PM Mass-Based Standard for Achieving PM Emissions Commensurate with Model Year 2022 GPF Technology for Light-Duty and Medium-Duty Vehicles

new filter | GPF | no GPF

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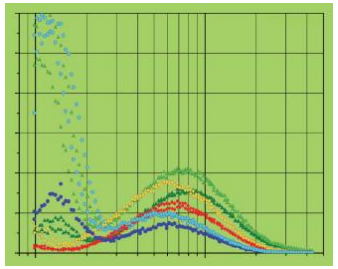

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EPA Proposed Rulemaking

April 2023, EPA proposed multipollutant emissions standards (criteria pollutants and GHG)

Light-duty and medium-duty vehicles; GVWR ≤ 14,000 lb (6350 kg)

Applies to MY 2027 – 2032

Performance-based, inter-dependent, synergistic

Public comment period through July 5, 2023, plans for final rule by March 31, 2024

Criteria pollutant fleet phase-in

	GVWR ≤ 6000 lb	**6001 – 8500 lb**		**8501 – 14,000 lb**	
		default*	early**	default*	early**
2027	40%	0%	40%	0%	40%
2028	80%	0%	80%	0%	80%
2029	100%	0%	100%	0%	100%
2030-2032	100%	100%	100%	100%	100%

* Default phase-in provides 4 years lead time as required by CAA

** Incentives for choosing early phase-in (e.g., carry forward NMOG+NO_x credits)

Light-Duty Vehicle Standards (LDV, LDT, MDPV)

NMOG+NOx standards

- 30 → 12 mg/mi fleet average standard, BEVs included (60% reduction)
- Same standard over 4 cycles: 25°C FTP, HFET, US06, SC03
- Eliminates higher bins (no high emitters) and adds lower bins
- -7°C fleet average standard: NMHC → NMOG+NO_x; 300 mg/mi; BEVs not included so fleet average doesn't decline
- New engine start-up standards: PHEV high power starts (cold start US06), early driveaway (in gear at 6 seconds), intermediate soak (10 min, 40 min, 3-12 hr)

PM

0.5 mg/mi (0.3 mg/km) per vehicle standard (cap) for -7°C FTP, 25°C FTP, US06 (from na/3/6 mg/mi)

CO

1.7 g/mi per vehicle standard (cap) for 25°C FTP, HFET, US06, SC03

10.0 g/mi per vehicle standard (cap) for -7°C FTP

HCHO

4 mg/mi per vehicle standard (cap) for 25°C FTP

Elimination of the allowance for the use of commanded enrichment for power or component protection

Medium-Duty Vehicle Standards (Class 2b and Class 3)

NMOG+NOx standards

- 178/247 → 60 mg/mi fleet average standard, BEVs included (66-76% reduction)
- Same standard over 4 cycles: 25°C FTP, HFET, US06, SC03
- Eliminates higher bins (no high emitters) and adds lower bins
- New -7°C fleet average standard: NMOG+NO_x; 300 mg/mi; BEVs not included in fleet average so fleet average doesn't decline

PM

0.5 mg/mi (0.3 mg/km) per vehicle standard (cap) for -7°C FTP, 25°C FTP, US06 (from 8/10 mg/mi in FTP and 10/7 mg/mi in HD-SFTP for class 2b/3)

CO

3.2 g/mi per vehicle standard (cap) for 25°C FTP, HFET, US06, SC03

New 10.0 g/mi per vehicle standard (cap) for -7°C FTP

HCHO

6 mg/mi per vehicle standard (cap) for 25°C FTP

Elimination of the allowance for the use of commanded enrichment for power or component protection

MDV with GCWR > 22,000 lb comply with HD engine-dynamometer-based criteria pollutant standards

PM Standards

EPA 2027+ Proposal	Euro 7 Proposal
Measurement	
PM mass (mg/mi)	Solid PN (#/km)
Includes solid and semi-volatile PM	Excellent sensitivity at low PN
Health benefits quantifiable by PM2.5 epi studies	Addresses nanoparticles with very low mass (toxicology studies)
Test Cycles	
-7°C FTP	WLTC
25°C FTP	RDE normal conditions (0 to 35°C, …)
US06	RDE extended conditions (-10 to 40°C, …)
	RDE budget for <10 km trips
Standards	
0.5 mg/mi for all cycles ~$6x10^{11}$ #/km >23 nm (SAE 2019-01-0314)	$6x10^{11}$ #/km in WLTC and RDE normal conditions, >10 nm
	$9.6x10^{11}$ #/km in RDE extended conditions, >10 nm
	$6x10^{12}$ #/trip budget for <10 km trips, >10 nm
Stringency	
Significant stringency during -7°C cold start (high engine-out PM), high load (passive regen), and enrichment (semi-volatile PM)	More stringent wrt nanoparticles, especially in moving to >10 nm
	Significant stringency during RDE extended conditions: low temperature (-10°C) high speeds (160 km/h), high max ave power <2 km after cold start, and towing

