13th CRC ON-ROAD VEHICLE EMISSIONS WORKSHOP

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Session 8: Heavy Duty Buses

Comparison of Particle Size Distributions for Diesel and CNG Transit Buses with After-treatment

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ABSTRACT

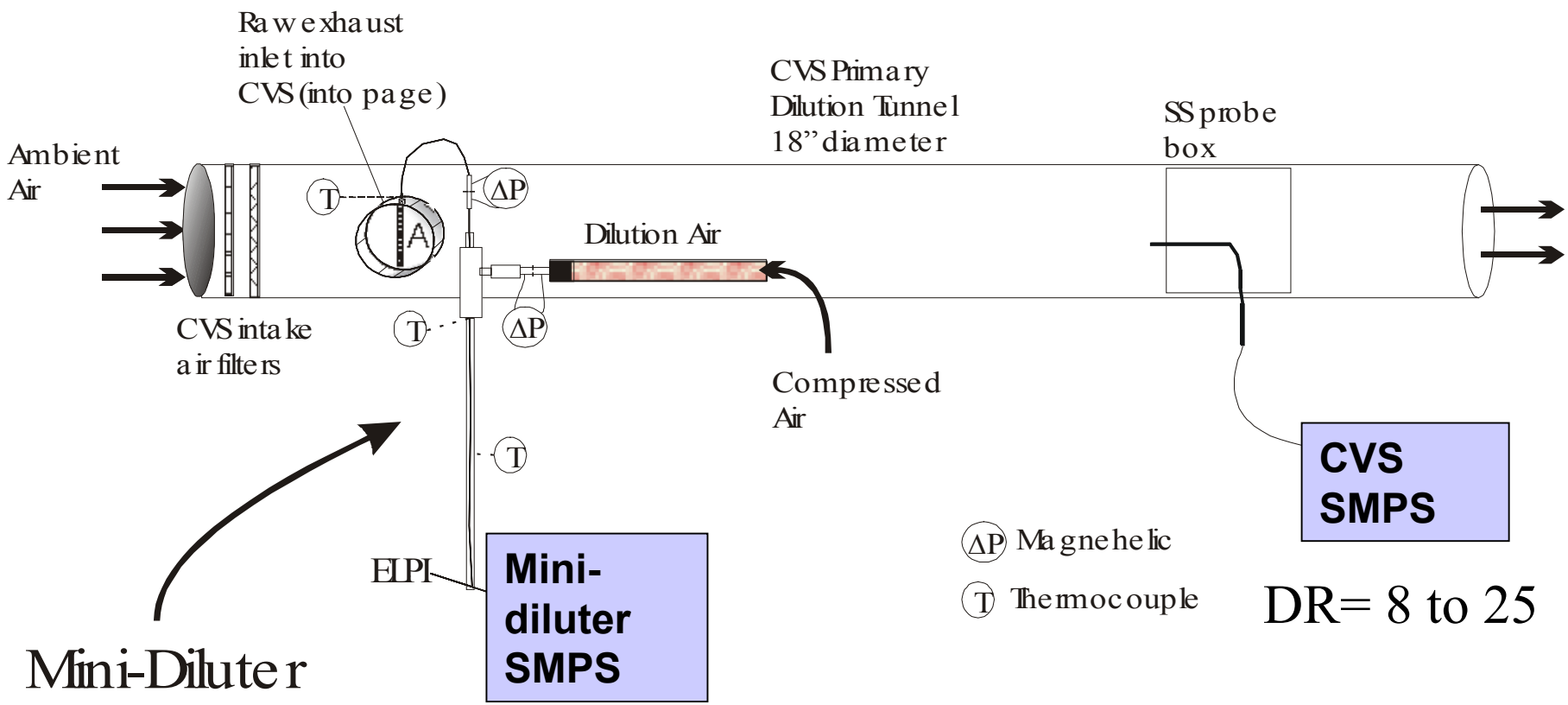
The California Air Resources Board (CARB) has conducted a comparative study of emissions from late-model transit buses and results have been reported. The study consisted of extensive chassis dynamometer testing and included the physical characterization of PM particle emissions using two Scanning Mobility Particle Sizers (SMPS) for simultaneous sampling at two locations. At one location, raw-exhaust sampling was carried out with the use of an ejector-type mini-diluter. At the second location, diluted exhaust was taken from a primary dilution tunnel using a probe co-located with other probes for collection of regulated PM and gaseous emission samples. To date, CARB has tested a diesel bus in two configurations: 1) with a diesel oxidation catalyst (DOC) and 2) with a catalyzed diesel particulate filter (DPF). Two CNG-fueled buses have also been evaluated. One CNG bus was tested: 1) with an oxidation catalyst (OC) and 2) without an OC. A second CNG bus, equipped with an OC by the original equipment manufacturer (OEM), was also tested.

