



Evaluation of Passive and Active Soot Filters for Removal of Particulate Emissions from Diesel Engines

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Outline

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- Acknowledgements

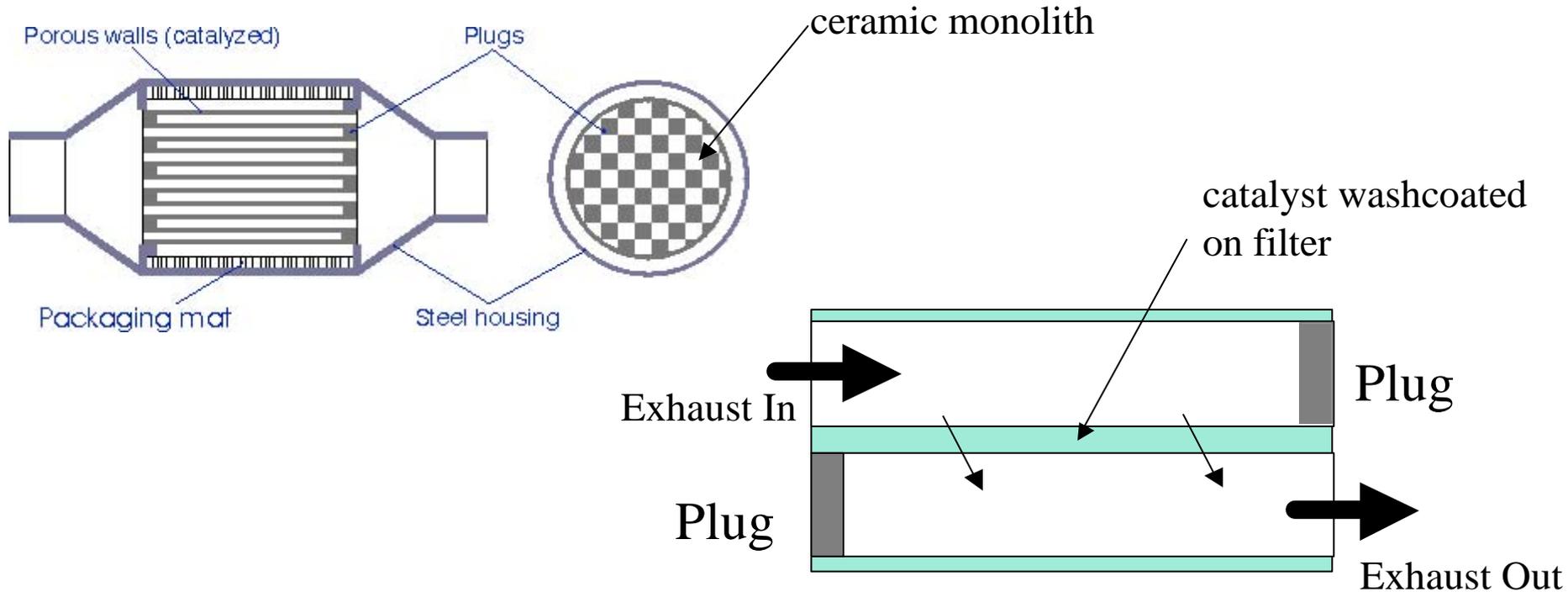


Purpose of Program

- Demonstrate catalyzed soot filters and active soot filters for reducing particulate matter (PM) emissions
- Demonstrate CO and hydrocarbon reduction with catalyzed soot filters
- Survey DoD diesel engine operating characteristics to establish the range of catalyzed soot filter applicability
- Conduct 8 month field test of eight low precious metal catalyzed soot filters on non-tactical buses and trucks at Camp Pendleton and Fort Irwin
- Conduct 4 month field test of two electrically regenerated soot filters on mobile generator-sets at Edwards Air Force Base
- Measure chassis dynamometer emissions with the University of Utah and the California Air Resources Board