Purpose of PM Test Cycles

-7°C FTP

-7°C important real-world temperature (addresses uncontrolled cold PM in Tier 3)

Differentiates vehicles with GPF-level PM from vehicles with Tier 3 levels of PM

25°C FTP

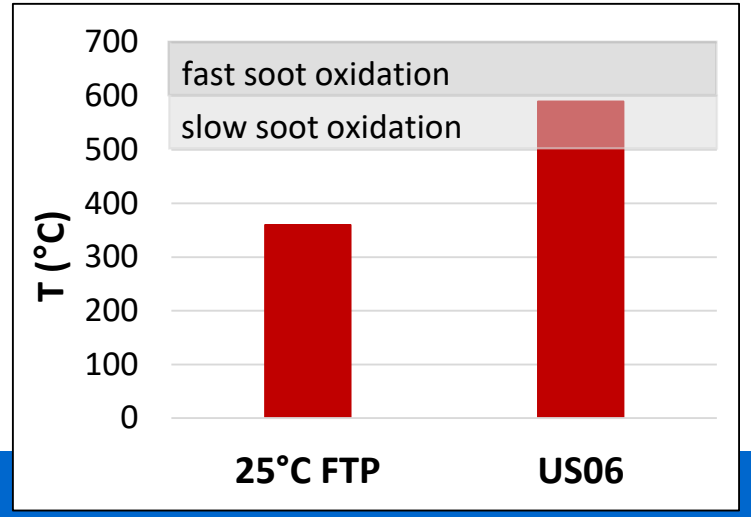
Standards at 25°C and -7°C ensure clean vehicle operation over a range of temps

US06

High load real-world driving

Ensures good PM control during and immediately after GPF regeneration by inducing on-cycle passive GPF regeneration

Max GPF Inlet Temperature
F150, underfloor GPF



Selected Elements of PM Mass Test Procedures (CFR Part 86, 1065, 1066)

Critical elements

Pure PTFE membrane filters (Part 1065.170)

- Less gas-phase artifact than borosilicate fibers reinforced with woven glass cloth and bonded with PTFE

Static charge removal using an α-emitter (Part 1065.190)

- e.g., five 500 µCi strips of ^{210}Po placed around filter on microbalance

Increase PM signal-to-noise ratio

Use lower half of allowable dilution factor range (7-20) (Part 1066.110)

Increase FFV from 90→140 cm/s (Part 1066.110). Improves signal-to-noise ratio[1,2]

Load 1 filter/test (not 1 filter/phase) (Part 1066.815). Improves signal-to-noise ratio[1,2]

1) Xue, Durbin, Kittelson, et al., 2018, Journal of Aerosol Science, 117, 1-10.
2) CRC E-99

Other important considerations

Temperature, dewpoint, grounding, HEPA-filtered dilution air, filter handling (Part 1065.140/190)

Coarse particle separator (removes >50% of PM10 and <1% of PM1 at sampling conditions) (Part 1065.145)

Robotic auto-handler weighing (Part 1065.190)

Background correction ≤ 5ug or 5% of std (Part 1066.110)