In this paper, we present a comparison of the particle size distributions for these three buses tested in five configurations over a 55 mph steady-state cruise condition. Previously, we compared the particle number distributions of the diesel bus with after-treatment to the CNG bus without after-treatment. Now, we offer results for the OC effect on CNG ultrafine particle (<100 nm) number emissions within the context of the previous comparison. Both the DPF for the diesel bus and the OC for the CNG bus were found to significantly reduce particle number concentrations across the size range from 6 to 230 nm under some, not all, engine operating conditions. In general, the OC and the DPF reduced particle number concentrations by one order of magnitude compared to the same bus type without such after-treatment. However, the CNG particle size distributions (with and without OC) are dominated by approximately 20 nm particles whereas the diesel particle size distributions show a peak at approximately 50 nm.

Overview

- **CARB Bus Emissions Study**
  - Collaborative effort: CARB, UCD, UCONN, SCAQMD
  - Chassis dynamometer testing of late-model, in-use transit buses
  - Diesel+DOC, Diesel+CRT, and CNG(no after-treatment) (Phase 1.A)
  - CNG+OC and CNG(no after-treatment) (Phase 1.B)
- **SMPS Particle Size Distributions Focus**
  - Idle and Steady-State (20, 40, 55 mph) full scans
  - Single-diameter transient cycle (CBD)