Catalyzed Soot Filter

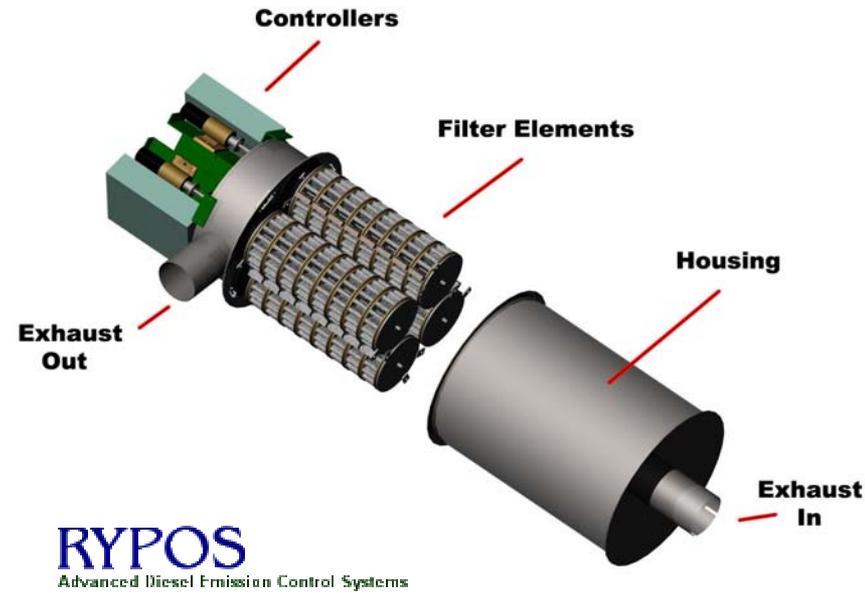
- The engine exhaust enters the filter where it is forced to flow through a porous wall



- Soot collects in wall and also forms a layer on the catalyst washcoat

Soot Filter Operation-Electrically Regenerated Soot Filter

- uncatalyzed sintered metal fibers act as both the filtration media and the resistive element for electrical regeneration
- the media is assembled into several cartridges, that are regenerated sequentially when required
- electrical power is supplied by gen-set output for power generating applications or by second or larger alternator for mobile applications





