Characterizing Test Methods and Emissions Reduction Performance of In-Use Diesel Retrofit Technologies from the National Clean Diesel Campaign

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Overview

- Introduction
- In-Use Test Objectives
- Test Methods
- Retrofit Emission Reduction Performance
- Conclusions

EPA's Priorities

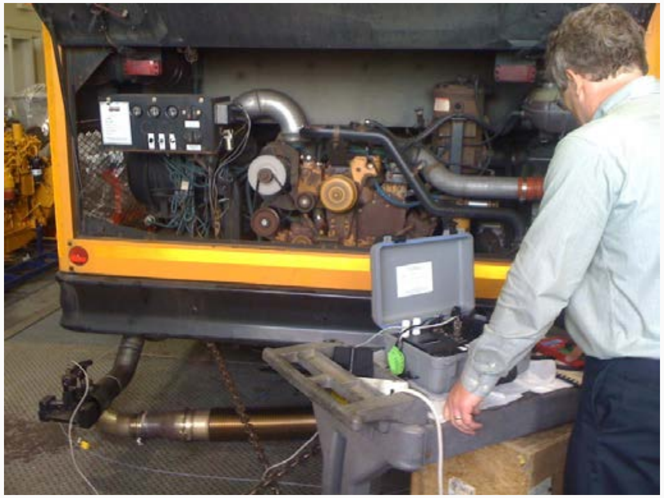
- Protecting public health and the environment
- Improving air quality
- Reducing exposure to pollutants
- Reducing diesel engine emissions
  - HC, CO, NO_x, CO_2, toxics
  - Particulate Matter (PM)

Clean Diesel Technology Assessment Center

- Comprehensive approach to reducing emissions (criteria and GHG) from HD fleets.
- Verification of Retrofit Technologies
  - Verify emission and fuel-saving technologies to inform the market and support incentive programs
- Protocol Development
- In-Use Performance and Testing
  - Research, test and evaluate emission reduction and fuel-saving technologies and strategies
  - EPA In-Use Testing

Testing Objectives

- Evaluate test methods and protocols
- Explore improvements to the verification process
- Filling gaps – addressing new sectors/technologies
- Increase confidence that technologies perform as expected
- Assess real-world durability