Two Sampling Stations



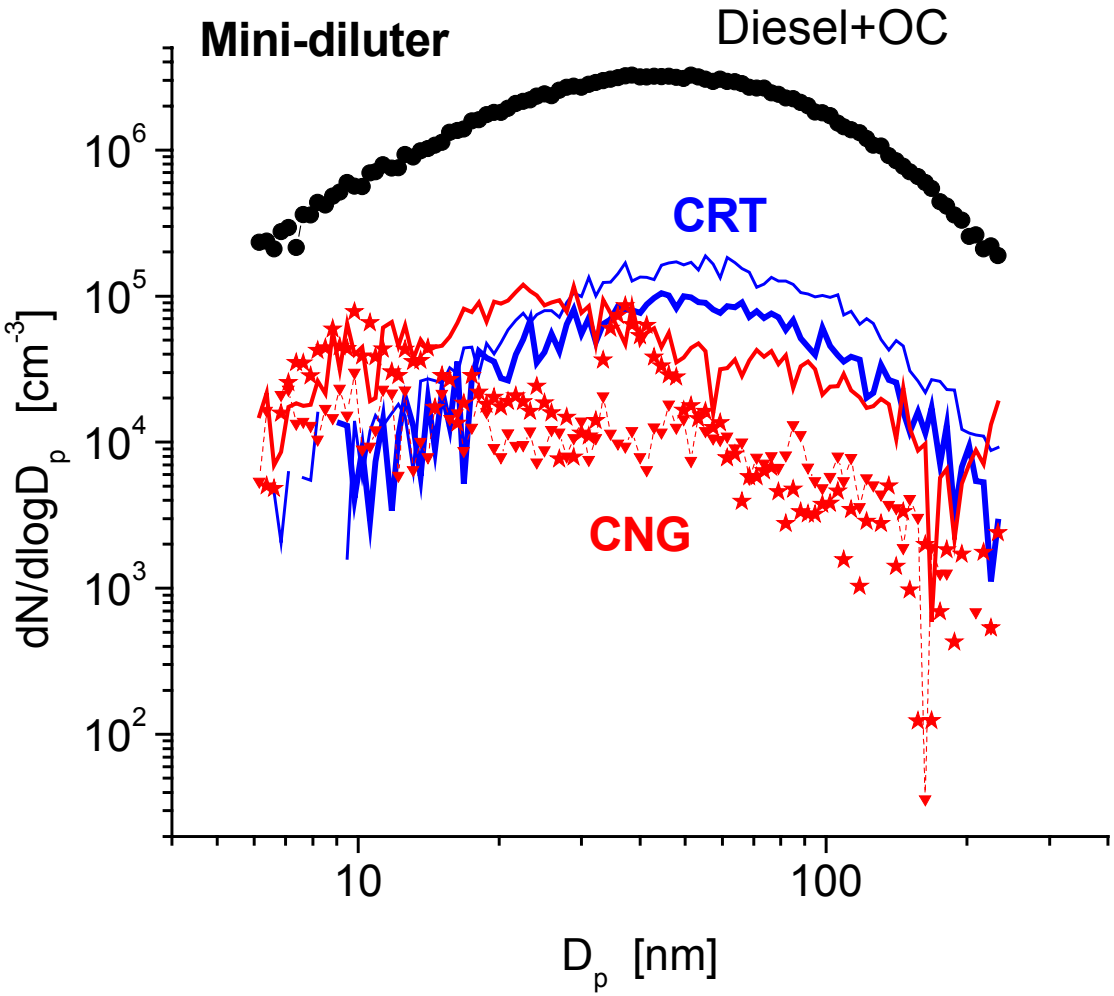
DR= 8 to 25

Dilution Ratio = 64 or 18

Scanning Mobility Particle Sizer

- TSI 3080 Classifier, 3025A CPC
- 1.45 Lpm aerosol flow rate (14.5 Lpm sheath)
- 2-min up-scans & 30-sec retrace
- 6 – 225 nm
- dN/dlogDp (AIM ver4.3)
- TB and DR-corrected

Comparison of Particle Size Distributions (SS55 mph)