Emissions Sampling Techniques-U of Utah

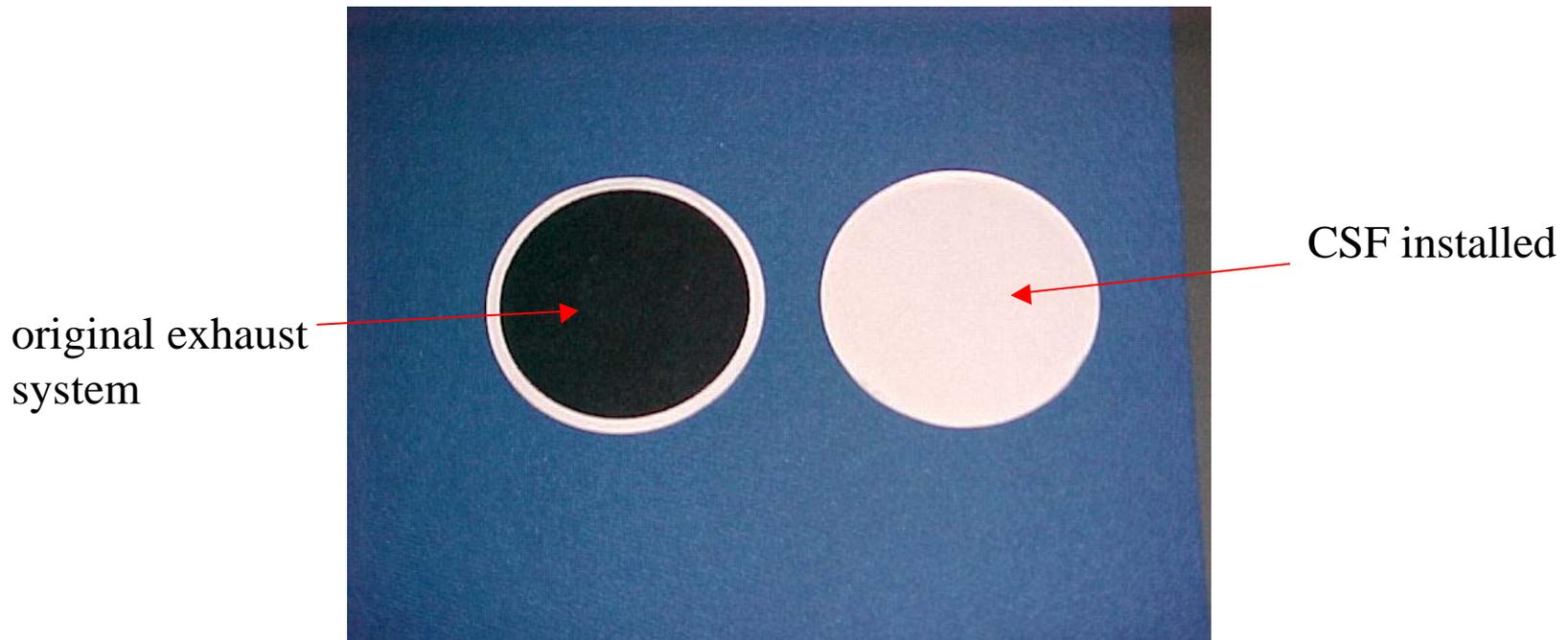
- PM reduction was determined by tests with and without filters installed
- Tests were conducted at beginning and end of field tests to measure any change in filtration capability
- Near real-time measurements were made of:
 - particle distributions (14.6 nm-661 nm) by scanning mobility particle sizer
 - total particle count ($< 10 \mu\text{m}$) by optical particle counter
 - carbon mass by photoacoustic analyzer
 - PAH by photoelectric aerosol sensor





Emissions Sampling Techniques-CARB

- Chassis dynamometer with constant volume sampling (CVS) system
- Gravimetric analysis to determine filtration efficiency





