ECT-2025
Session 2
Light Duty Applications
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Gasoline Particulate Filter (GPF) strategy for GDI engine in response to future Indian regulation

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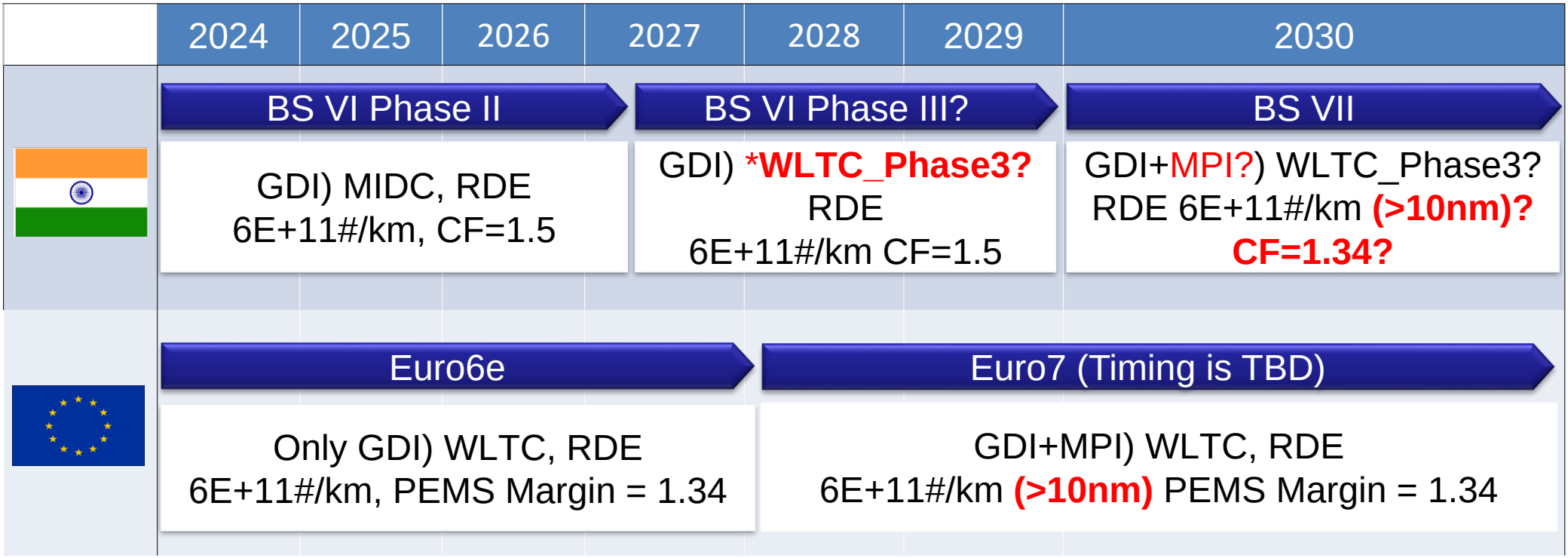
PC/LDV Gasoline Regulation



*BS VI Phase III may apply WLTC up to Phase 3, which has a shorter distance than Euro6e's WLTC up to Phase4. (WLTC up to Phase3 Approx.15km, WLTC up to Phase 4 Approx. 23 km)

This suggests that BS VII could become a significantly stricter regulation, affecting a broader range of vehicles.

Gasoline RDE condition

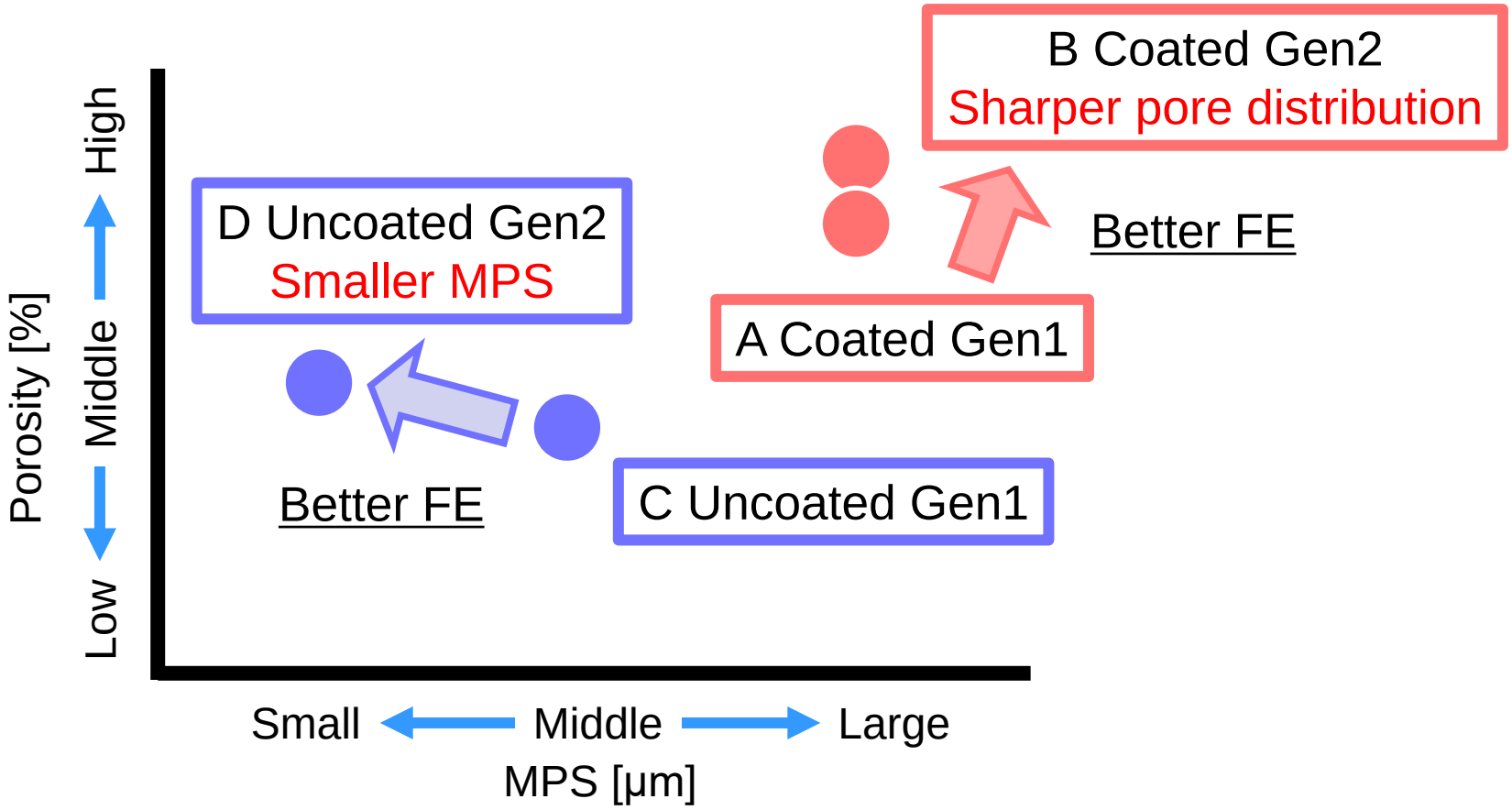
Regulation		BS VI StageII	Euro 6d
Timing		2023 / April	2020 / Jan -
Ambient temp.	Moderate	10 – 40°C	0 – 30°C
	Extended	40 – 45°C	30 – 35°C
		8 – 10°C	-7 – 0°C
Altitude	Moderate	≦ 700 m	
	Extended	≦ 1300 m	
Pre-conditioning		30 – 60min drive → Soak 6 – 56hrs	
Speed	Urban	0 – 45km/h (34±10%)	0 – 60km/h (29 – 44%)
	Rural	45 – 65km/h (34±10%)	60 – 90km/h (33±10%)
	Motorway	65 – 100km/h (34±10%)	90 – 145km/h (33±10%)
Measurement Duration		90 – 120min	