Test Methods

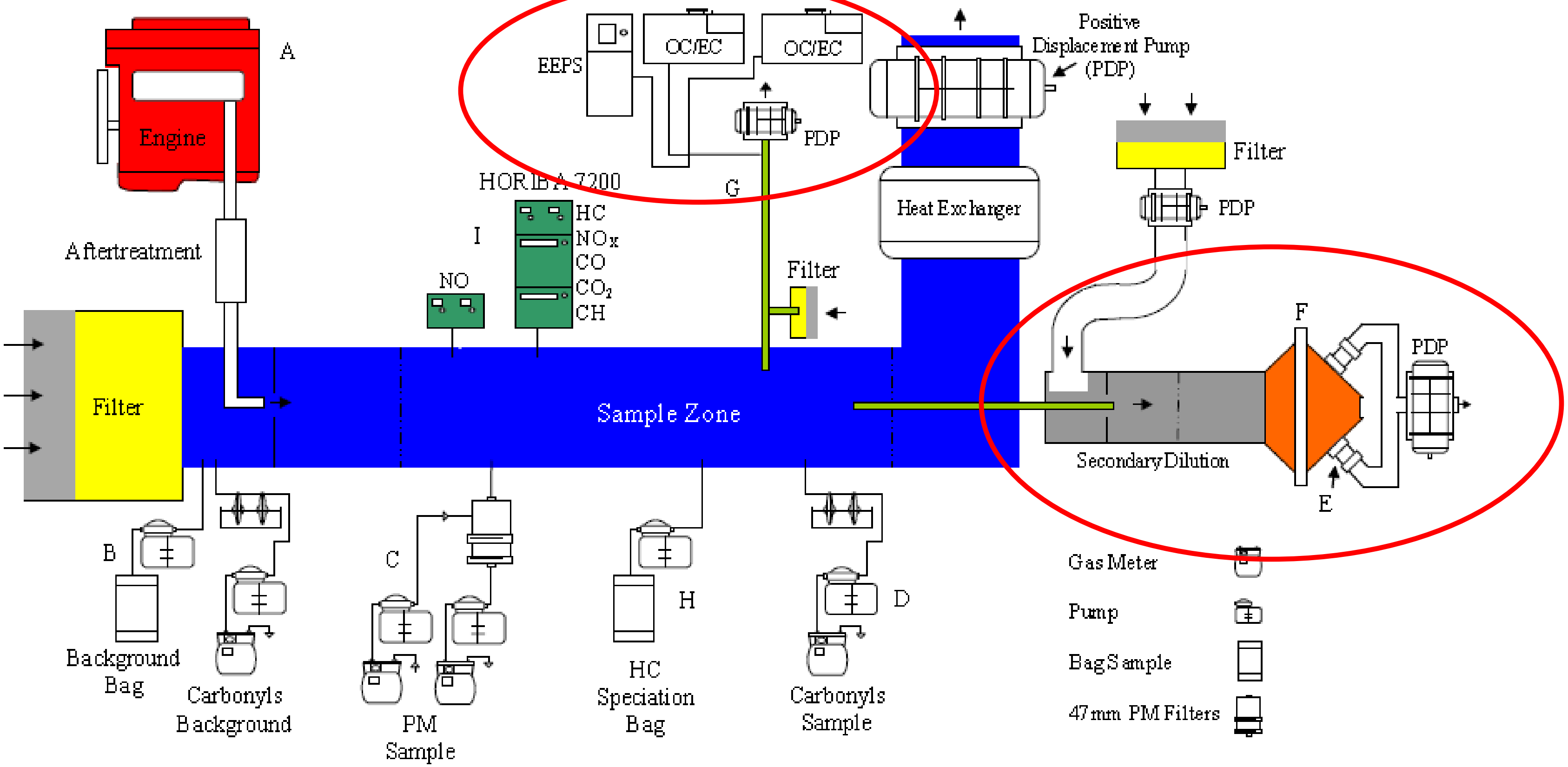
- Engine Dynamometer Testing
  - 40 CFR Part 86 and Part 1065
  - Transient FTP cycles, 1 cold + 3 hot starts
  - Criteria pollutants, PAH sampling, EC/OC, PM number size distributions
- Chassis Dynamometer Testing
  - Test Cycles: Heavy-Heavy Duty Diesel Truck (HHDDT) Cycle; City Suburban Cycle (CSC)
  - Criteria pollutants and fuel economy
- Smoke Opacity Testing
  - SAE 1667
  - Snap acceleration smoke testing using 3 different meters

Test Engines

Engine Manufacturer	Navistar	Cummins	Caterpillar (chassis test)
Engine Model	T444E B190	ISB 215	3126
Model Year	1999	1999	2002
Displacement	7.3 liter	5.9 liter	7.2 liter
Cylinder Configuration	V-8	Inline 6	Inline 6
Rated Power	190 hp @ 2300 rpm	215 hp @ 2700 rpm	210 hp @ 2400 rpm

Test Devices

- Source application: School Bus
- Location of source fleets: School districts across the U.S., including Pennsylvania, Maryland, Texas and California
- Retrofits originally funded with EPA DERA grants
- DOCs and DPFs



A	1999 Navistar T444E diesel engine
B	Background bag sample of dilution air for CO, CO_2, NO_X, NO, N_2O, HC, CH_4, and speciation of C_2 – C_{12} VOCs
C	Regulated PM using Teflo media filter
D	DNPH impinger for carbonyls
E	XAD traps for gas phase semi-volatile PAH compounds
F	Filter (8x10 inch Zefluor) for particulate-phase semi-volatile PAH compounds
G	Secondary dilution tunnel with two OC/EC instruments and one EEPS
H	Proportional bag sample for hydrocarbon speciation of C_1 through C_{12} VOCs and N_2O
I	Horiba MEXA 7200 for THC, CO, CO_2, NO_X, and NO