Laboratories, Vehicles, GPFs

EPA, Ann Arbor, MI
HTF, CTF, cell 5

ECCC, Ottawa, Canada
cold test facility

FEV, Auburn Hills, MI
cold test facility

2011 3.5L F150
GPF, no GPF

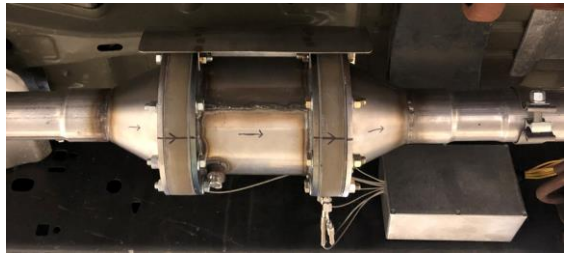
2019 5.0L F150
GPF, no GPF

2021 F150 3.5L HEV
GPF

2021 Corolla 2.0L
no GPF

2022 F250
GPF, no GPF

2019 catalyzed
underfloor

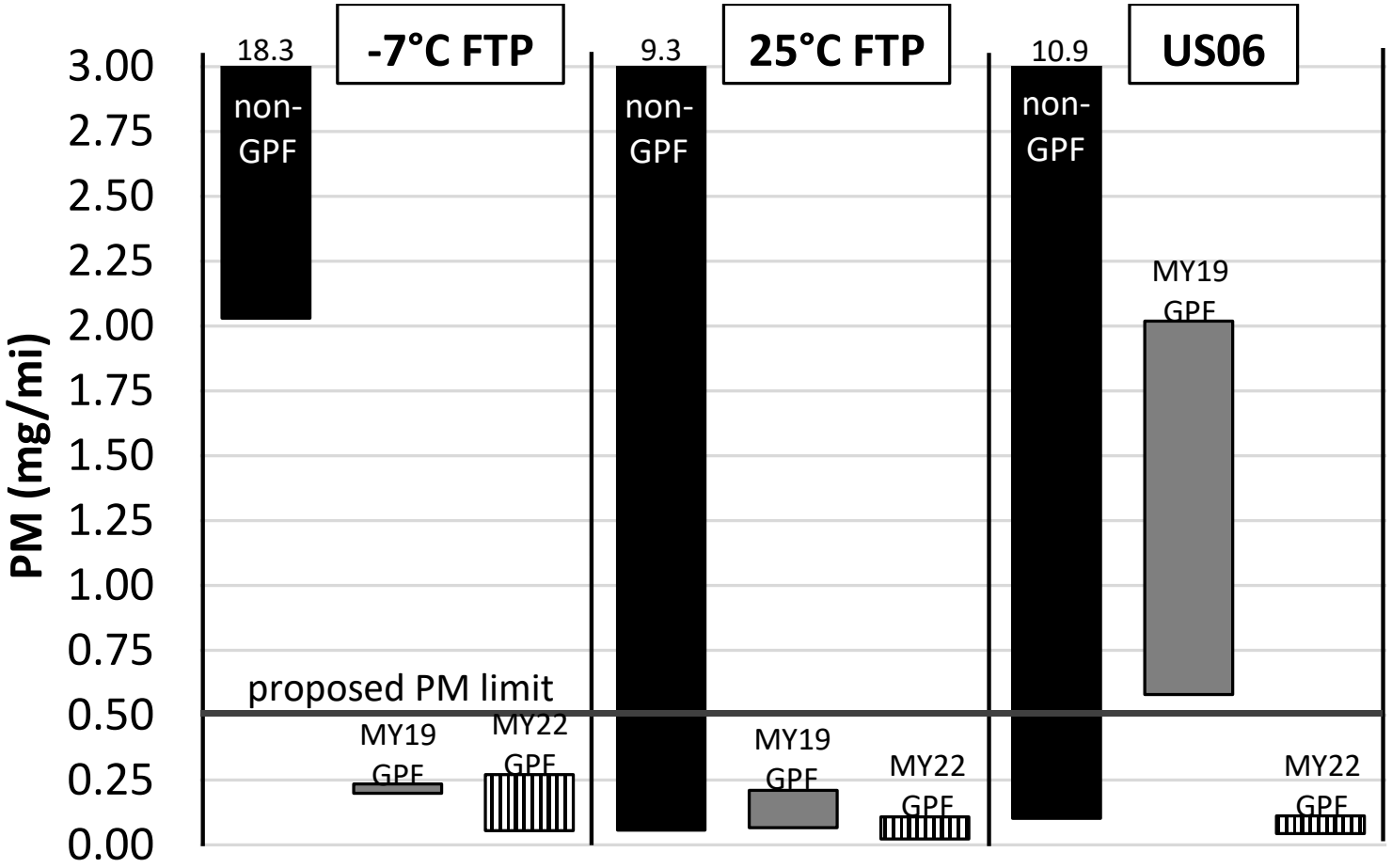