- Indian RDE conditions allow higher ambient temperatures than Europe, with a minimum of 8° C vs. -7° C, favoring lower emissions.
- Indian RDE also involves generally lower driving speeds.

Investigated how these Indian-specific conditions affect PN emissions for GDI engine.

NGK Development Roadmap for GPFs

MPS: Mean Pore Size
FE: PN Filtration Efficiency



- NGK has improved PN filtration performance of GPF from Gen1 to Gen2.
- Above 4 types of GPF are currently used in the European market and should be expanded to India market.

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Sample Matrix

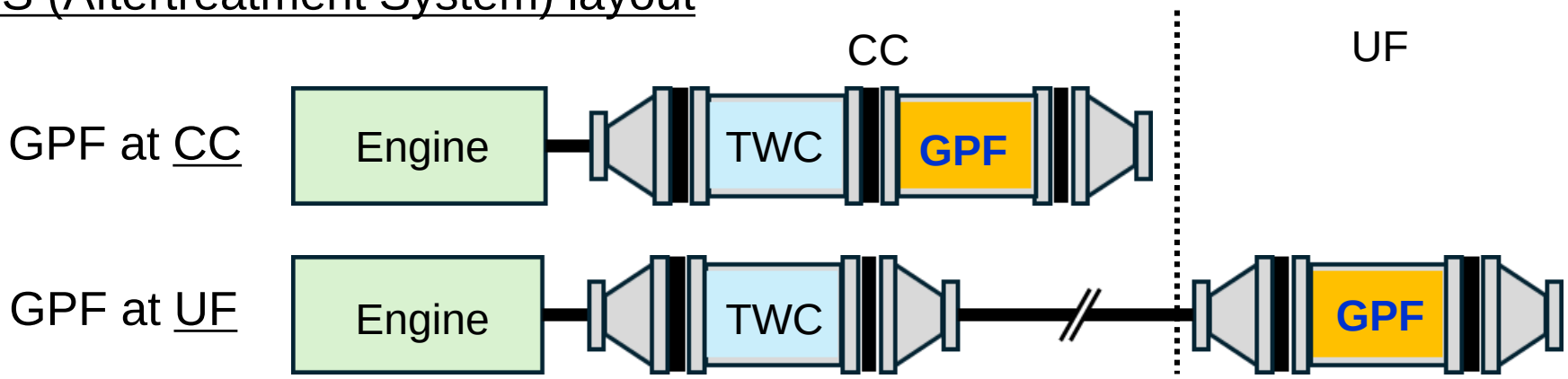
CC: Closed Coupled
UF: Under Floor
MPS: Mean Pore Size

Test Sample : TWC 0.8L + GPF 1.2L

Symbol	GPF Type	GPF	
		MPS	Position
A	Coated Gen1	Large	CC
B	Coated Gen2	Large (Sharp)	CC
C	Uncoated Gen1	Middle	CC
D	Uncoated Gen2	Small	UF

* For all systems, TWC and GPF's total amount of PGM (Platinum Group Metals) is kept constant.

