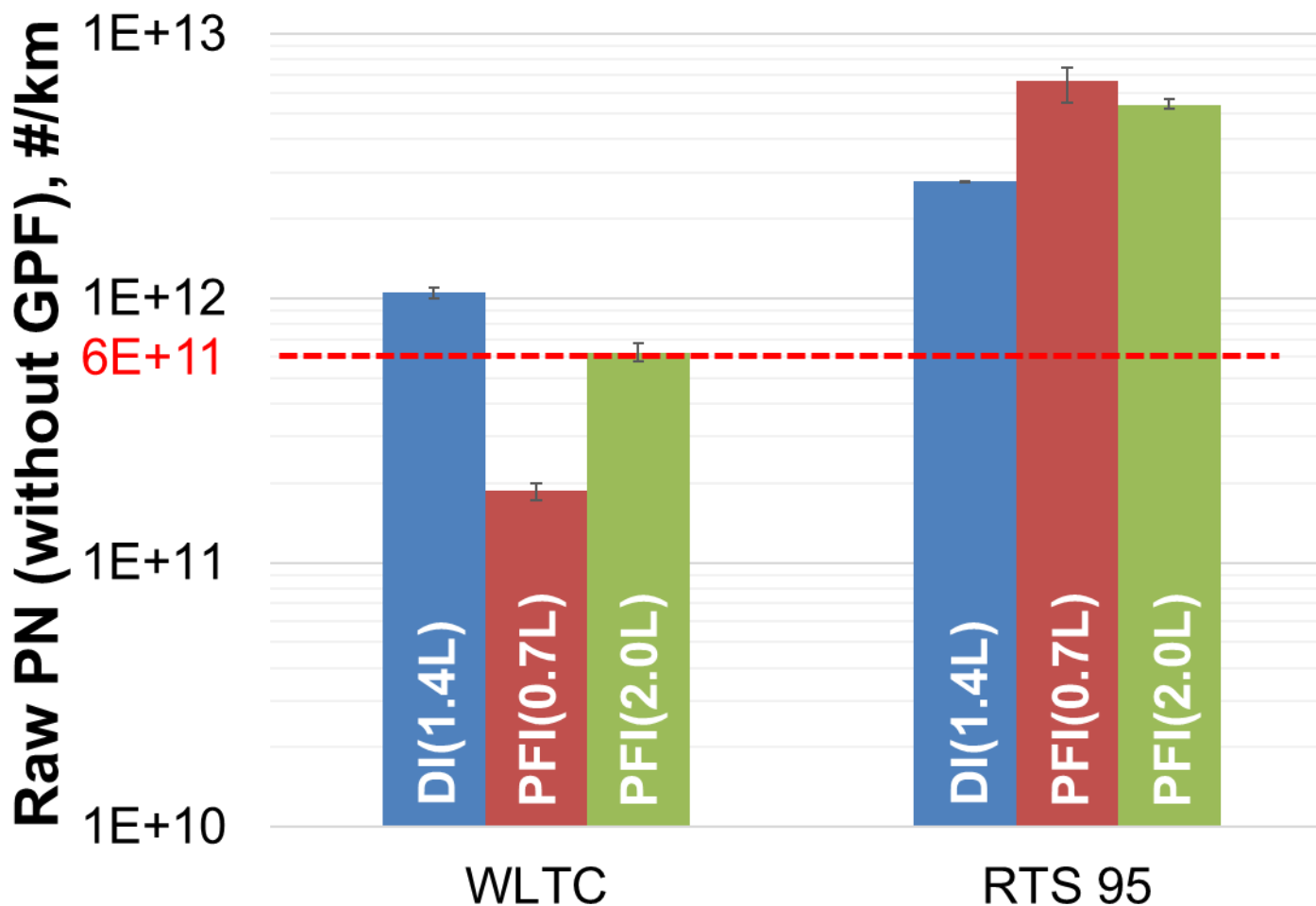
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Summary