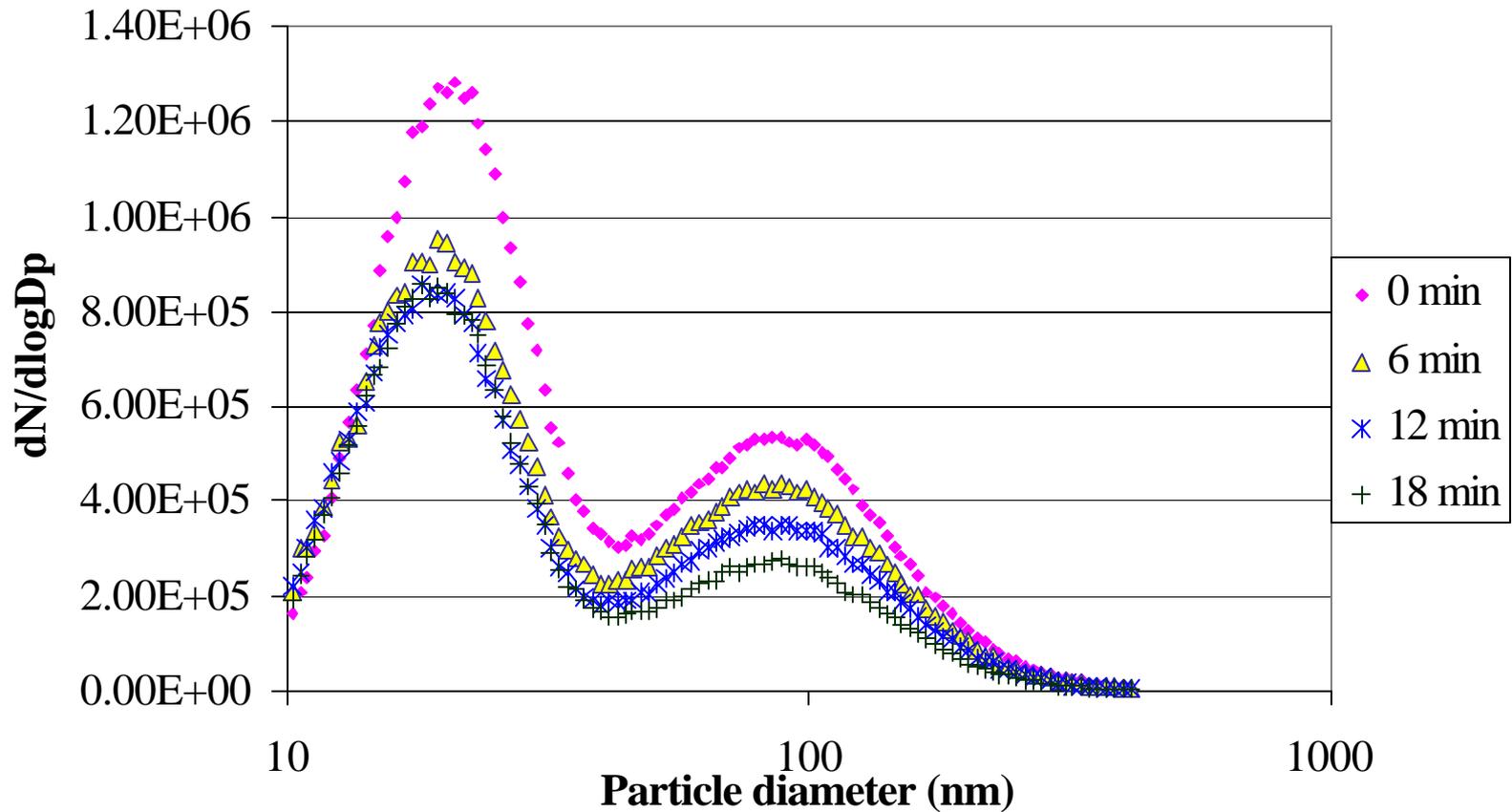
Soot Filters Tested

Vehicle	Year	Engine	Technology	Emissions Tests Run	
				Utah	CARB
Camp Pendleton					
Thomas Bus-00582	1999	CAT 3126, 330HP	catalyzed soot filter 11.25" x 12" 5 g/ft ³ PM	X	
Thomas Bus-00583	1999	CAT 3126, 330HP	catalyzed soot filter 11.25" x 12" 5 g/ft ³ PM	X	X
Bluebird Bus-294509	1996	Cummins B5.9-190 HP	catalyzed soot filter 10.5" x 12" 10 g/ft ³ PM	X	
Ft. Irwin					
Thomas Bus-00172	1998	Cummins ISB-230 HP	catalyzed soot filter 10.5" x 12" 5 g/ft ³ PM		
Thomas Bus-00177	1998	Cummins ISB-230 HP	catalyzed soot filter 10.5" x 12" 5 g/ft ³ PM		
Bluebird Bus-35898	1996	Cummins B5.9-230 HP	catalyzed soot filter 10.5" x 12" 10 g/ft ³ PM		
Stake Truck-16431	1994	Cummins B5.9-190 HP	catalyzed soot filter 10.5" x 12" 10 g/ft ³ PM		
Stake Truck-14719	1997	Cummins B5.9-175 HP	catalyzed soot filter 10.5" x 12" 10 g/ft ³ PM		
Edwards AFB					
Gen-set DX-02	1998	Cummins B5.9-C 185 HP	electrically regenerated soot filter	X	
Gen-set DX-04	1998	Cummins B5.9-C 185 HP	electrically regenerated soot filter	X	