ATS (Aftertreatment System) layout

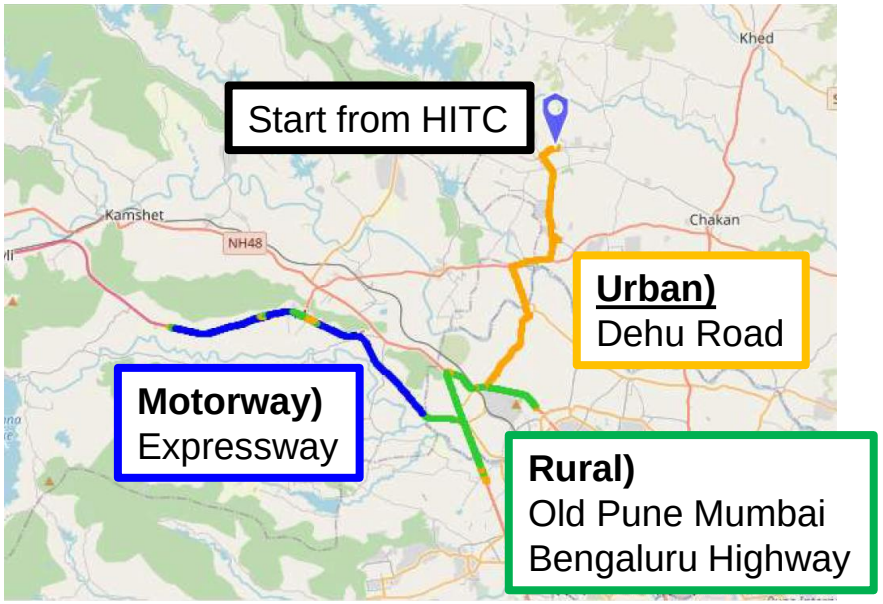


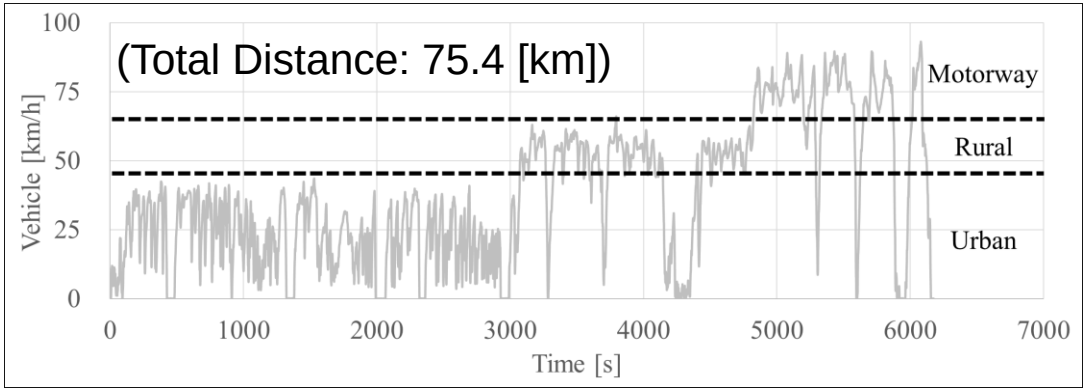
Test Detail

Vehicle	1.2L GDI Engine		
Tested Cycle	PN measurement		
	Engine out	Tailpipe	PEMS
MIDC	✓	✓	
WLTC (Up to Phase 3)	✓	✓	
RDE	-	-	✓

RDE) Driving Route and Target Speed

HITC : HORIBA INDIA TECHNICAL CENTER





Items	Urban	Rural	Motorway
Average speed [km/h]	25.4	57.4	80.5
Distance [km]	25.0	25.3	25.1

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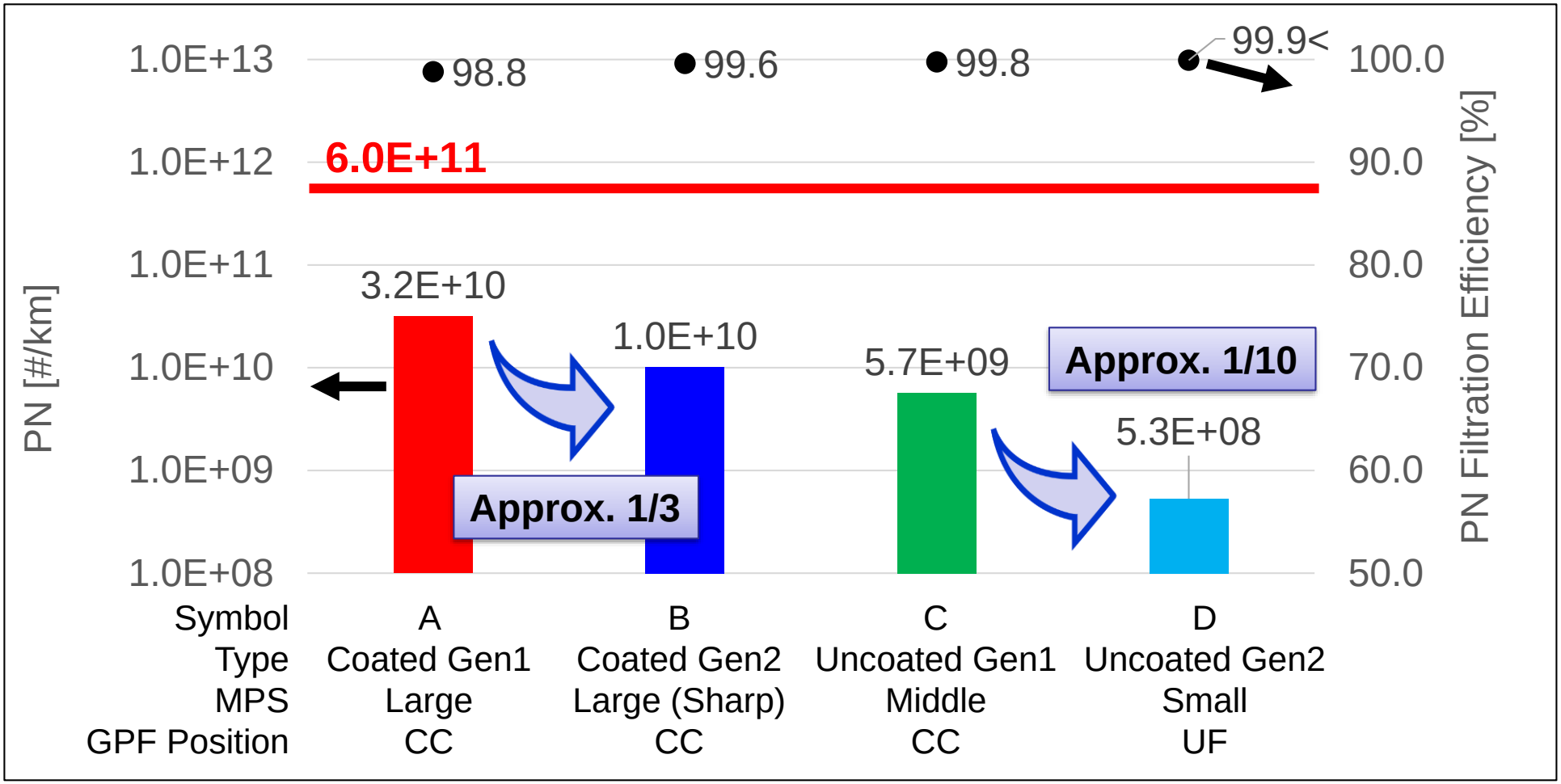
MIDC PN emission & Filtration Efficiency