Cycle	WLTC	RTS95
<p>Time vs Vehicle speed</p>	 <p>The graph shows vehicle speed in km/h over 1800 seconds. It is divided into four phases: low (0-450s), medium (450-1000s), high (1000-1500s), and excluded (1500-1800s). The speed peaks at approximately 98 km/h in the high phase.</p>	 <p>The graph shows vehicle speed in km/h over 900 seconds. It is divided into three phases: low (0-300s), Medium (300-600s), and excluded (600-900s). The speed peaks at approximately 100 km/h in the Medium phase.</p>
<p>Max speed</p>	<p>98 km/h</p>	<p>100 km/h</p>
<p>Total time</p>	<p>1477 s</p>	<p>585 s</p>
<p>Distance</p>	<p>15.0 km</p>	<p>5.6 km</p>
<p>Concept</p>	<p>Legislation cycle (high speed phase is excluded)</p>	<p>Aggressive cycle / worst case? (high speed phase is excluded)</p>



In some driving condition, PFI vehicle has higher engine out PN than DI and raw PN emission is above 6E+11 #/km.

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Vehicle Durability Test on Catalyzed GPF 160k km

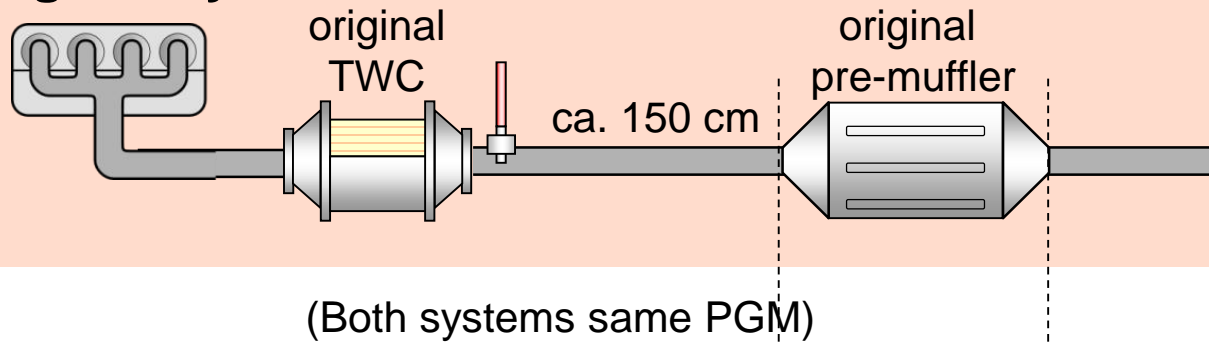
Vehicle and GPF details:

- Engine: 1.8L turbo DI, Euro 5
- Gen1 coated GPF, 10mil / 300cpsi, 1.3L with TWC

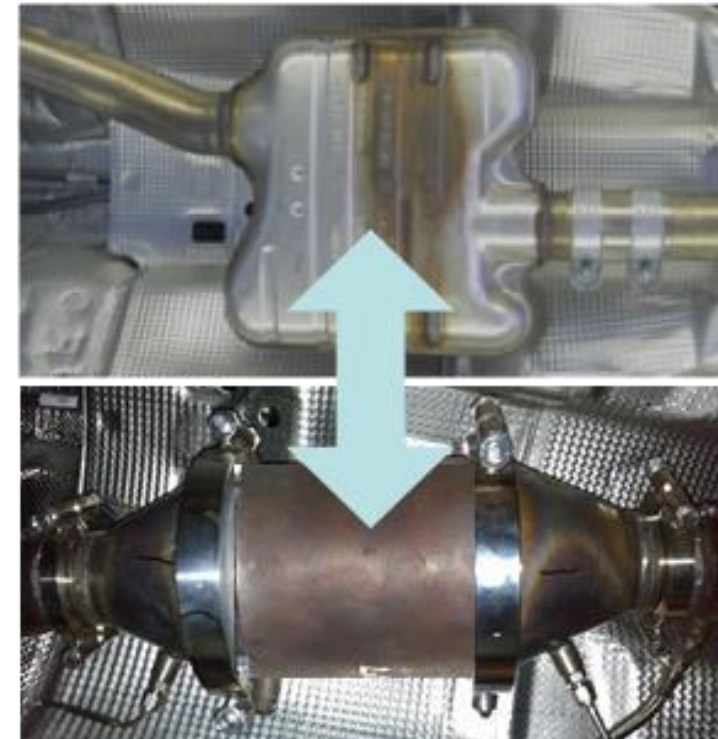
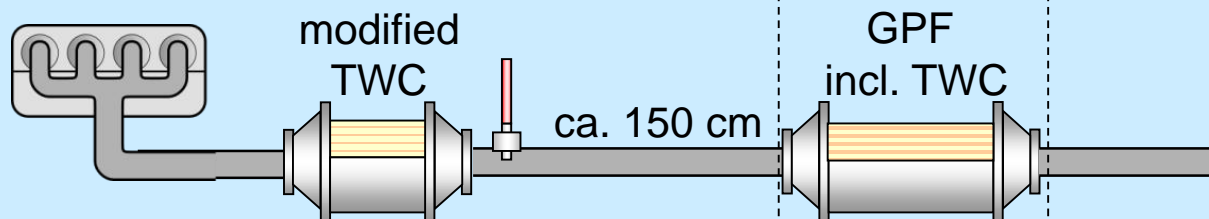
Driving Mode:

- Urban 6% (≤ 50 km/h)
- Extra-urban 11% (≤ 100 km/h)
- Motorway 81% (≤ 220 km/h)
- Transit 2%

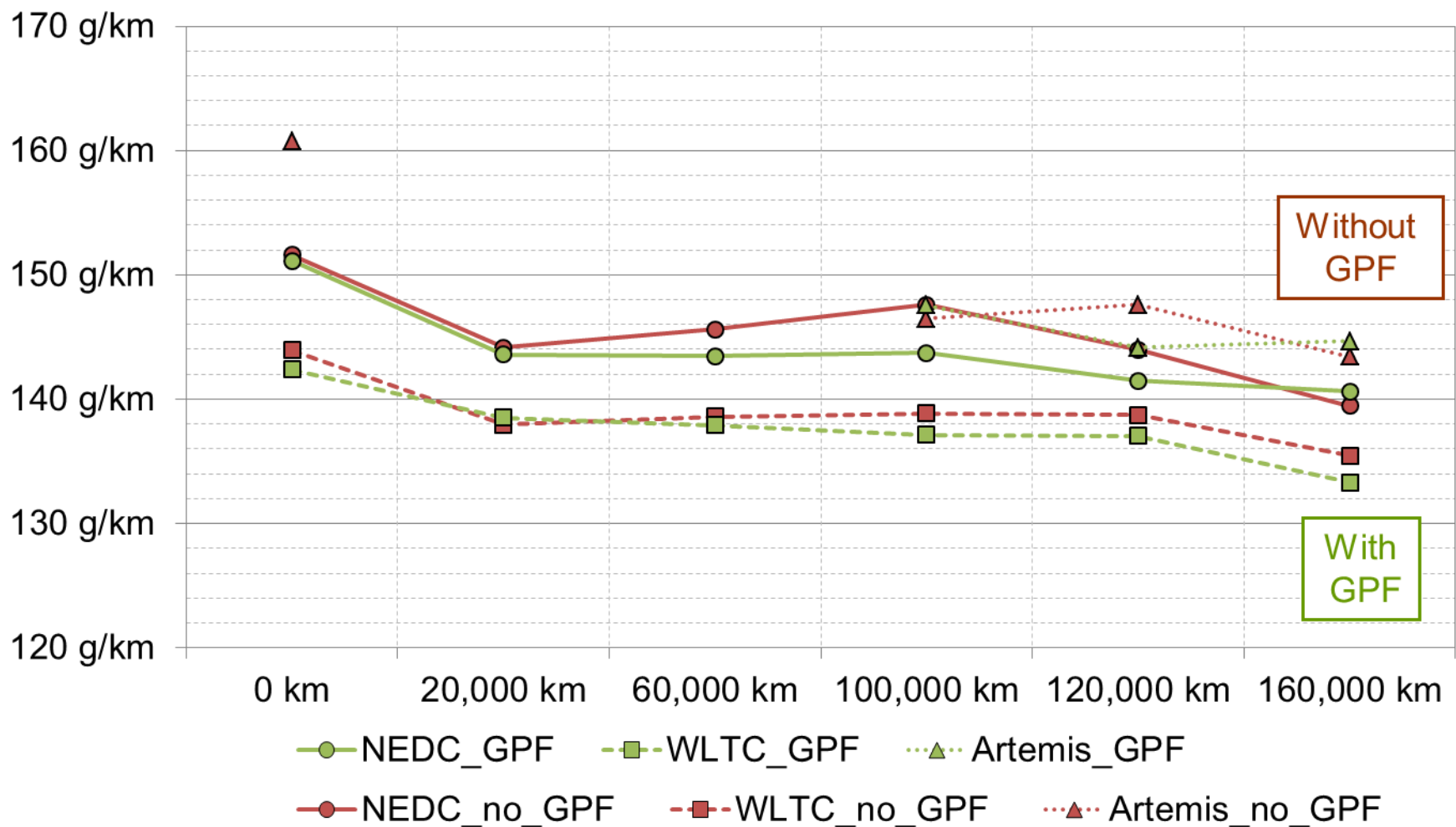
Original System



Modified System

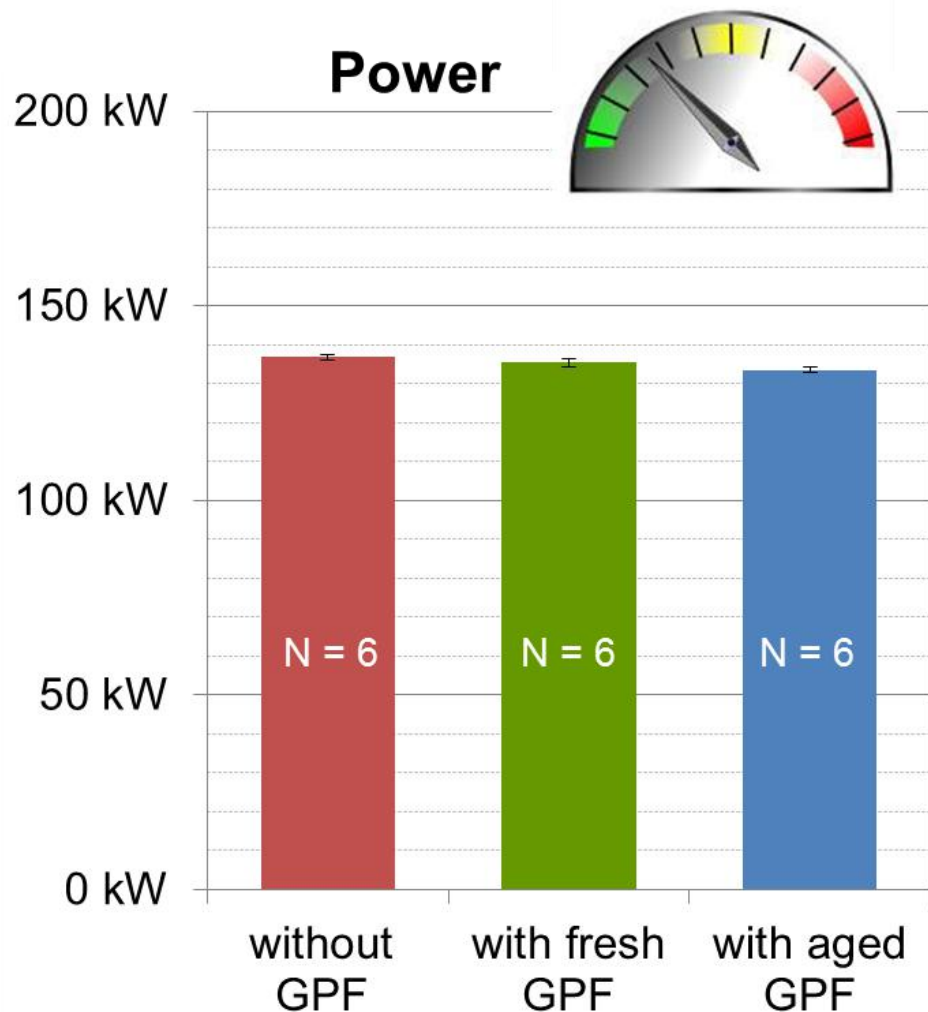


CO2 Emissions