U of Utah Test Findings-Degreening of Filter

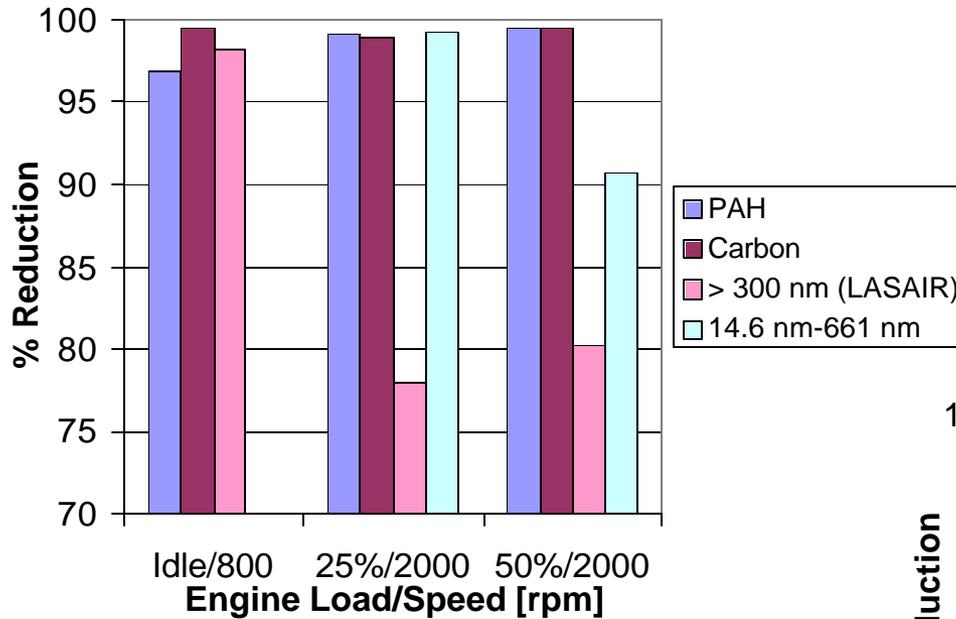
- When the filter is new, filtration ability increases with increased soot loading





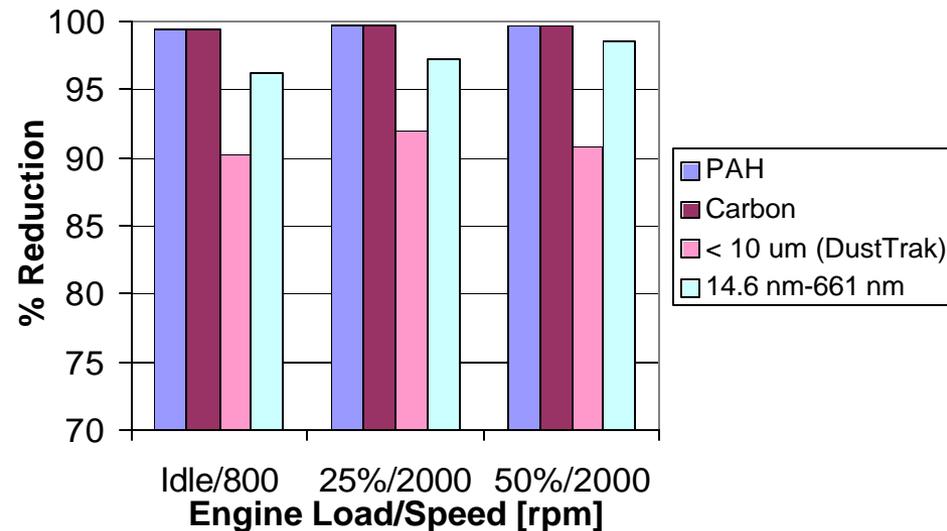
University of Utah Results-Camp Pendleton