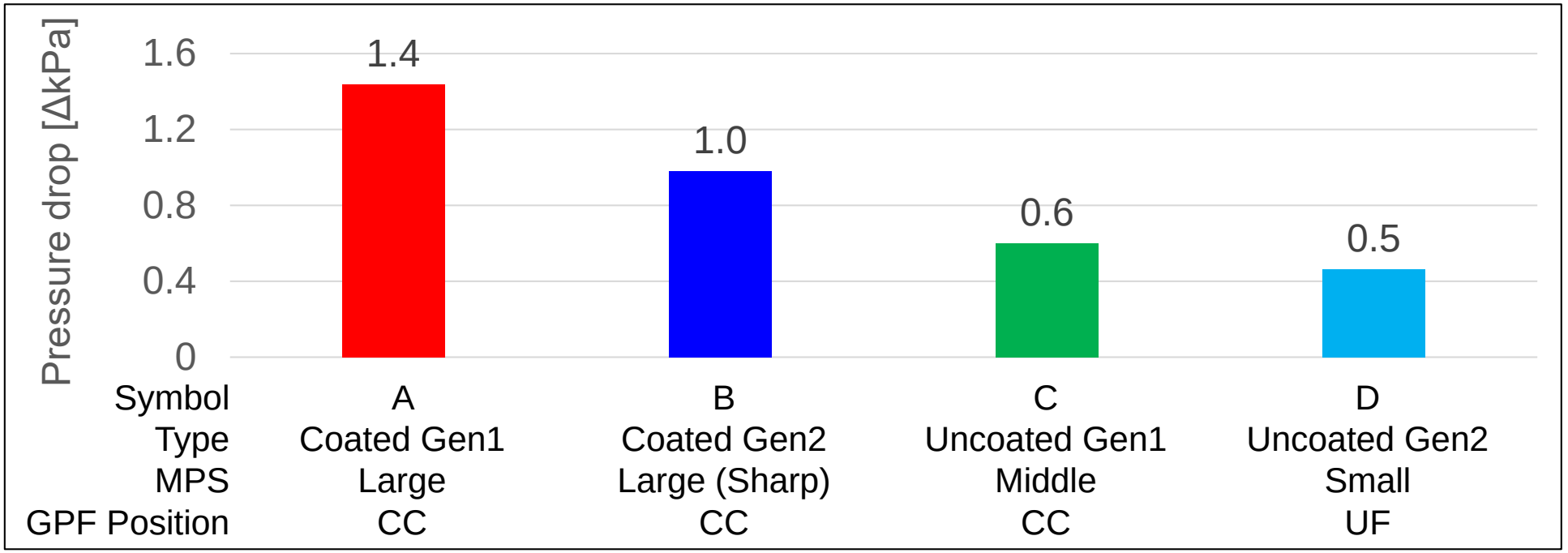
FE: Filtration Efficiency
MPS: Mean Pore Size



- All GPFs achieved sufficient margin below regulatory limits and FE is above **98%**.
- Gen2 exhibited better PN results than Gen1 as expected.

MIDC Pressure Drop

PD: Pressure Drop
MPS: Mean Pore Size

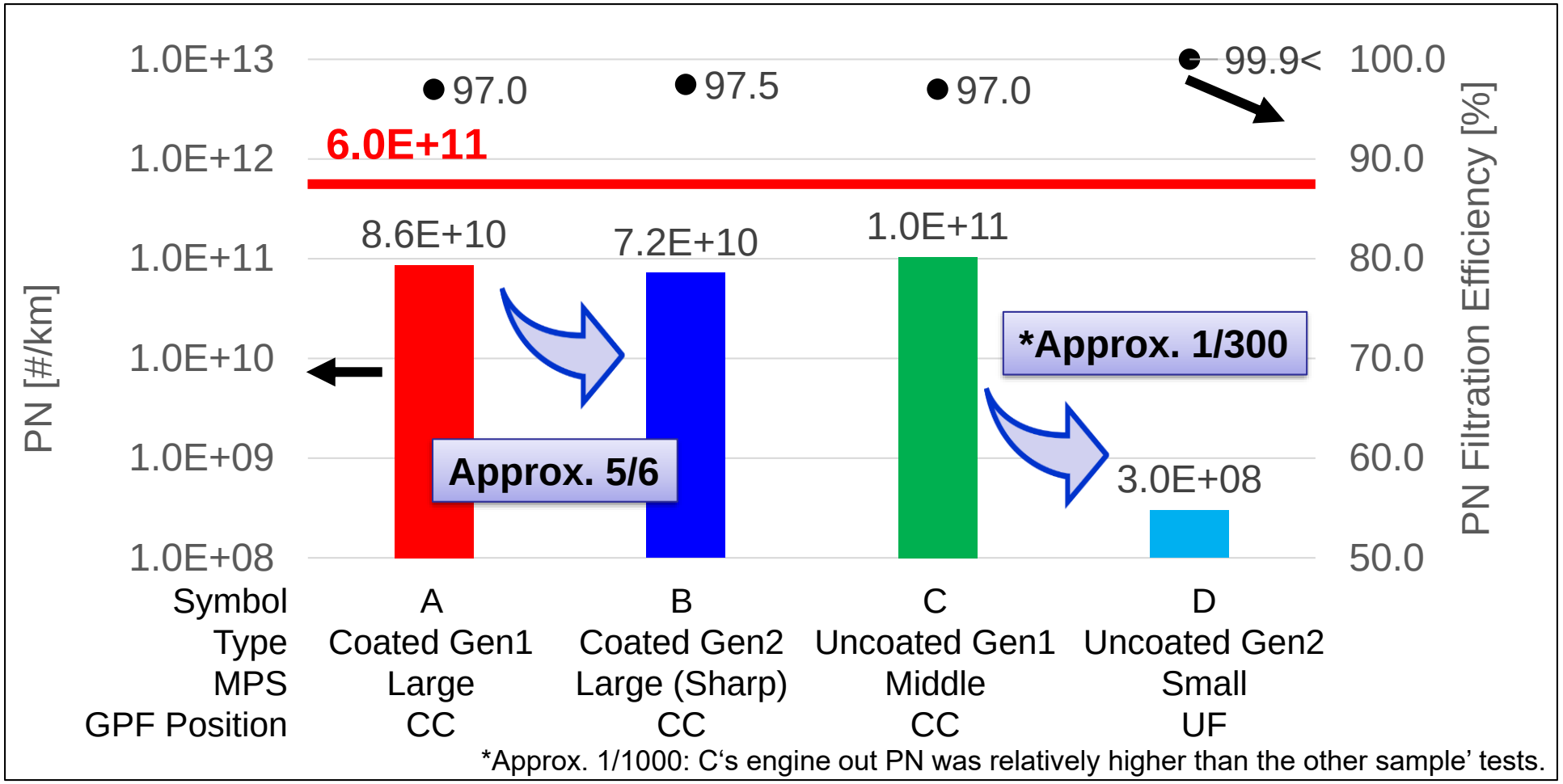


※Estimated PD based on stabilized data, assuming 225° C and a flow rate of 1 m³/min.