Impact on CO2 emission from a catalyzed GPF is negligible during most drive patterns.

Wide Open Throttle Power Measurement



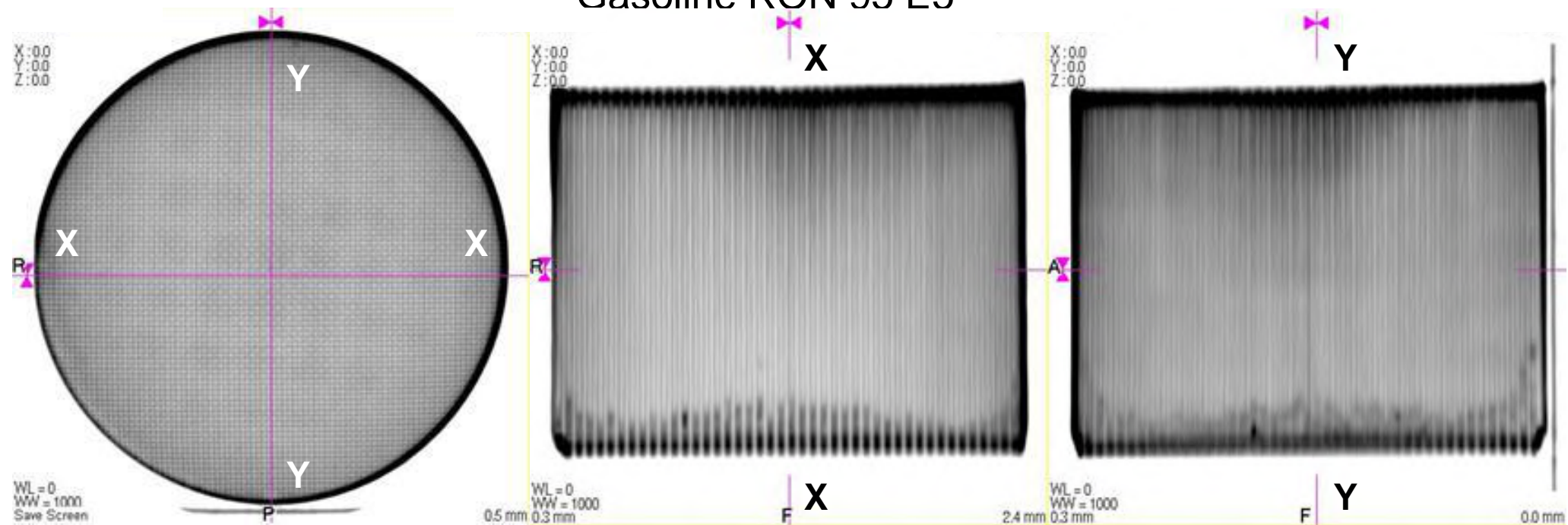
Less than 3% power loss and torque loss with aged GPF is observed during wide open throttle acceleration.

CT Scan of GPF after 160,000 km

Average Oil Consumption:
0.305 l/10,000 km
5W-30

Average Fuel Consumption:
8.46 l/100 km
Gasoline RON 95 E5

Average Speed:
80 km/h



No cracks was observed in GPF.

Deposits of ash were detected mainly at the rear of GPF.

Ash amount determined after 160,000 km -> 22 g ash.