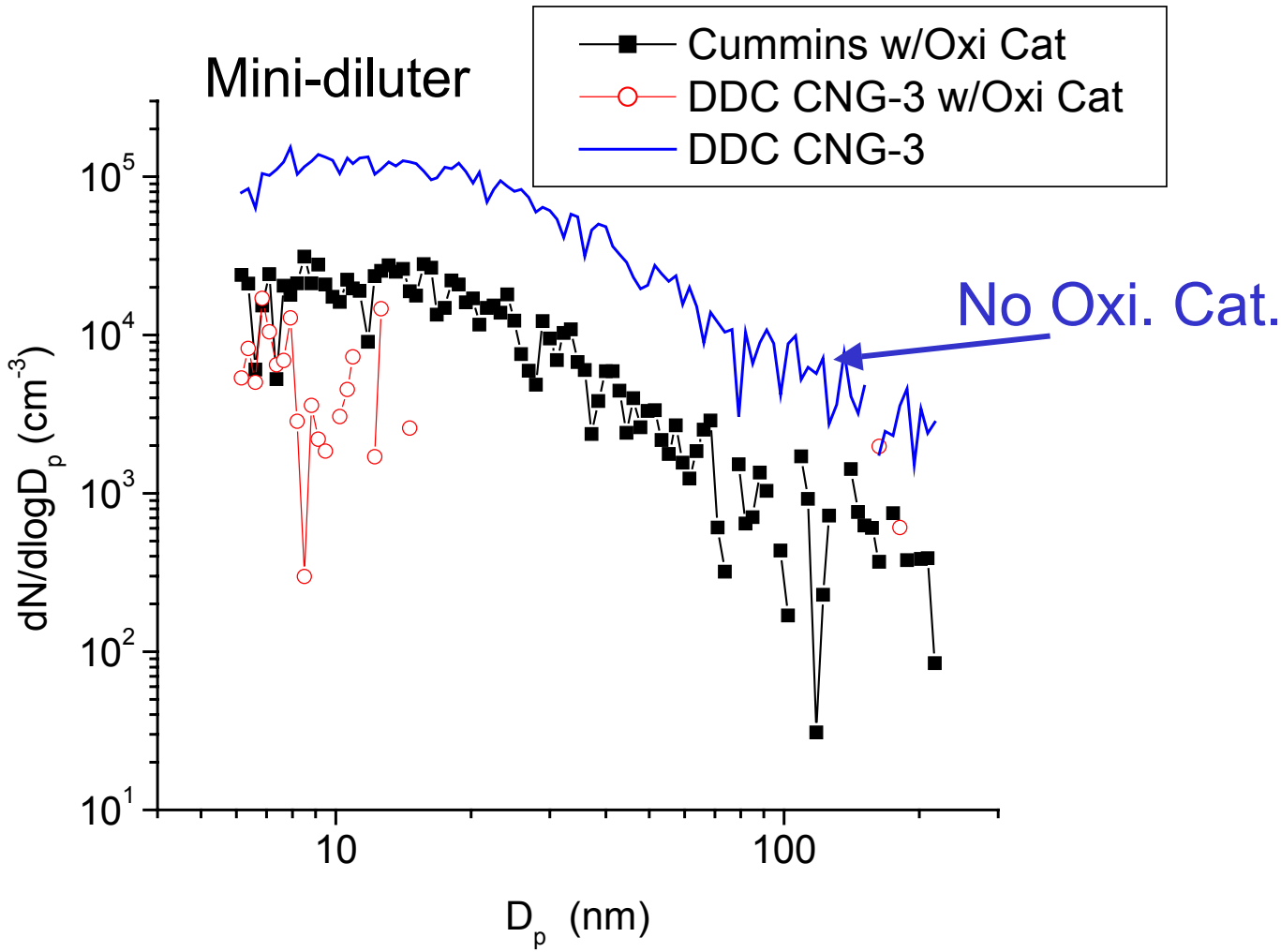


References: **12th CRC On-Road Vehicle Emissions Workshop, Apr. 15-17, 2002**

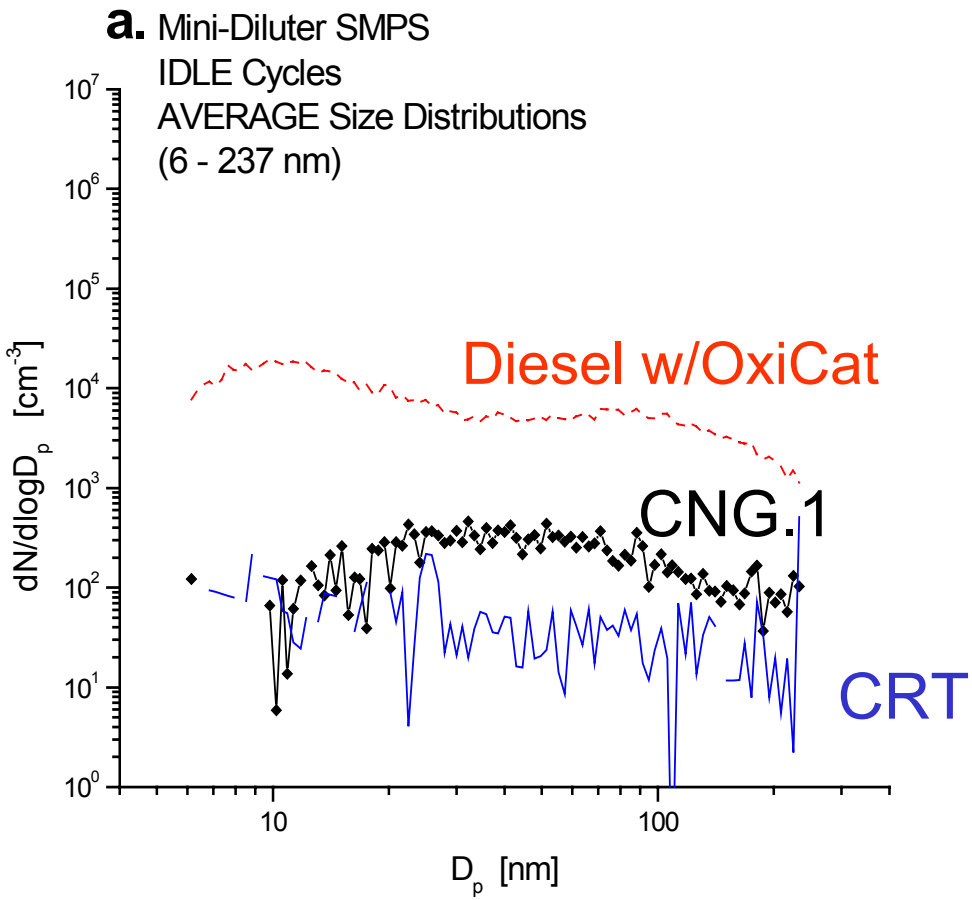
Environ. Sci. Technol. 2002, Vol. 36, No. 23, pp.5041-5050