PD results	Comments
A, B (Coated) > C, D (Uncoated)	Washcoat penetration in pores resulting in blockage of substrate channels.
A > B (Sharper pore distribution)	Fewer small pores resulting in restricted washcoat penetration.
C ≧ D (Smaller MPS)	Supports in prevention of soot penetration in GPF pores.

WLTC PN emission & Filtration Efficiency

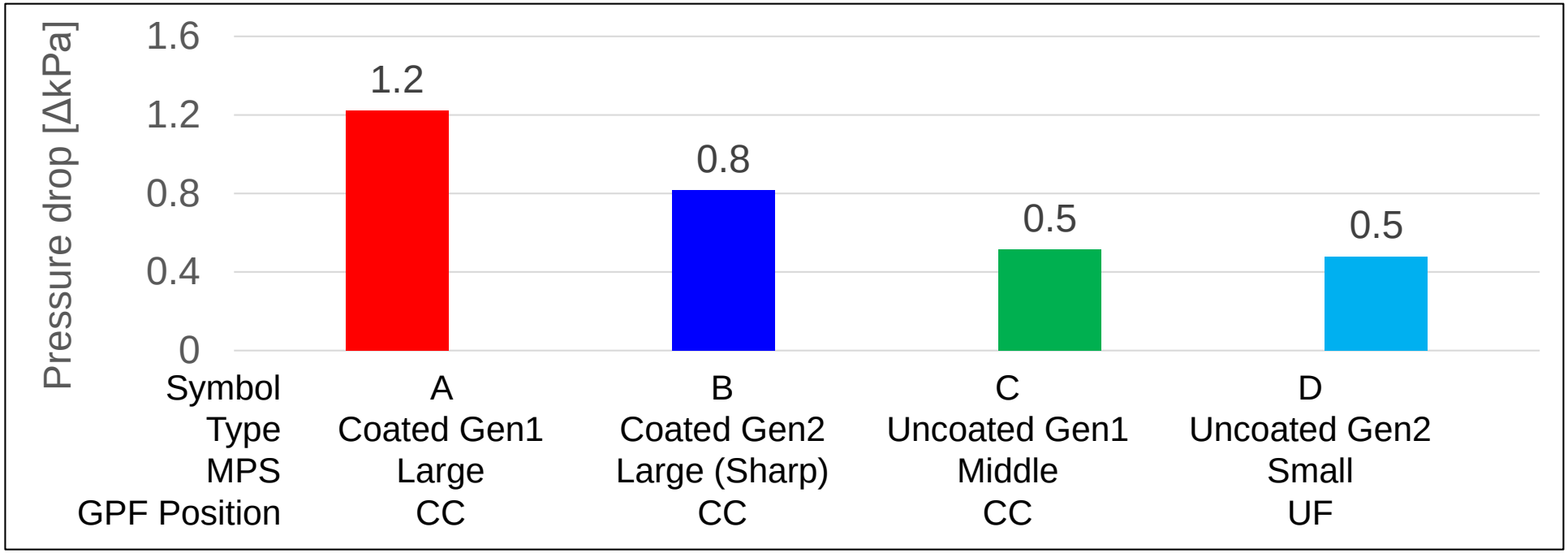
FE: Filtration Efficiency
MPS: Mean Pore Size



- All GPFs achieved sufficient margin below regulatory limits and FE is above **97%**.
- Gen2 exhibited better PN results than Gen1 as expected.

WLTC Pressure Drop

PD: Pressure Drop
MPS: Mean Pore Size



※Estimated PD based on stabilized data, assuming 225˚ C and a flow rate of 1 m³/min.

