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TRANSIENT ULTRAFINE PARTICLE EMISSION MEASUREMENTS WITH A NEW FAST PARTICLE AEROSOL SIZER FOR A TRAP-EQUIPPED DIESEL TRUCK

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The California Air Resources Board (CARB) has tested the utility of the Model 3090 Engine Exhaust Particle Sizer (EEPS™) by TSI in measuring pre- and post-trap particulate matter (PM) emissions from a medium-duty truck. The instrument has been described by Johnson et al., 2004. Pre- and post-trap measurements are used to evaluate the effect of engine operation on PM emissions and trap effectiveness.

Because of mounting evidence that ultrafine (UF) particles are harmful, regulatory agencies are investigating new and promising instrumentation for improved characterization of such particles in emissions. This is especially true for fast-response instruments that can be used to size-resolve real-time UF emissions from prominent sources such as diesel engines. The EEPS uses diffusion charging, electrical mobility segregation, and electrometers. It is designed for the number measurement of transient aerosols in the size range of 5.6 to 560 nm. It collects 10 measurements per second at a flow rate of 10 lpm.

We sampled the emissions from a model year 2000 Isuzu medium-heavy-duty delivery truck. The truck was retrofitted with a Johnson Matthey Continuously Regenerative Trap (CRT™) and fueled by ultra low sulfur diesel (ULSD). Pre- and post-trap partial-flow samples of raw exhaust were taken using a double-stage Dekati diluter. Primary and secondary dilution ratios of approximately 8 each resulted in a total dilution of 64:1. The vehicle was operated over steady-state (50 mph cruise and idle) and transient (CBD and NYBC) duty cycles.

The EEPS measurements suggest that without a trap, the size of the particles emitted by the diesel engine is highly dependent on the driving cycle. Emissions of particles smaller than 120 nm were greatest during accelerations and emissions of particles larger than 250 nm were greatest during decelerations and idle. Bursts of particularly high emissions of particles smaller than 10 nm were seen immediately after accelerations.

The pre-trap size distribution was bi-modal during both steady state and transient engine operation. Peak concentrations were observed at or below 10 nm and at 60 nm at concentrations, uncorrected for dilution, of 10^5-10^6 N/cc. The post-trap size distribution and concentration did not change significantly as a function of driving cycles. The post-trap size distribution was bi-modal with peaks at 10 and 30 nm and peak concentration of 10^2 N/cc.

The EEPS measurements showed substantial effectiveness of the CRT in reducing both transient and steady-state UF particle emissions over the entire size range. In the current study the CRT reduced the total number concentrations by two to three orders of magnitude. Our findings have been summarized in Ayala and Herner, 2005.

References:

Johnson, T., Caldow, R., Pocher, A., Mirme, A., Kittelson, D. 2004. "A new electrical mobility particle sizer spectrometer for engine exhaust particle measurements." *Society of Automotive Engineers – SAE Technical Paper Series.* 2004-01-1341.

Ayala, A. and J. Herner. "Transient Ultrafine Particle Emission Measurements with a New Fast Aerosol Sizer for a Trap Equipped Diesel Truck." *Society of Automotive Engineers – SAE Technical Paper Series.* 2005-01-3800.

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* Photo courtesy of Fleetguard Inc.
** Photo courtesy of TSI Incorporated.

TRANSIENT ULTRAFINE PARTICLE EMISSIONS MEASUREMENTS WITH A NEW FAST AEROSOL SIZER

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Abstract

The emerging evidence of statistically significant associations between combustion-generated ultrafine (UF) particles and adverse health effects fuels the continued interest of regulatory agencies in new and promising instrumentation for improved characterization of exhaust aerosols. This is especially true for fast-response instruments that can be used to size-resolve real-time UF emissions from prominent sources such as diesel engines. This interest was the impetus for a recent and brief exercise conducted at CARB's Heavy-duty Emissions Testing Laboratory with TSI's new Engine Exhaust Particle Sizer (EEPS™).

We used the emissions from a model year 2000 Isuzu medium-heavy-duty delivery truck (8.3L engine, GVWR of 22,285 lbs) tested at 18,000 lbs and operated on a chassis dynamometer to experiment with and develop opinions about the new 3090 EEPS™ spectrometer. The EEPS uses diffusion charging, electrical mobility segregation, and electrometers. It is designed for the number measurement of transient aerosols in the size range of 6 to 560 nm at a sampling rate of 10 Hz and a flow rate of 10 lpm. The truck was retrofit with a Johnson Matthey CRT™ and fueled by ULSD. Pre- and post-trap partial-flow samples of raw exhaust were taken using a double-stage Dekati diluter. Primary and secondary dilution ratios of approximately 8 resulted in total dilution of 64:1. The vehicle was operated over steady state (50 mph cruise and idle) and transient (CBD and NY Bus) duty cycles.