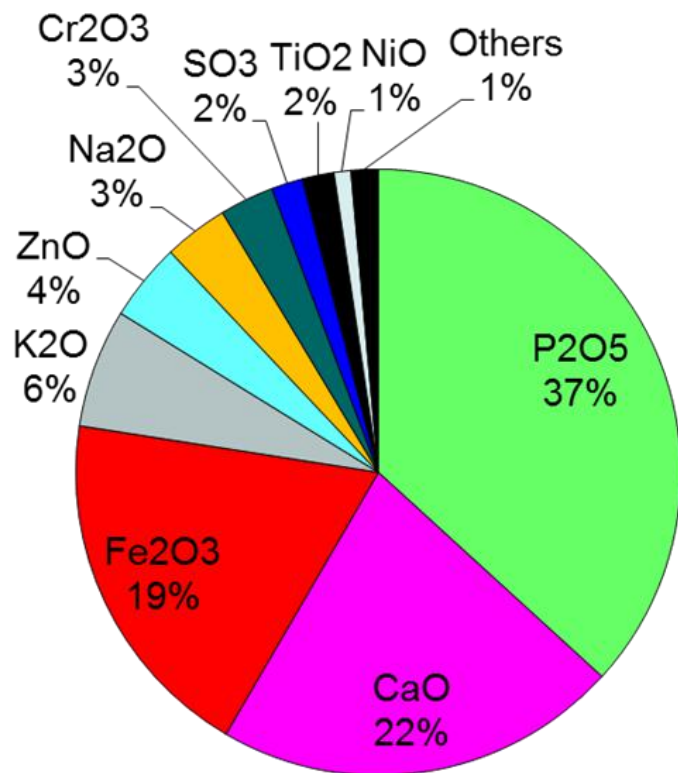
Oil Ash Components Analysis

Engine oil : 5W-30

Measured by XRF(X-ray Fluorescence Analysis)

Unit: wt%

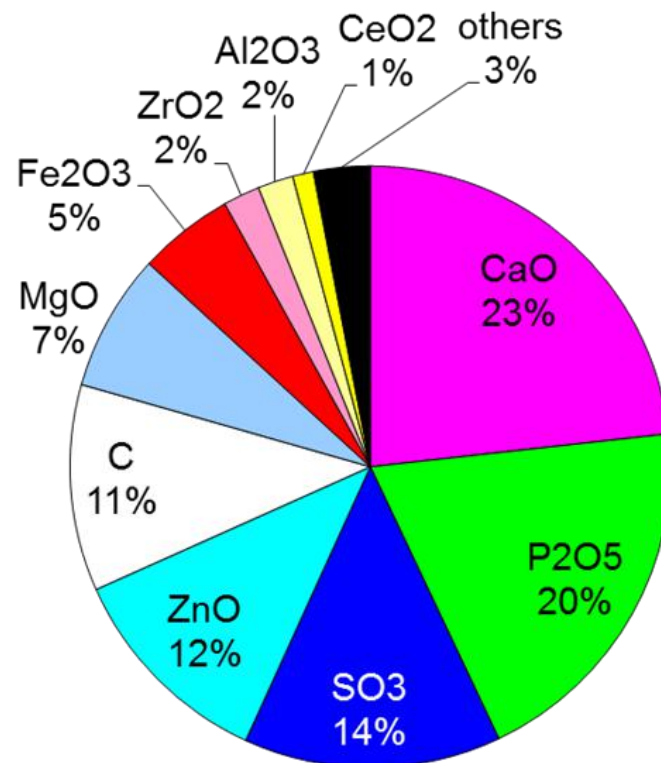
Ash from 1.8L turbo GDI with catalyzed GPF