Diagram of Test Set-Up, Source: SwRI

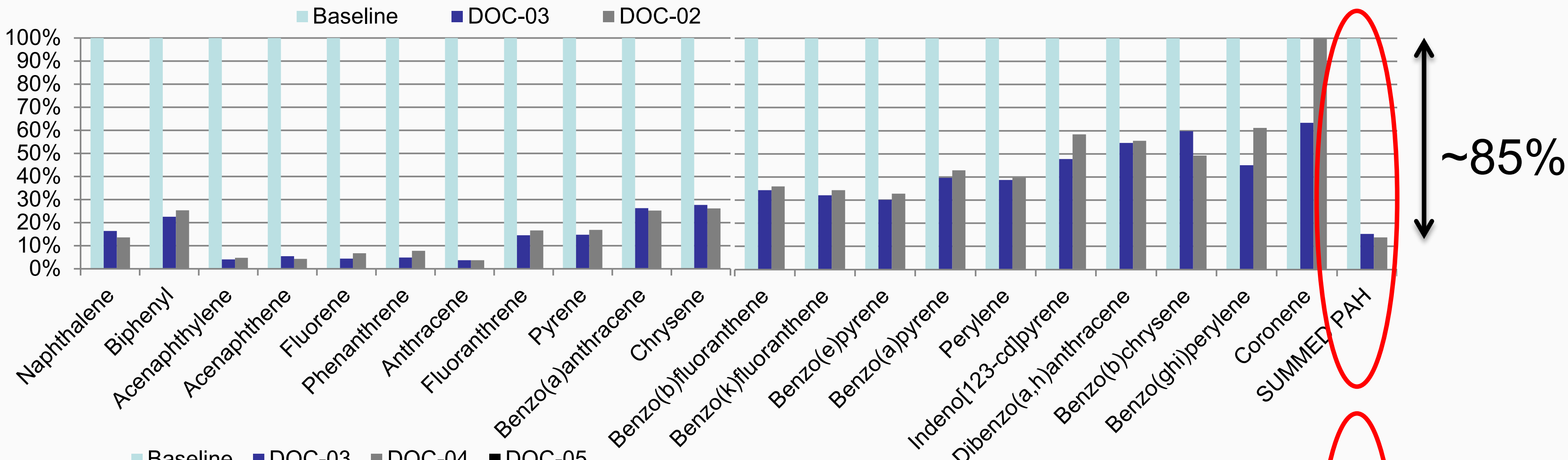
Test Method Evaluation

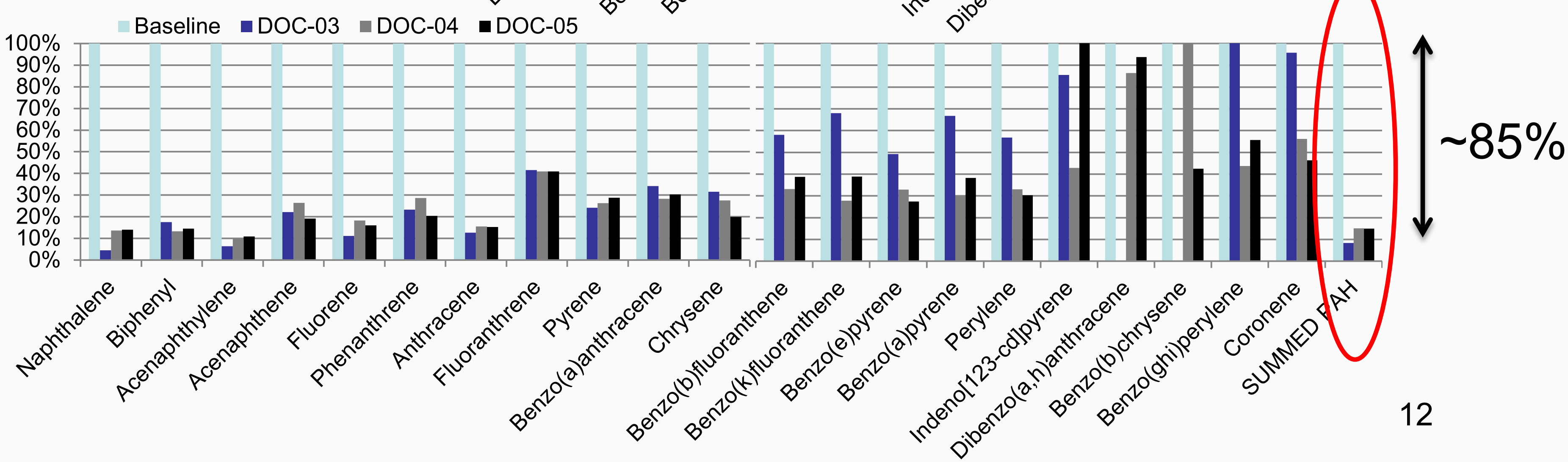
- 40CFR Part 86 and Part 1065
- Legacy engines certified using Part 86
- Evolution of PM sampling filter media
  - T60A20, Fluorocarbon coated glass fiber filter
  - TX40, PTFE bonded glass microfiber filter
  - Teflon Membrane
- Engine exhaust PM characteristics
  - Organic carbon fraction of PM varies between engines