PD results	Comments
A, B (Coated) > C, D (Uncoated)	Washcoat penetration in pores resulting in blockage of substrate
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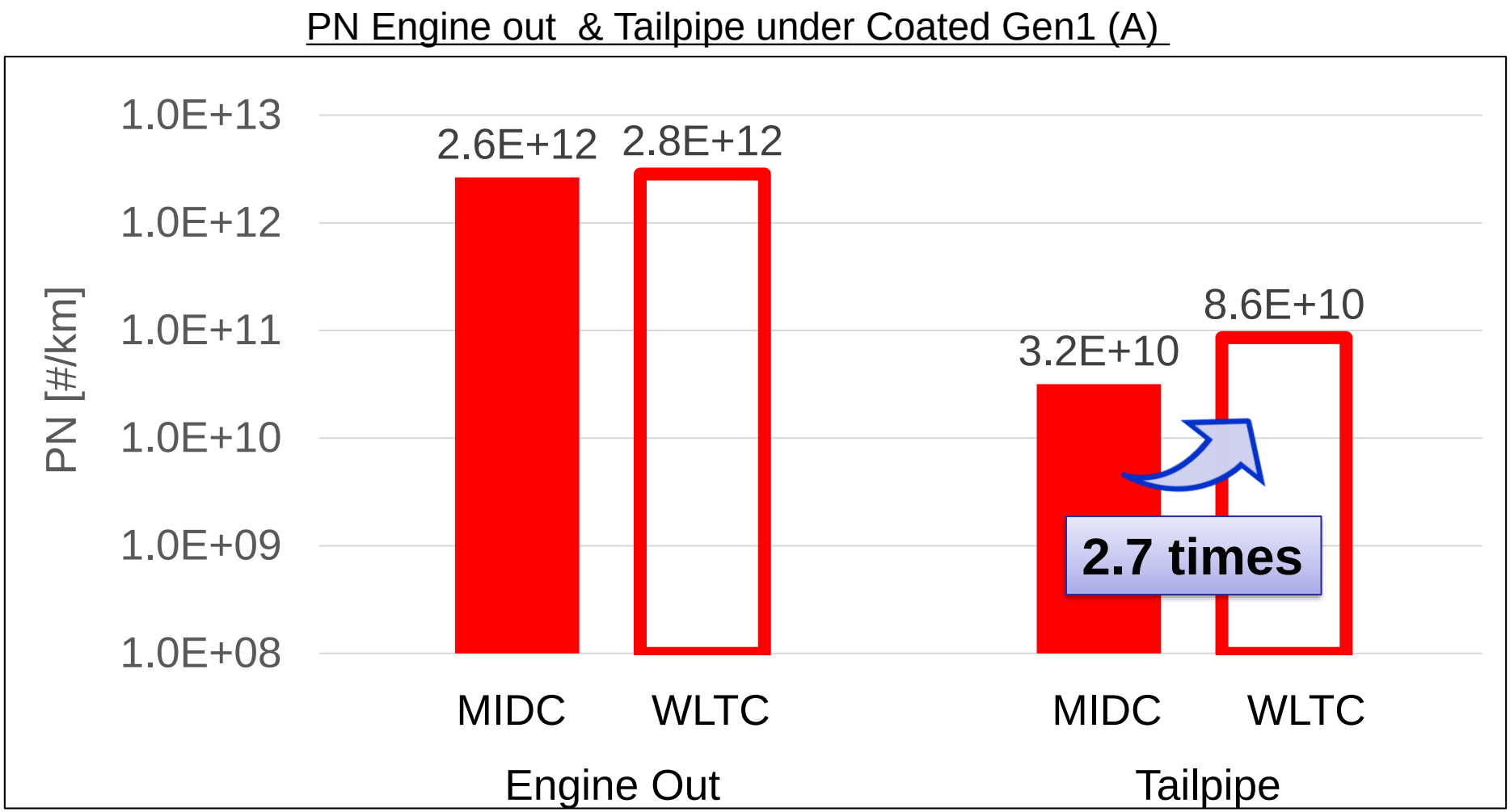
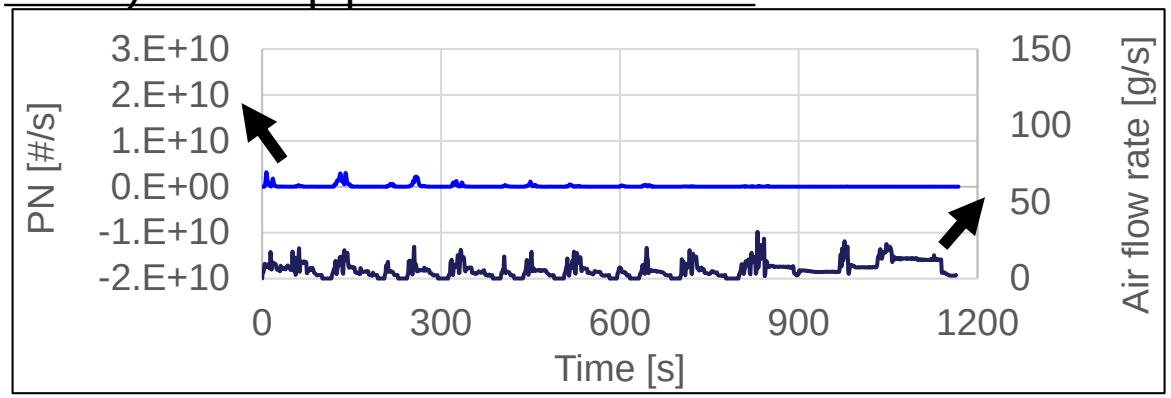
PN differences between MIDC and WLTC



- Tailpipe PN in WLTC was **2.7 times higher** than that in MIDC while the Engine out PN were almost same.

Consideration for PN differences b/w MIDC & WLTC

MIDC) PN Tailpipe and Air flow rate



WLTC) PN Tailpipe and Air flow rate

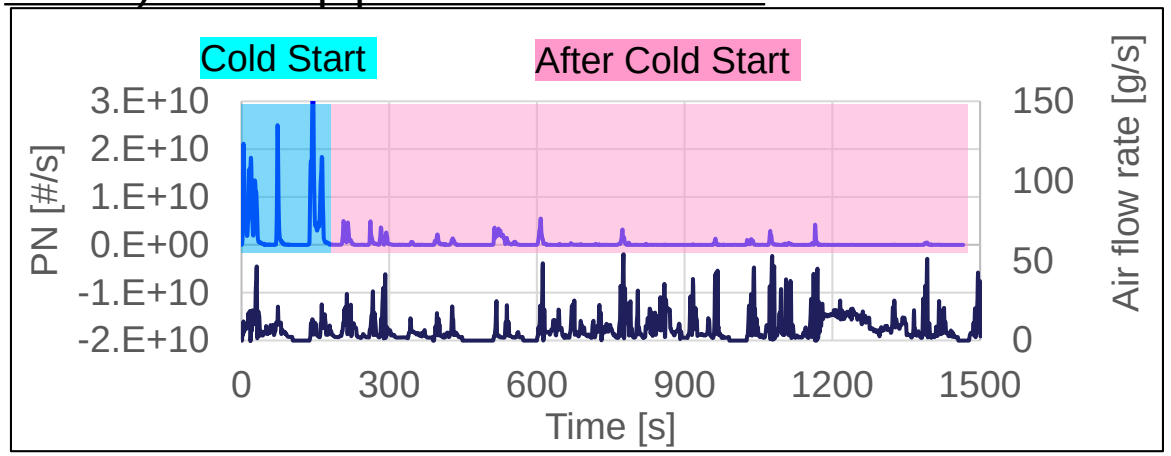
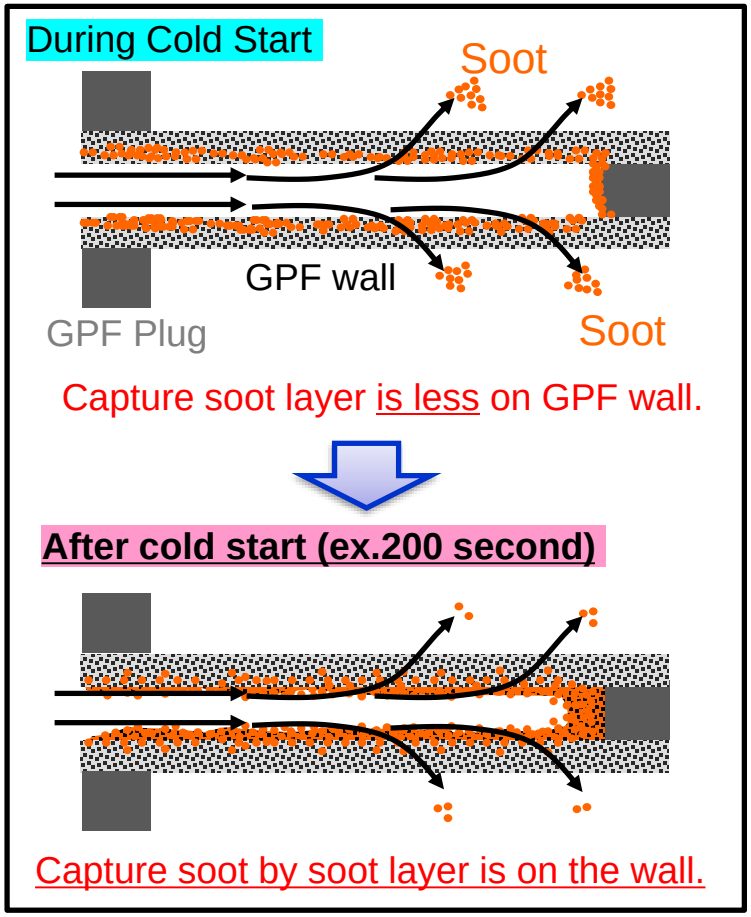