2019 catalyzed
close-coupled

2022 bare
underfloor

2022 bare
underfloor

Overview of PM Data across -7°C FTP, 25°C FTP, US06 Test Cycles

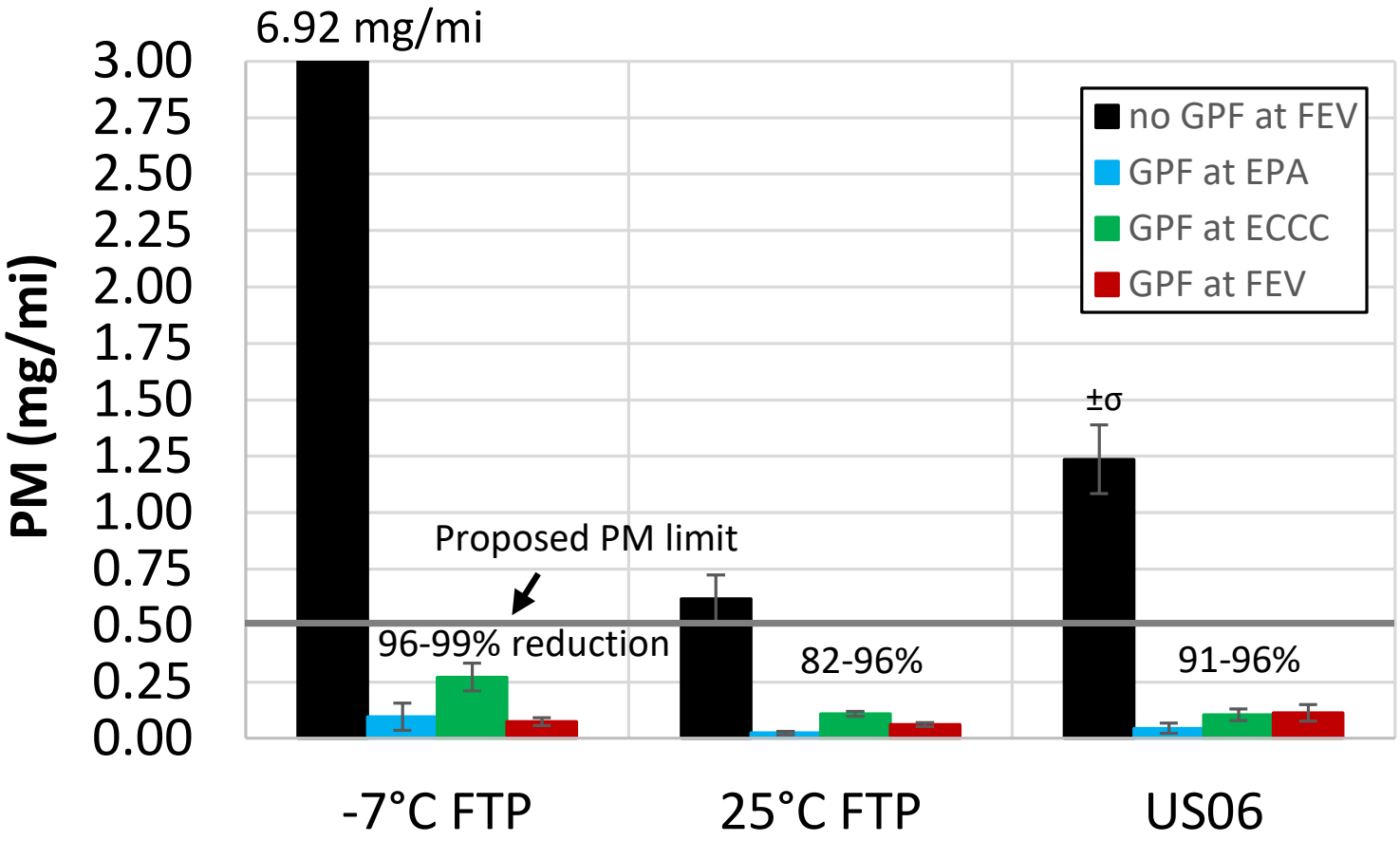


GPF results are conservative because

1) Data not background corrected
2) GPF tests performed with little or no stored soot (unloaded GPF)
3) GPF technology will improve further between now and 2027