DOC Test Method Evaluation

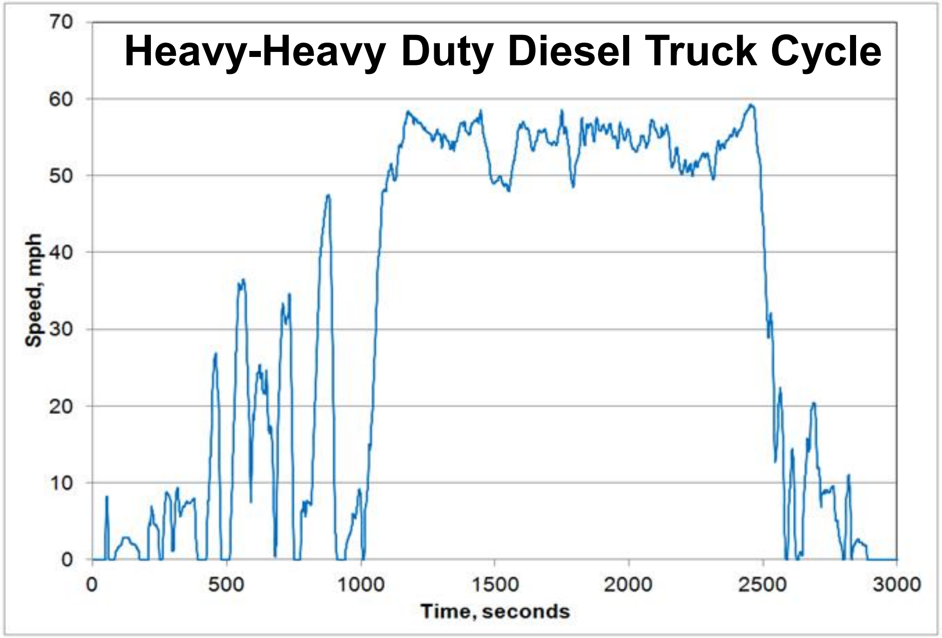
Device	Filter Media	PM	HC	CO	SOF
DOC#1	T60A20	20%	76%	63%	29%
DOC#2	T60A20	16%	81%	66%	29%
DOC#3	T60A20	20%	70%	37%	29%
DOC#3	TX40	13%	95%	41%	24%
DOC#4	TX40	11%	95%	41%	24%