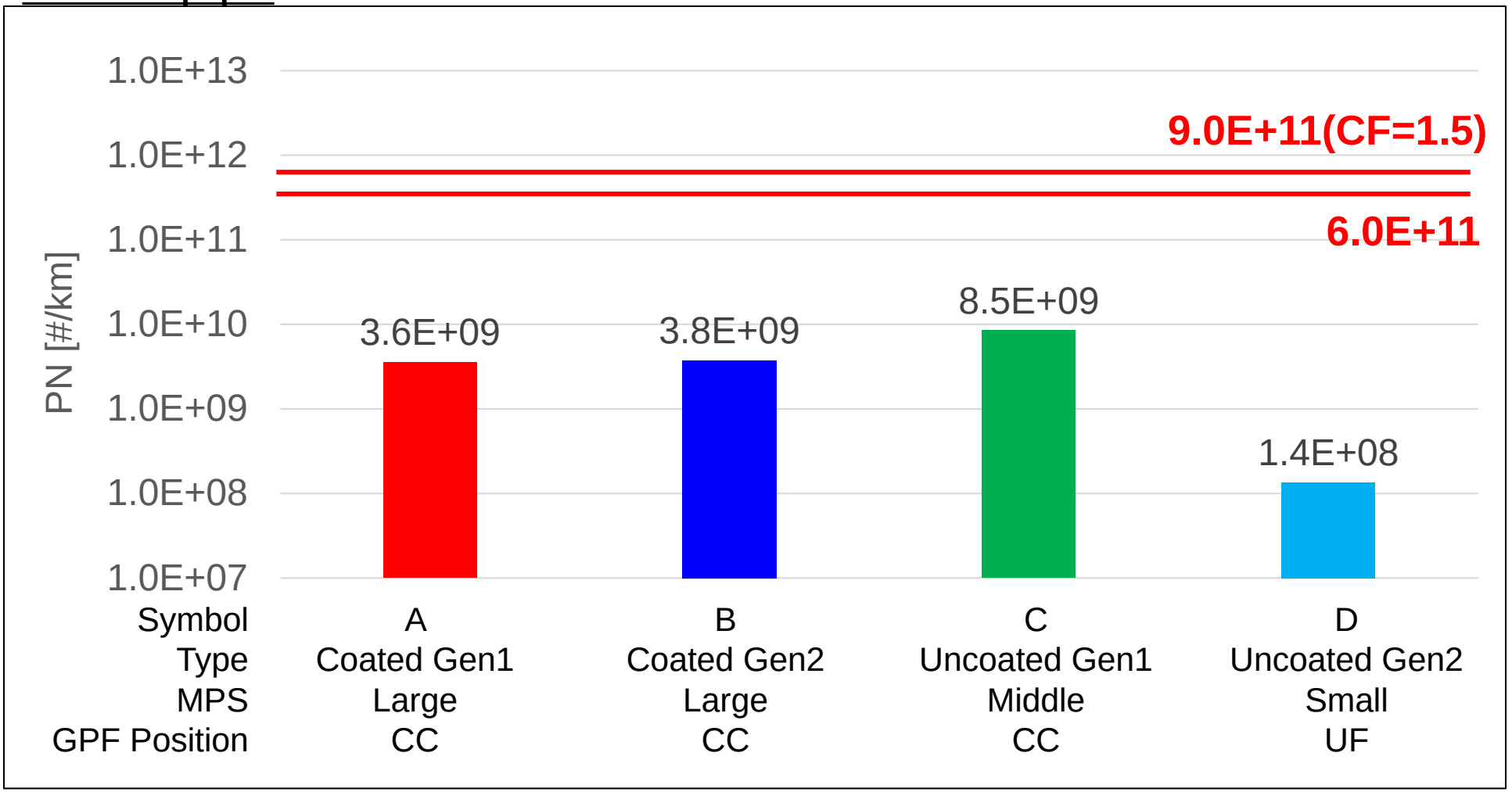
Image) Soot capturing mechanism



- WLTC (more rapid accelerations & higher driving loads than MIDC) ➡ Higher air flow rate and PN emission.
- Absence of soot layer on the GPF wall resulting in major PN emissions during cold start.