AAAR Meeting, Oct. 7 - 11, 2002

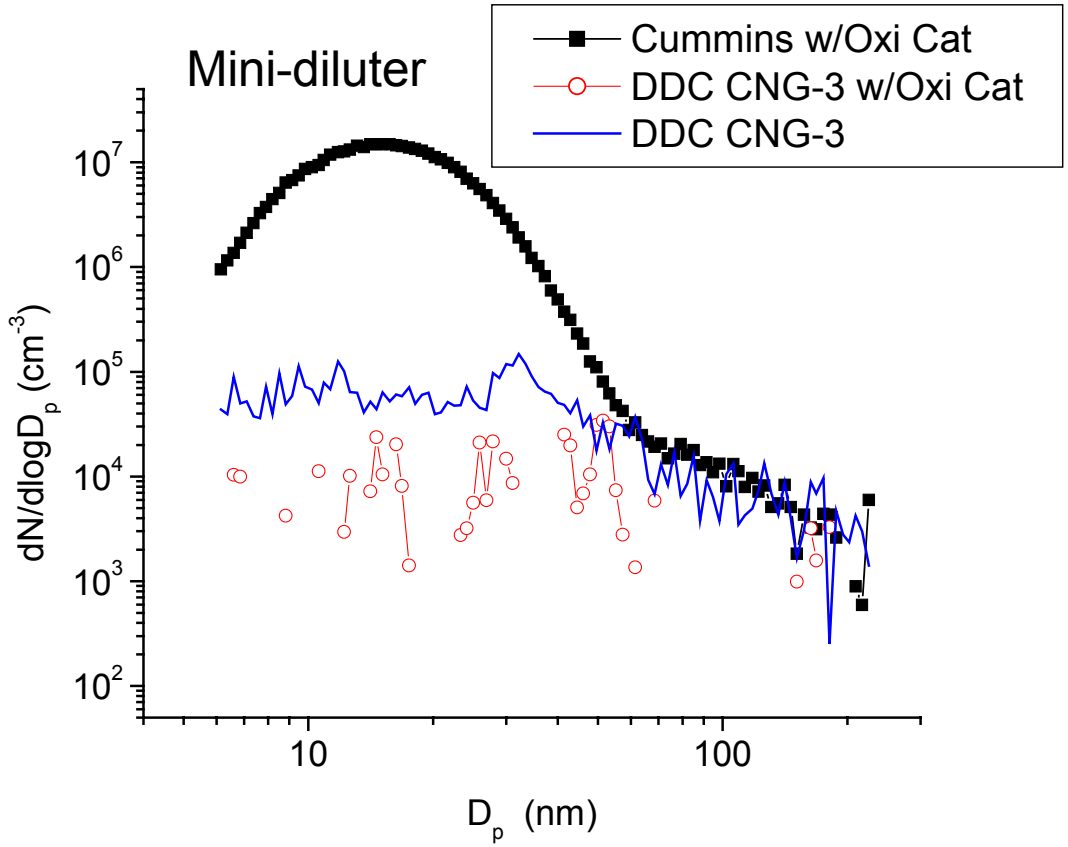
Effect of OC for CNG buses (SS55mph)