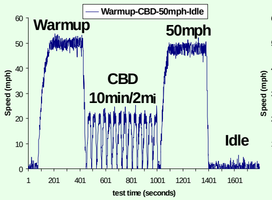
The poster presents key findings, which include the following. The instrument appeared well suited for the dynamometer laboratory environment. The post-trap number concentrations measured were above the instrument's limit of detection defined as the RMS noise. The plug-and-play features of the EEPS yielded convenience and flexibility for the hectic demands of emissions testing. The EEPS measurements confirmed the trap effectiveness for reducing both transient and steady-state UF particle emissions over the entire size range in a laboratory setting.

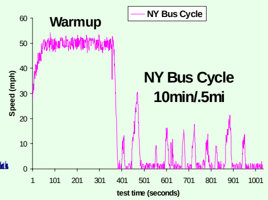
Project Objectives

- Brief testing exercise to "*kick-the-tires*" of the new instrument
- Integrate EEPS into existing dilution schemes and testing setup in emissions laboratory
- Collect meaningful data on diesel trap effectiveness
- Compare results
- Assess the potential for turn-key, user-friendly operation of new instrument

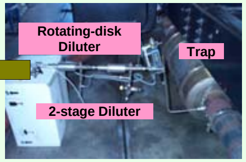
Experimental Approach

- Trap-equipped MHD diesel truck fueled with ULSD
- Chassis dynamometer testing
- Transient duty cycles (CBD & NY Bus Cycle)
- Steady-state operation (55 mph cruise & idle)
- Raw exhaust sampling with 2-stage Dekati diluter (DR_1~8, DR_2~8)
- Pre- and post-trap measurements



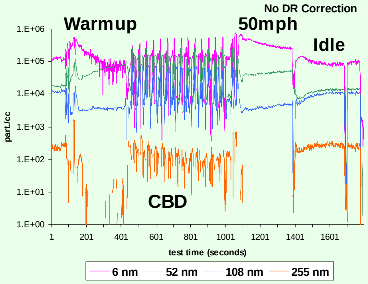


Test Setup

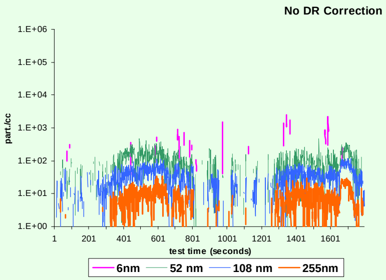


Results

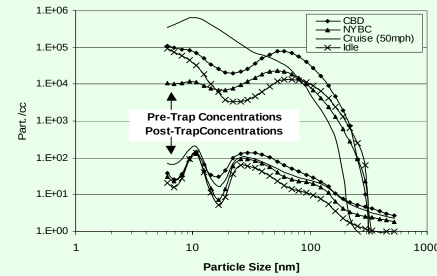
Warmup-CBD-50mph-Idle Before Trap



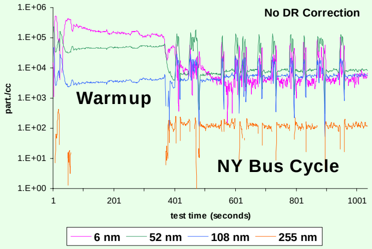
Warmup-CBD-50mph-Idle After Trap



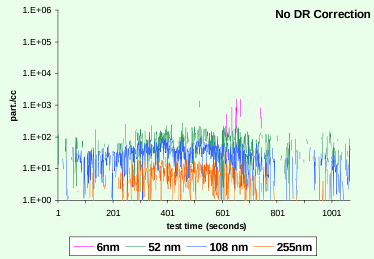
Avg. Size Distribution Before and After Trap



NY Bus Cycle Before Trap



NY Bus Cycle After Trap



Final Remarks[1]

- Trap reduces particle concentrations across entire size range (6-560nm)
- The CRT showed reductions in total number concentrations of two to three orders of magnitude
- Average pre-trap cruise and idle size distributions were bimodal with peak nuclei-mode concentrations before correction for dilution of approximately 10^6 N/cc and 10^5 N/cc, respectively
- These were reduced to concentrations before correction for dilution on the order of 10^2 N/cc
- Before and after the trap, the highest number concentrations corresponded to the smallest particles
- For the transient cycles, pre-trap number concentrations varied over approximately two orders of magnitude and in concert with vehicle speed
- After the trap, variations in number concentrations with cycle were not easily distinguishable
- Negligible nucleation mode particles (<40nm) in after trap measurements

[1] *Ayala, A. and J. Herner, "Transient Ultrafnie Particle Emission Measurements with a New Fast Particle Aerosol Sizer for a Trap Equipped Diesel Truck," SAE Tech. Paper. 2005 Powertrain and Fluid Systems Conference, October 24-27, San Antonio. Accepted.*

ACRONYMS

EEPS™	TSI's Engine Exhaust Particle Sizer
CRT™	Continuously Regenerating Trap
CBD	Central Bus District Cycle
UF	Ultrafine
ULSD	Ultra-Low-Sulfur Diesel Fuel
MHD	Medium Heavy Duty

Disclaimer

The statements and opinions expressed here are solely the authors' and do not represent the official position of the California Air Resources Board. The mention of trade names, products, and organizations does not constitute endorsement.

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