RDE PN emission

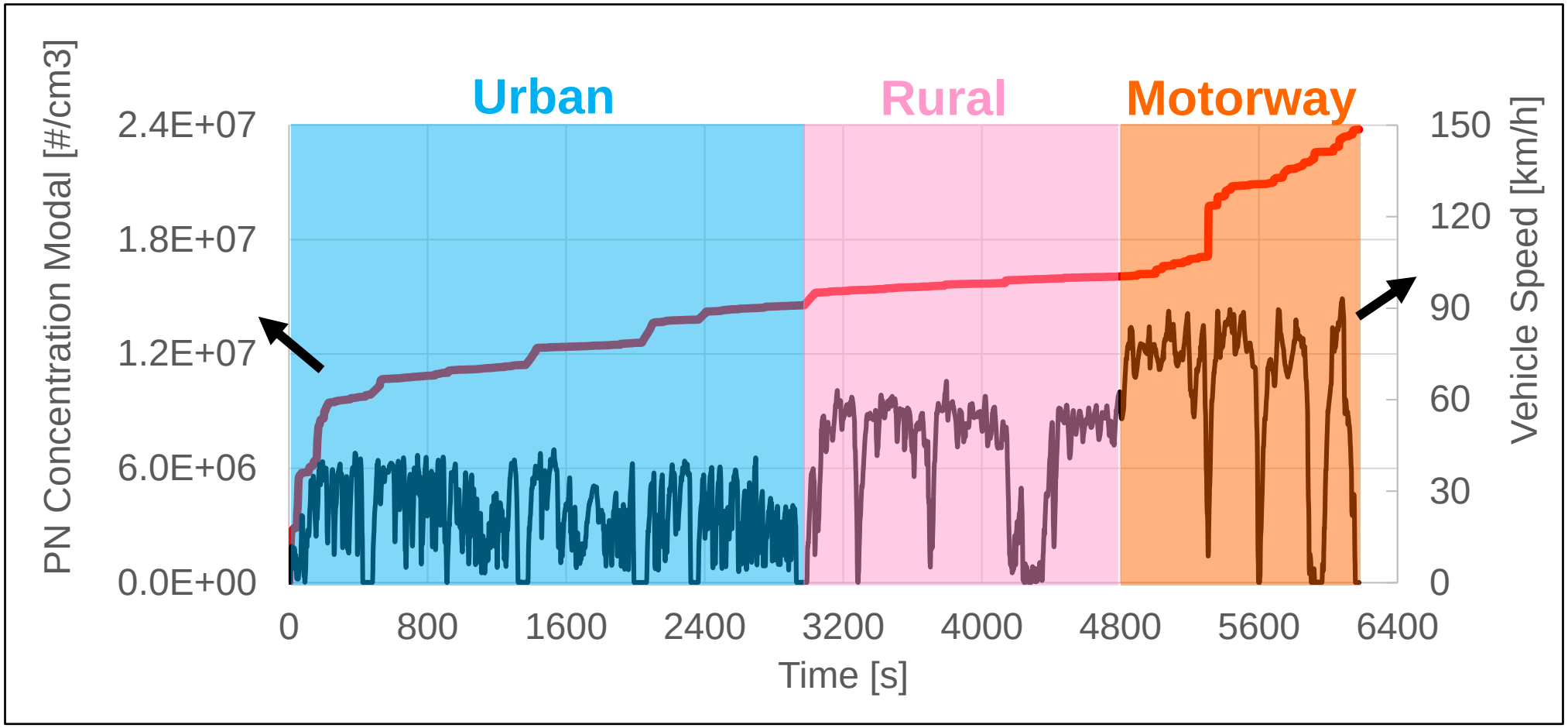
PN Tailpipe



All GPFs achieved sufficient margin below regulatory limits.

RDE PN emission

PN times series data for Coated Gen1(A)



Most of the PN emissions were observed in urban areas.
(Total PN ratio…Urban: 61.7%, Rural: 5.9%, Motorway: 32.4%.)

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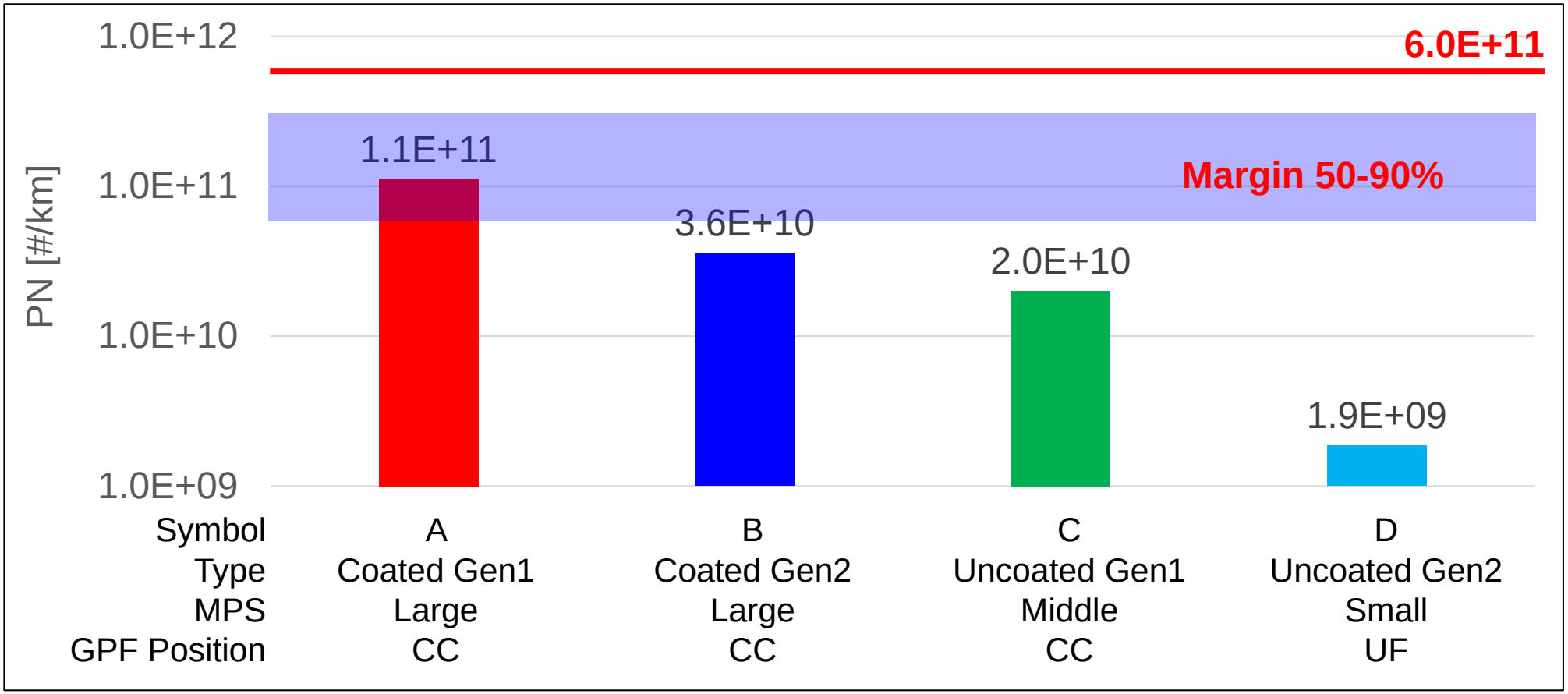
Considering Suitable GPF for India Gasoline GDI

Estimated PN emission at tailpipe under WLTC with *PN10



*Estimated 30% increase in PN tailpipe when switching from PN23 to PN10, presumed from past findings.

The selection of GPF technology to be based on the allowable PN regulation limit.

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- NGK GPF technologies currently used in the European market are highly to comply with PN requirements under actual Indian driving conditions.

- For the upcoming BS VII regulation, NGK is planning to test GPF technologies for MPI vehicles with PN10 emission limits.

Thank you