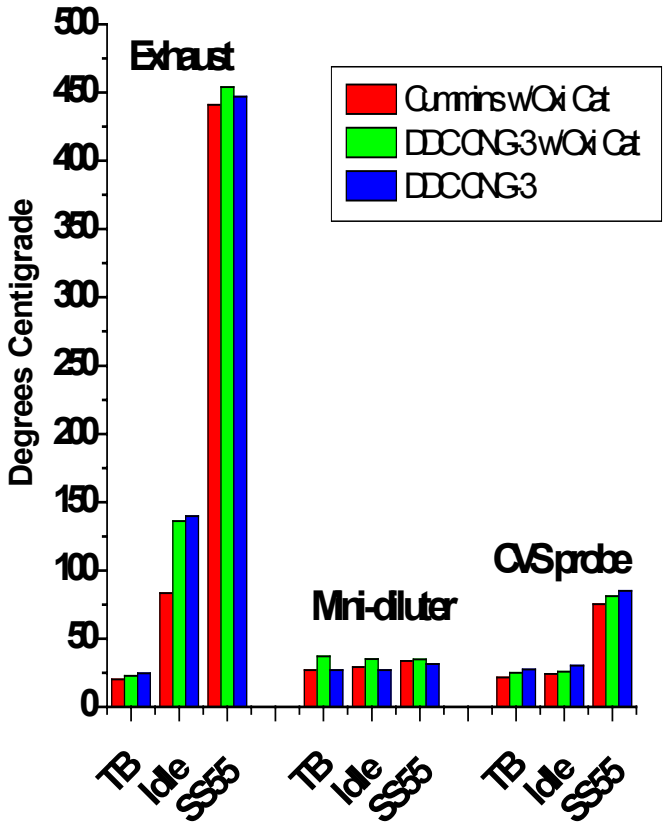


Idle (Phase 1.A) Results

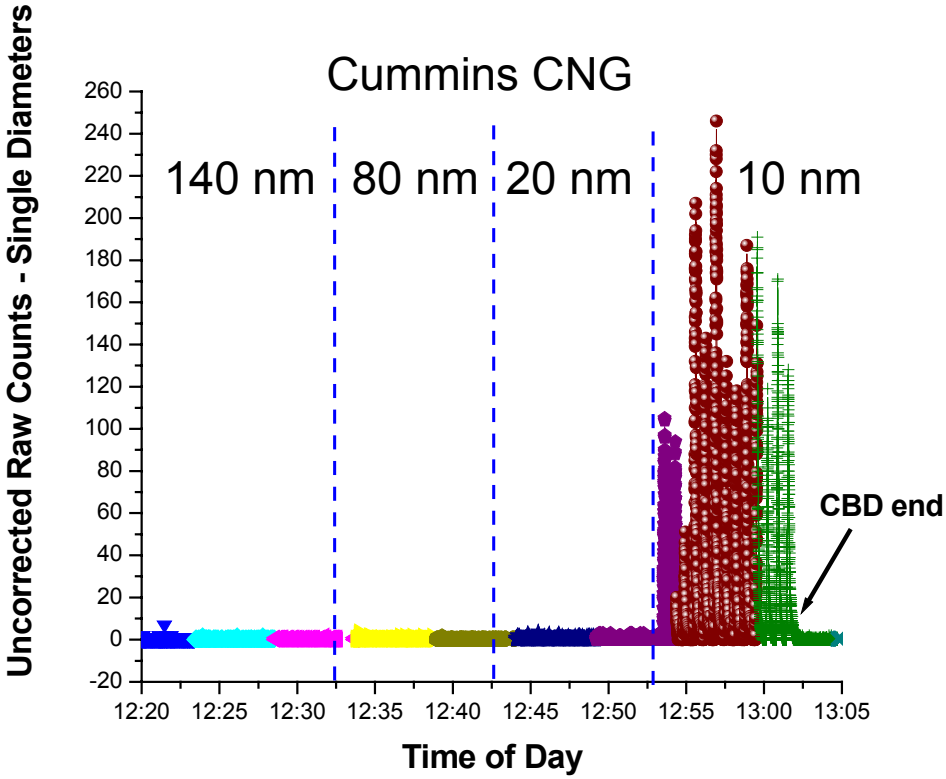


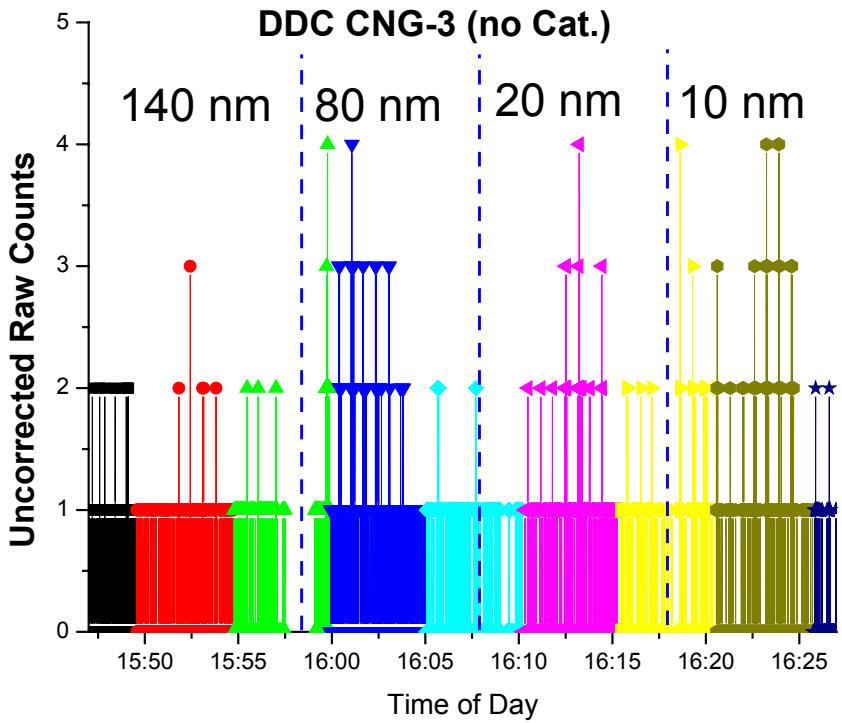
CNG buses (Phase 1.B): Idle





Single Diameter CBD Cycles

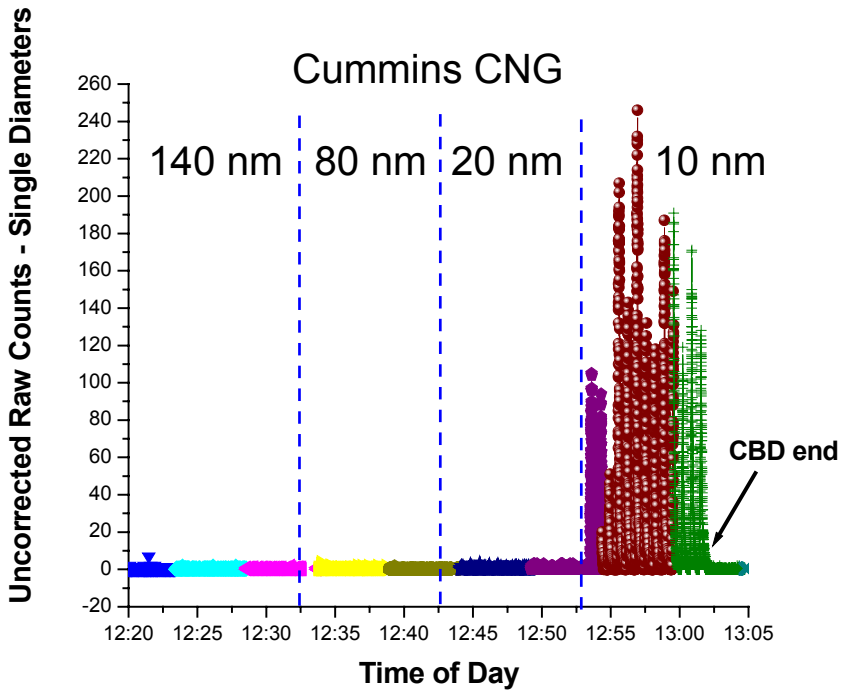


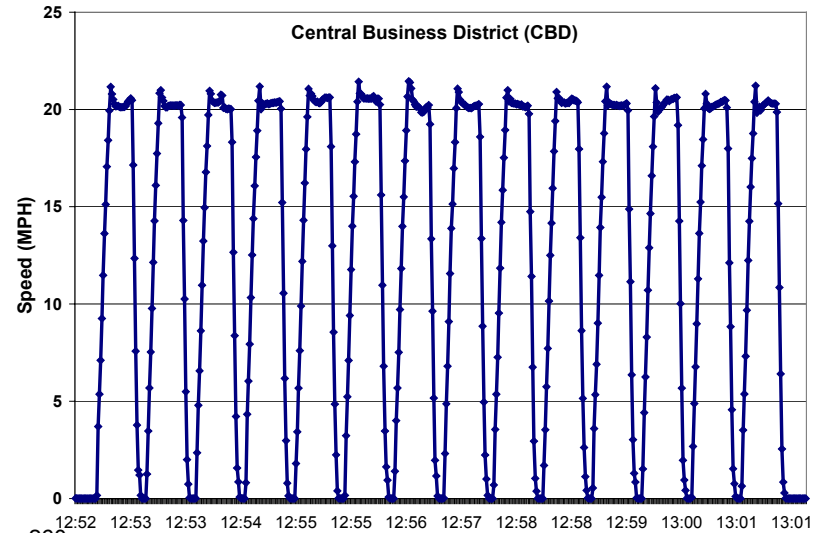