PAH Reduction Efficiency: DOCs





Chassis Dynamometer Test Cycles



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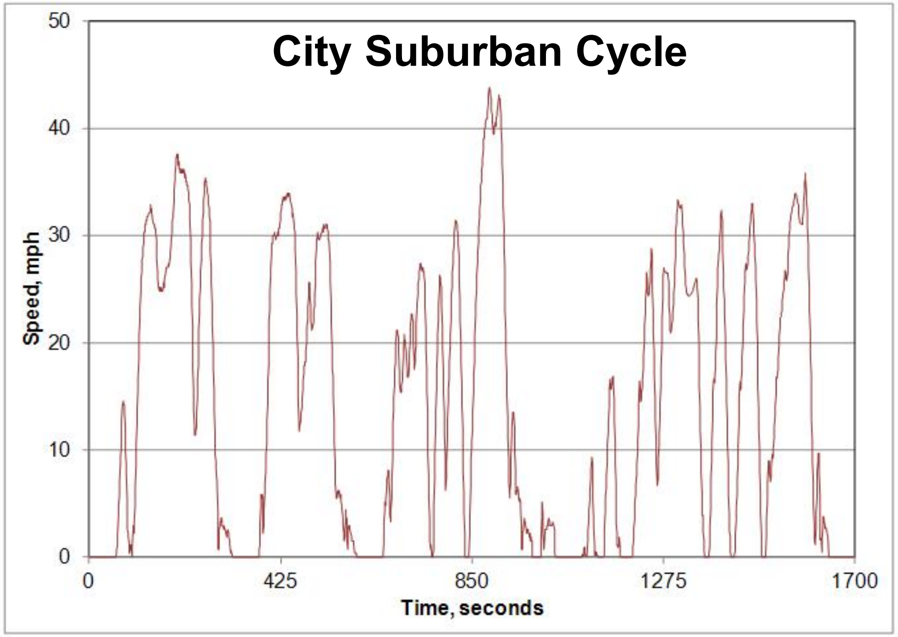


Developed by WVU

Chassis Dynamometer Results

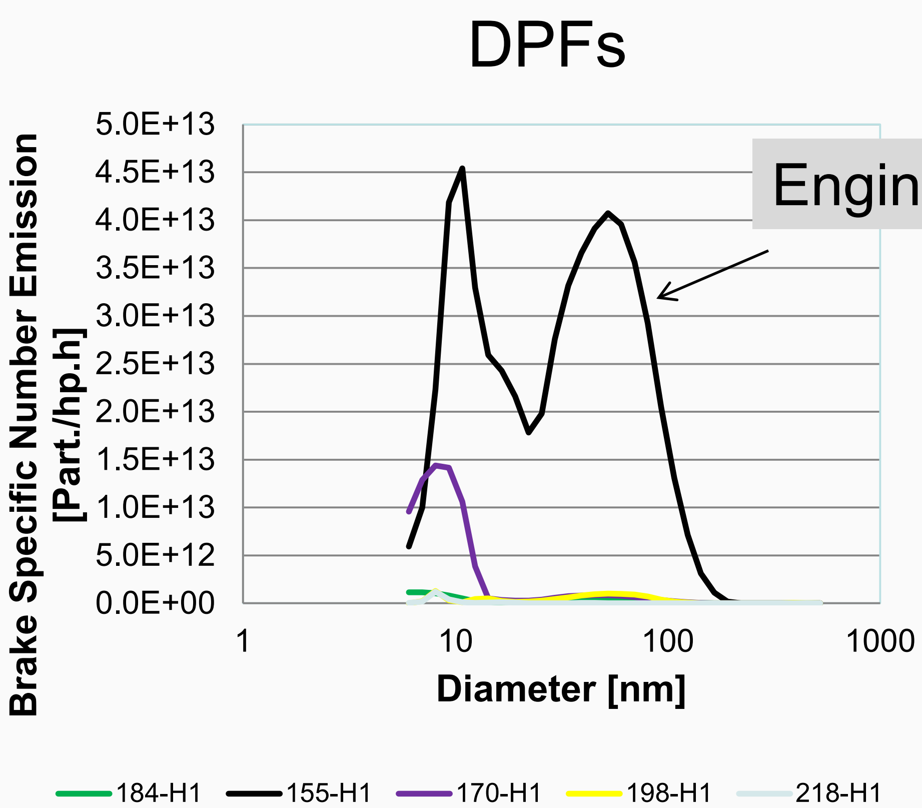
Level of Emissions Reduction						
Devices	**HC**	**CO**	**NO_x**	**PM**	**CO_2**	**Drive Cycle**
DPF6C	90%	98%	6%	95%	1%	HHDDT
	95%	99%	6%	98%	1%	CSC
DPF7C	91%	97%	-5%	94%	-1%	HHDDT
	85%	92%	3%	98%	-1%	CSC

