Emissions Monitoring University of Minnesota Mobile Emission Laboratory

Application Note EM-001

Professor David Kittelson and a team of scientists in the Department of Mechanical Engineering at the University of Minnesota have developed methods to characterize particles emitted in the exhaust of cars and trucks during on-road tests. These particles form as exhaust dilutes and cools in the atmosphere. Nearly all of the particles are in the ultrafine range (<100 nm in diameter). To put the particle size into perspective, these particles are about 1,000 times smaller than the diameter of a human hair. Epidemiological studies suggest that exposure to these particles is harmful to health, but the degree of risk remains undefined.

University of Minnesota Mobile Emission Laboratory (MEL)
photo: W. F. Watts

MEL Housing rats for inhalation study
photo: W. F. Watts

One of the early activities conducted by the research team was to build a Mobile Emission Laboratory (MEL). The MEL is hauled by a full size Volvo tractor that is leased to the University at no cost. The sampling system in the MEL allows samples to be collected from a probes extending above the cab of the truck, from the front bumper, or from two sample probes located in rear corners of the MEL. This configuration allows samples to be taken either from the roadway or from the diluted exhaust plume of the tractor.

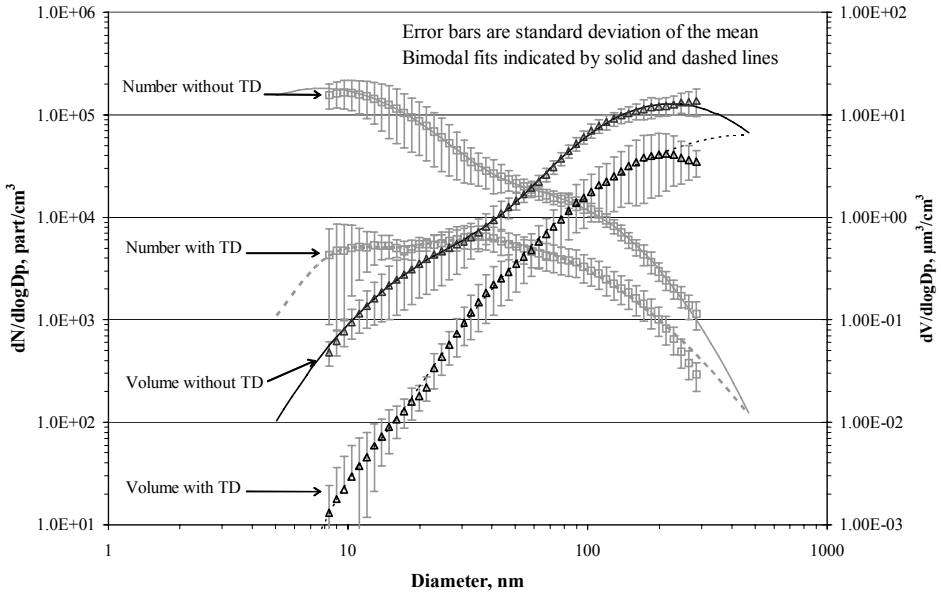
Other institutions have built smaller and more agile mobile labs. However, the large size of the MEL gives it unique advantages. The MEL is used as a platform for on-road rat inhalation studies to determine the adverse effects of breathing highway aerosol. It can evaluate diesel emission control devices, specially blended diesel fuels, and lube oils during real-world tests. Additionally, it can sniff the plumes of both automobiles and diesel trucks during on-road chase experiments.

Because the lab can operate independently from the Volvo tractor, the MEL is also useful as an air-quality monitoring station. It is outfitted with a full complement of aerosol instruments, including:

- Scanning Mobility Particle Sizer™ (SMPS™) Spectrometer
- Condensation Particle Counters (CPCs)
- Electrical low-pressure impactor
- Engine Exhaust Particle Sizer™ (EEPS™) Spectrometer
- Electrical Aerosol Detector
- Diffusion Charger
- Aethalometer™ suspended carbonaceous particulate detector
- Photoemission aerosol sensor
- CO, CO2, and NO_x gas analyzers

The EEPS™ spectrometer (TSI Model 3090) is the most recent addition. Although designed to operate in an engine laboratory the EEPS™ spectrometer has proven versatile and easy to operate in a field environment. It has extended the MEL's capability to size nanoparticles down to 5.6 nm and allowed the U of MN researchers to confirm the existence of a large concentration of particles below 10 nm in the roadway environment. Previously, they had inferred the existence of these particles from the difference between the integrated number concentrations derived from the SMPS™ spectrometer and the total number concentration determined by an Ultrafine CPC (TSI 3025A). However, the ability of the EEPS™ spectrometer to measure over a wider size range, in real-time, greatly improved the resolution of their on-road measurements.

SMPS™ number and volume weighted size distributions, with and without the TD, with bi-modal fits



Another interesting finding is illustrated in the graph to the right. It shows side-by-side measurements that were collected using two SMPS™ spectrometers (TSI Series 3936), while sampling on I-90 between Rochester and Buffalo, New York. One SMPS™ spectrometer was operated with an in-line thermal denuder (TD) that removed volatile material. As illustrated in the figure, removal of volatile material shrinks the nuclei mode by nearly two orders of magnitude, demonstrating that these particles are composed primarily composed of volatile material and not non-volatile carbonaceous compounds.

The researchers continue to find interesting applications for the MEL. In the very near future, a TSI Aerosol Time-of-Flight Mass Spectrometer (ATOFMS) will be installed and operated side-by-side with the other instruments. The ATOFMS will provide valuable information on mobile source air toxic emissions regulated by the United States Environmental Protection Agency. These include compounds containing chromium, manganese, nickel and lead, as well as diesel particulate matter and polycyclic

go city traffic or freewheeling on the highway, allows the researchers to collect unique data and offers a different perspective than data collected from stationary monitors.

The graph of side-by-side SMPS™ spectrometer measurements appears in:

Kittelson, D. B., W. F. Watts, J. P. Johnson, M. L. Remerowki, E. E. Ische, G. Oberdörster, R. M. Gelein, A. C. Elder, P. K. Hopke, E. Kim, W. Zhao, L. Zhou, and C.-H. Jeong. 2004. On-Road Exposure to Highway Aerosols 1. Aerosol and Gas Measurements. *Inhal. Toxicol.* **16**(suppl. 1):31-39.

This note was written by W.F. Watts and D.B. Kittelson of the Department of Mechanical Engineering at the University of Minnesota. TSI thanks the authors for this look inside their mobile laboratory.

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