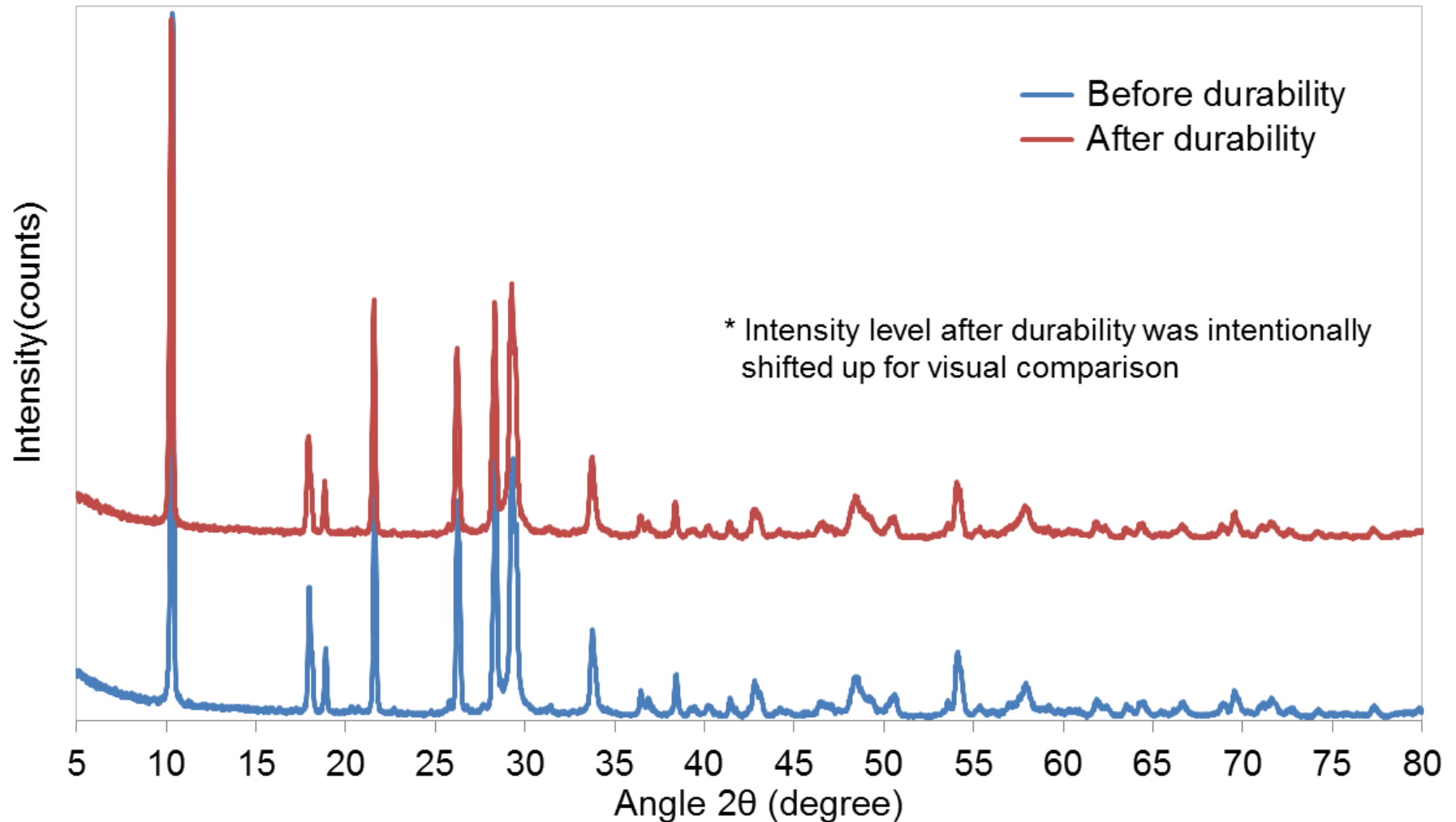
Engine oil : 5W-30

Measured by ICP-AES

Ash from diesel with catalyzed DPF



Gasoline engine oil ash components are similar to diesel reference oil ash. Ca and P are major components from oil.



No change for Cordierite crystalline structure after 160,000 km.
-> No reaction with ash occurred during this durability test.