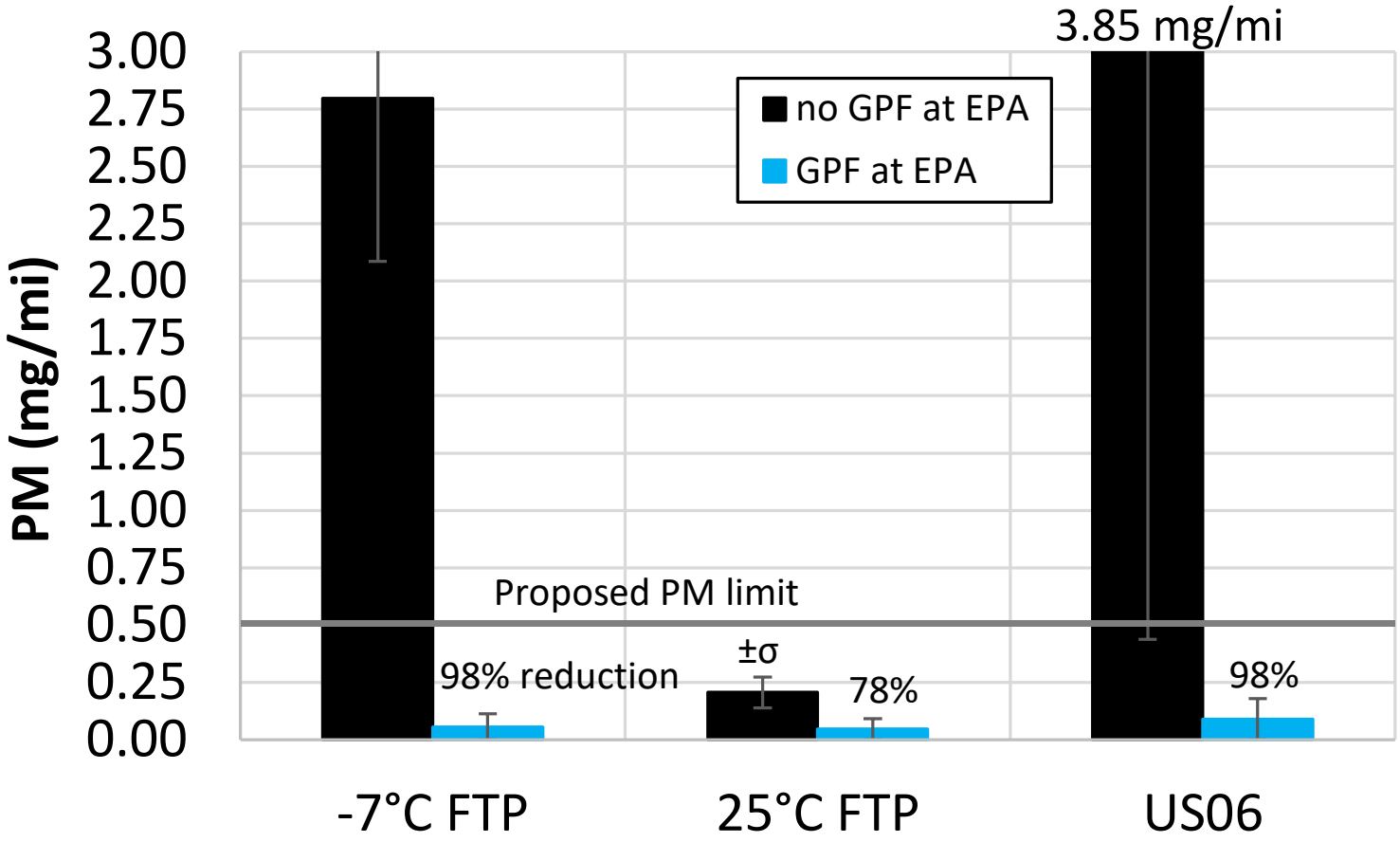
- Large gap between non-GPF and GPF-equipped vehicles in -7°C FTP (high engine-out PM)
- MY2022 GPFs performed significantly better than MY2019 GPFs in US06 (GPF regeneration) and easily meet the proposed 0.5 mg/mi standard

Light-Duty Vehicle (MY2021 F150 HEV) with MY2022 GPF



- GPF PM measurements shows some lab-to-lab bias exists (also reflected in tunnel blanks), but GPF PM results including lab-to-lab bias and test-to-test variability easily comply with the proposed 0.5 mg/mi standard.

Medium-Duty Vehicle (MY2022 F250) with MY2022 GPFs



- GPF is equally effective on medium-duty vehicle as on light-duty vehicle.
- GPF PM results, including test-to-test variability, easily comply with the proposed 0.5 mg/mi standard.

Summary

- Existing Part 86/1065/1066 procedures afford low lab-to-lab bias and low test-to-test variability, and can be used to require PM emissions commensurate with model year 2022 GPF technology

- -7°C FTP differentiates non-GPF and GPF-equipped vehicles.

- MY2022 GPFs demonstrate high filtration across three cycles and three testing organizations and perform significantly better than MY2019 GPFs in the US06.

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