Thomas Bus 00583- Prior to Field Test



Filtration efficiency remains > 90% after 7 month field evaluation

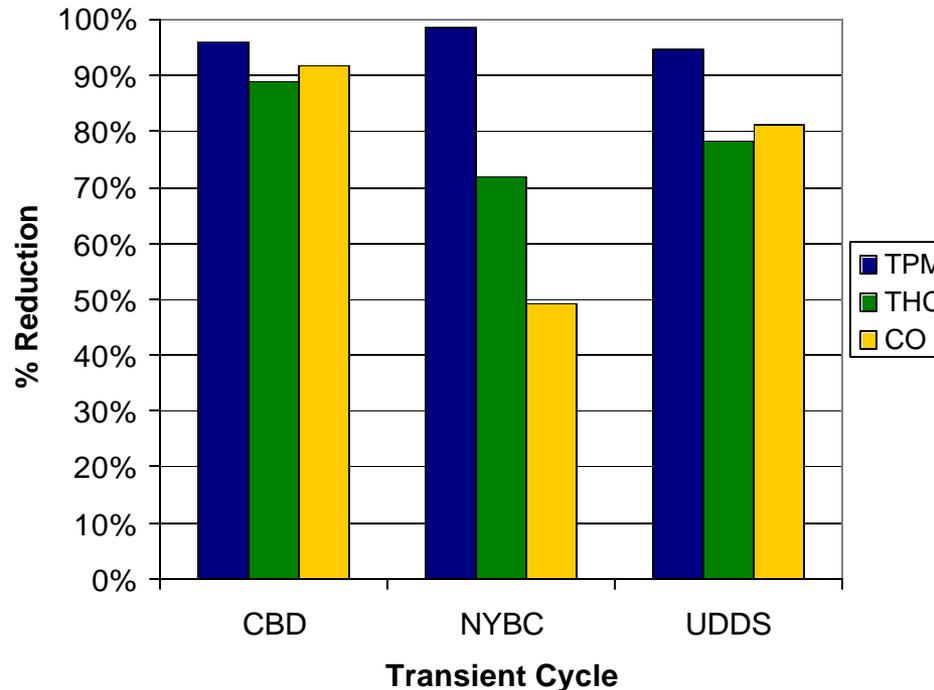
Thomas Bus 00583-Following 7 Month Field Test





CARB Transient Test Using Camp Pendleton Bus

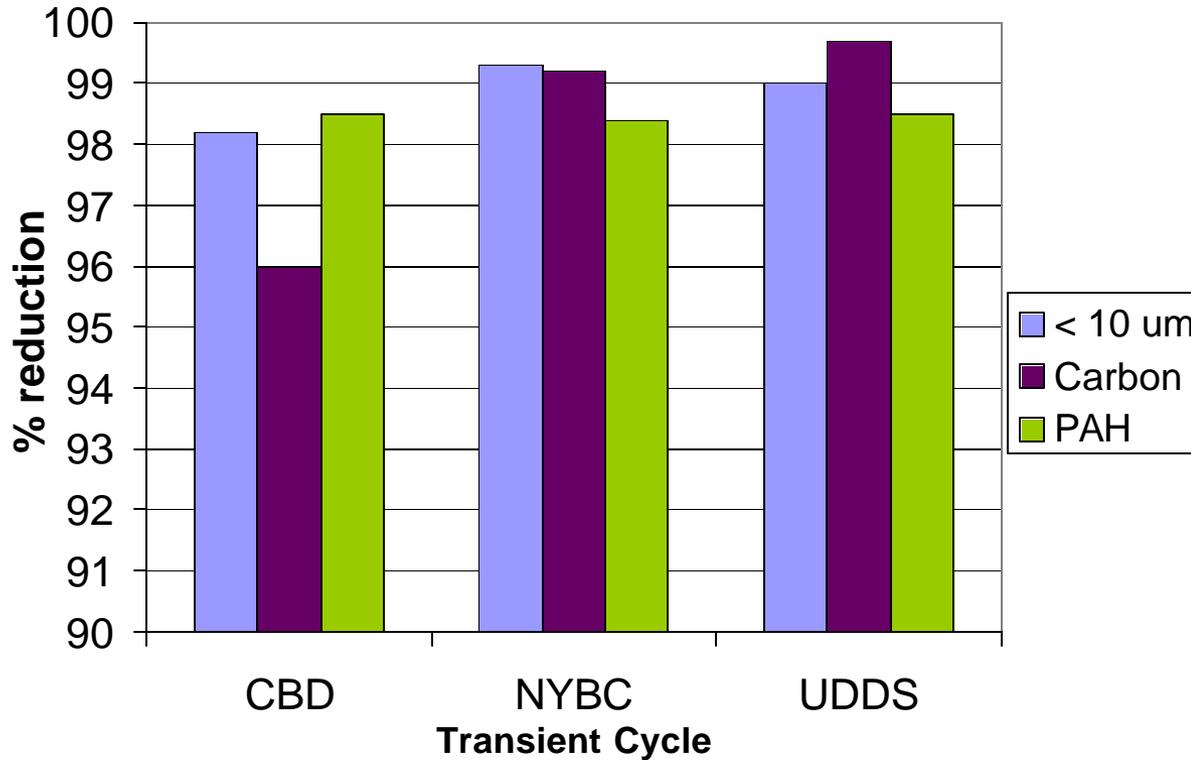
- Thomas Bus 00583 was tested at CARB's emissions testing facility in L.A.
- Three transient cycles were run on chassis dynamometer: Central Business District (CBD), New York Bus Cycle (NYBC), and Urban Dynamometer Driving Schedule (UDDS)