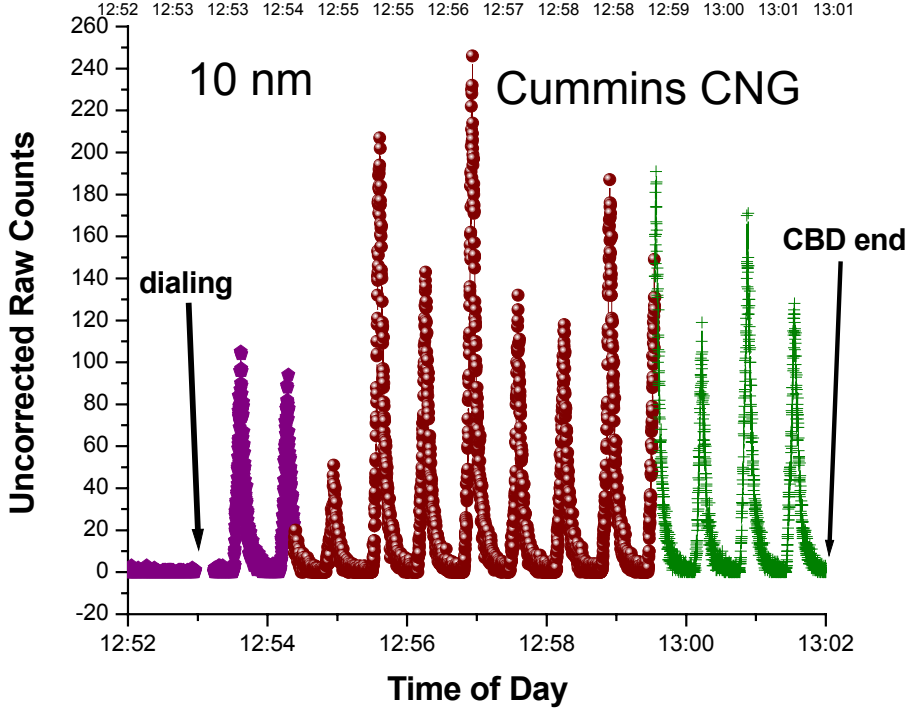
CWstprt CNG w/OxiCat

DDC CNG (No OC)

Single Diameter-CBD Cycles







CWstprt CNG w/Oxi Cat

Final Remarks

- Diesel+Trap and CNG+OxiCat result in similar number concentrations under some operating conditions
- Diesel+Trap and CNG (no OxiCat) reduce ultrafine N by 10 - 100 X compared to Diesel+OC
- Catalyst for CNG reduces UF N for some operating conditions
- At low load, Cummins Westport bus emitted very high nanoparticle concentrations
- “Clean” CNG and Diesel+Trap vehicles challenge current sampling/analytical methodologies
  - Role of tunnel blanks must continue to be addressed