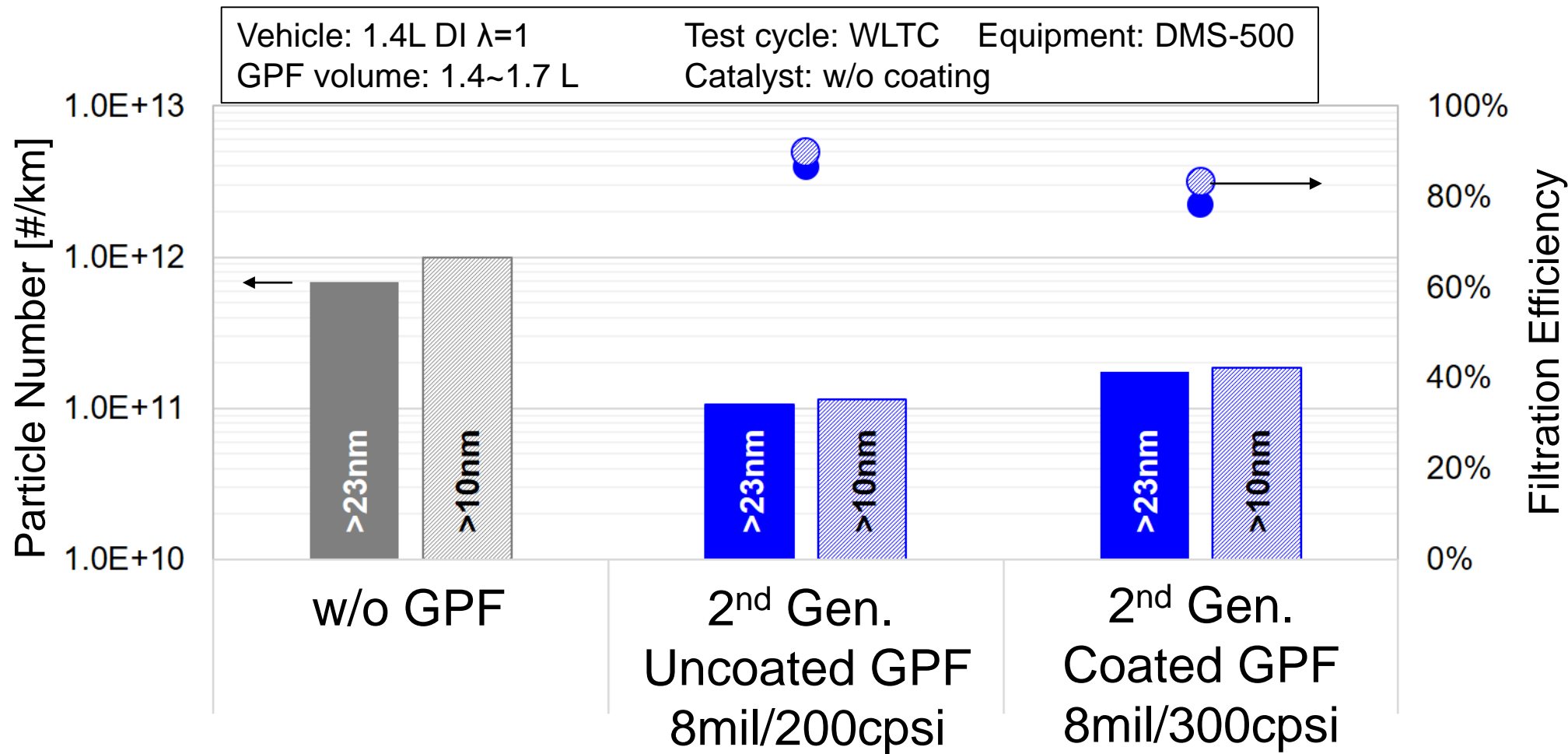
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Sub 23nm PN measurement results



PN emissions will increase by extending measurement range of PN size from >23 to >10nm. GPFs show higher filtration efficiency when counting >10nm particle size.

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PFI vehicle has higher engine out PN than DI in some driving condition and raw PN emission is above $6E+11$ #/km.

No obvious concern of GPF implementation with ash and/or under real driving is confirmed.

Potential BS7 PN regulation is not clear. However, NGK has enough GPF experience and proper GPF can be proposed based on the customers' FE requirement.

A large, light blue graphic of a hand with fingers spread, set against a darker blue square background.

Thank you

NGK