CARB Test-U of Utah's results

- The University of Utah sampled simultaneously to CARB



- Utah's results for particulate reduction are within 2.5% of CARB's (by PM_{10} vs. gravimetric)



Electrically Regenerated Soot Filter Testing-Edwards AFB

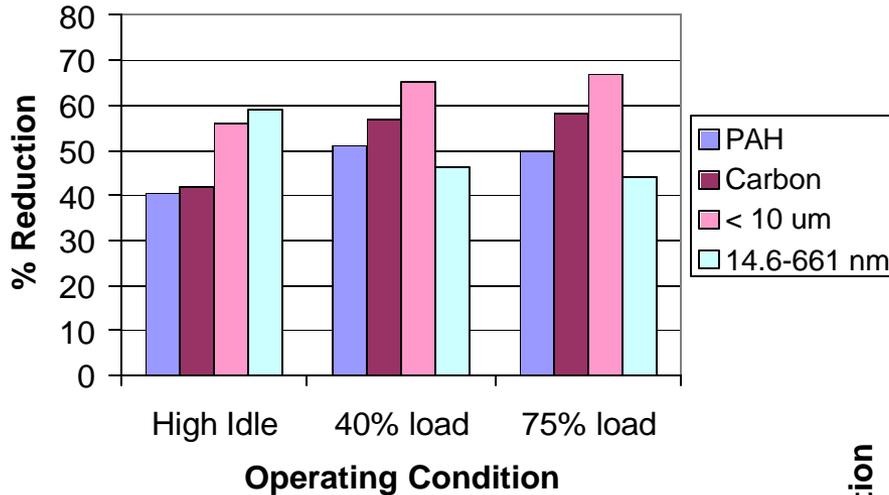
- Installation of systems on two 72 kW generator-sets at Edwards Air Force Base, used for ground maintenance of aircraft
- Engines were Cummins B5.9-185 HP
- Field test duration was 4 months
- 3 steady-state test points were chosen for Utah emissions measurements:
 - high idle
 - 40% load
 - 75% load