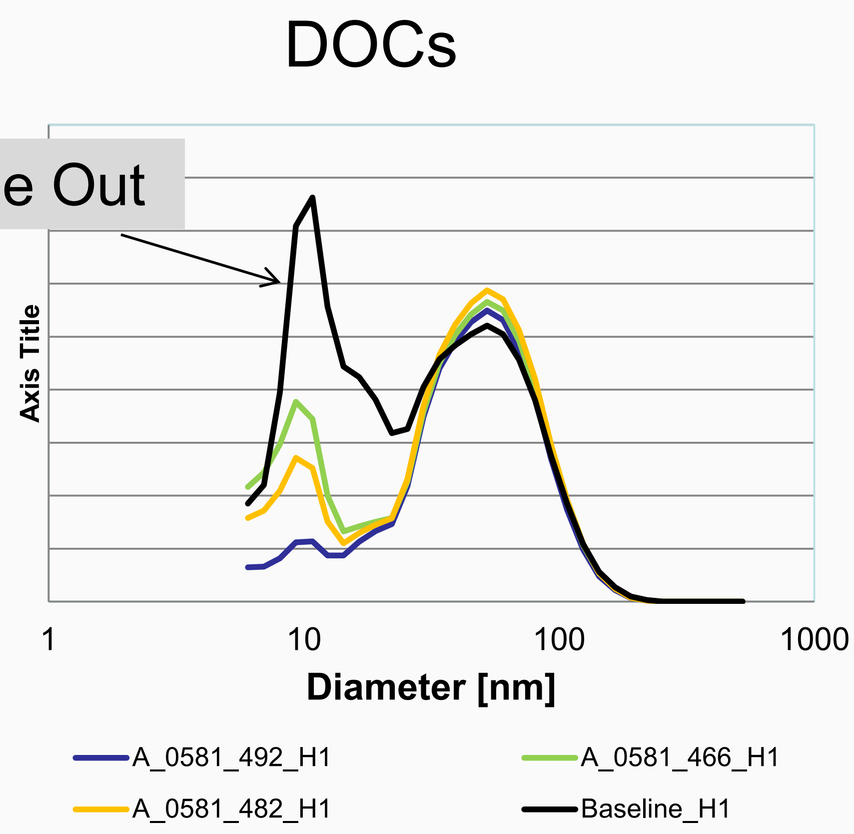
EPA Tested Levels of Reduction: DPFs

DPF Name	Label	Date Tested	PM In-Use	PM Verified
DPF1	DPF	2007-2008	95%	90%
DPF2A	Bus 940	Nov 2008	64%	85%
DPF3A	Bus 941	Nov 2008	65%	85%
DPF4B	Bus 124	Nov 2008	51%	60%
DPF5B	Bus 134	Nov 2008	82%	60%
DPF6C	Bus 2037	July 2012	97%	90%
DPF7C	Bus 2010	July 2012	98%	90%
DPF8A	Bus 48	July 2012	97%	85%
DPF9A	Bus 46	July 2012	99%	85%

Notes: All devices met the 75% threshold necessary to demonstrate a passing in-use device
DPFs that share the same letter at end of name share the same make/model