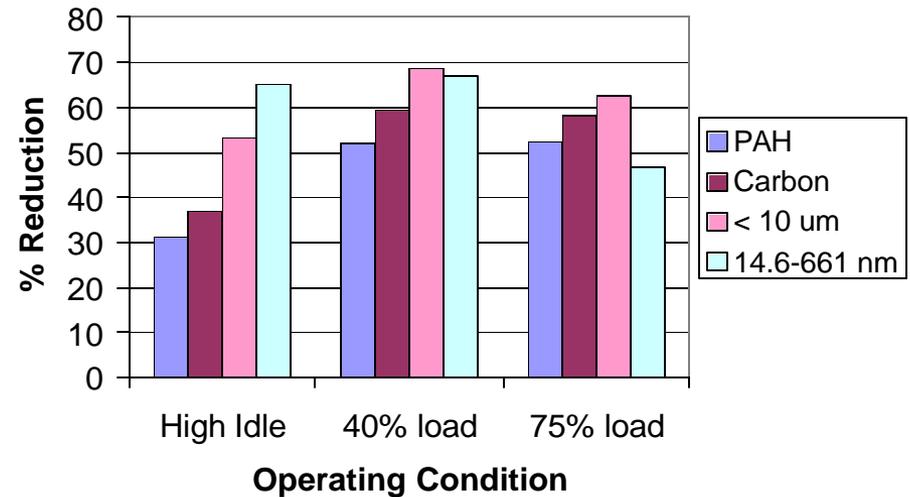
Electrically Regenerated Soot Filter Testing-Edwards AFB

DX-02, After Field Test



Average particle (<10 μm) reductions were 62%

DX-04, After Field Test

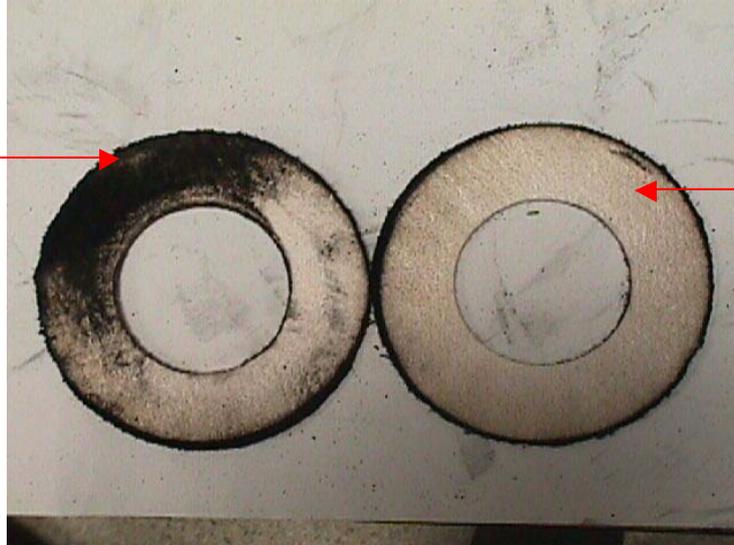




Electrically Regenerated Soot Filter-Post Test Inspection

- Low filtration efficiencies attributed to gasket leaks between the cartridges and a failed cartridge on DX-02
- On DX-04 unit, 30% of gaskets had leaked
- Overly aggressive regeneration strategy may have resulted in low efficiencies due to lack of soot layer build-up
- Improved design will be tested at Cummins

soot leakage



satisfactory
gasket



Conclusions

- Results met project objectives for emissions reduction
- The catalyzed soot filters demonstrated 95% to 98% filtration efficiency in removing total particulate matter, and 72% to 89% THC and 49% to 92% CO reductions during various transient tests
- On average, the electrically regenerated soot traps filtered 62% of the particulates smaller than 10 μm . Lower than expected filtration efficiency is attributed to gasket leakage and a failed cartridge. An improved design will be tested at Cummins
- Particulate measurement devices used by the U of Utah, such as particle counters, are more mobile than typical CVS systems, and can perform near real-time measurements. Particulate reduction numbers show good agreement with CVS measurements
- Filters should be degreened before testing to allow stable measurements to be made



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