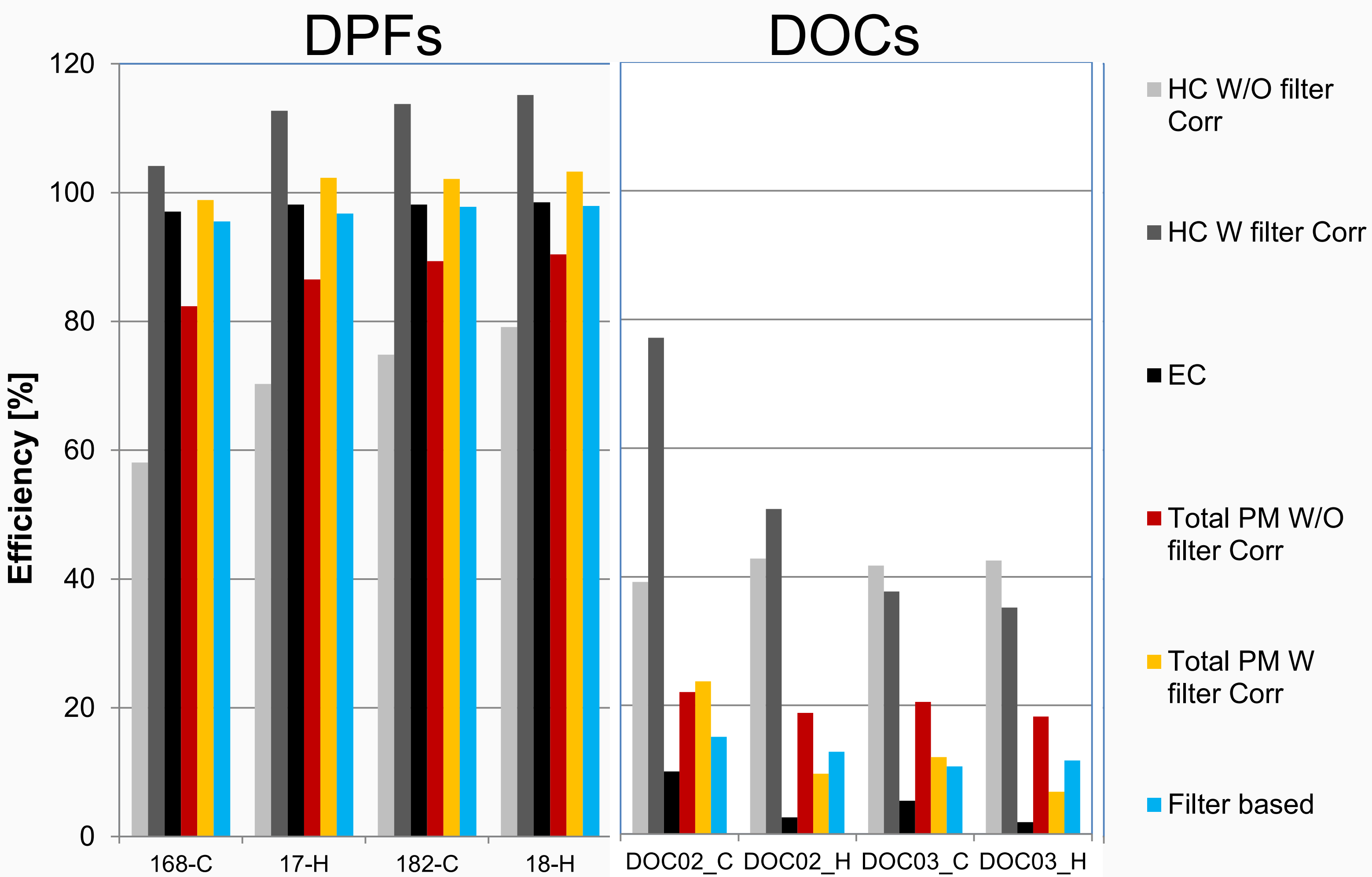
Particle Number Reduction



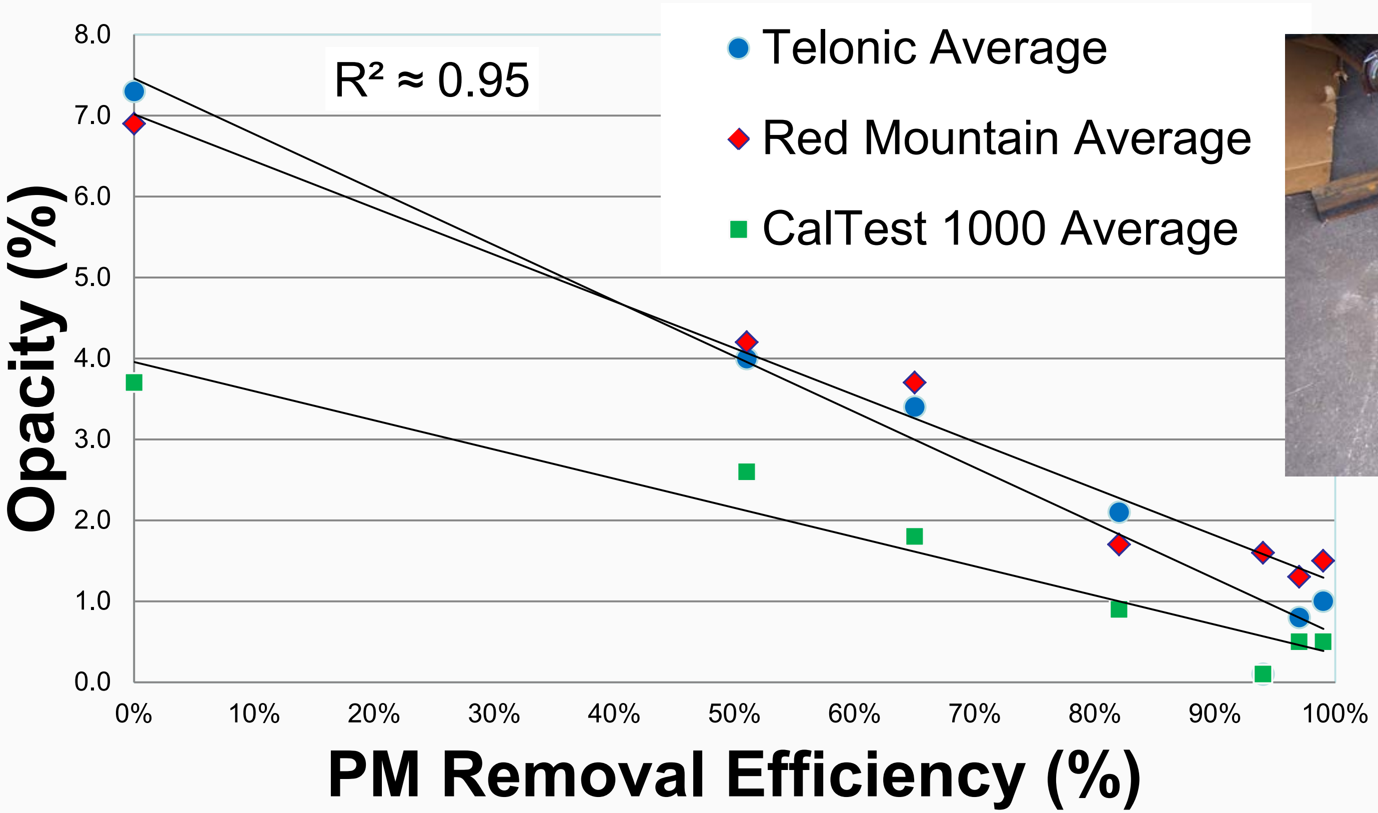


*Each line represents one device.

EC-OC Reduction Efficiency



Smoke Opacity Results



– Absolute opacity values depend on type of meter

Summary and Conclusions

- Evaluation of in-use DPFs shows levels of reduction within in-use testing objectives
  - Most recent DPF testing showed PM emission reductions > 90%
  - Reduce elemental/black carbon by ~99%
  - DPFs have proven durable in retrofit applications
- DOCs reduce PAHs and other toxic air contaminants
  - Cost effective retrofits for applications not suitable for DPFs
- Opacity testing needs further investigation but has the potential for use as a screening tool for DPF performance
- Test methods used for verification are appropriate for determining retrofit efficiency

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Thank you

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