Mobile Measurement Using an EEPS™ Spectrometer

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Abstract:

Laboratory measurements of engine exhaust provide meaningful information about engine emissions but the sampling and conditioning of the emissions affect the size distribution of the particle emissions. Roadside measurements, and increasingly on-road measurements provide an important link to what the emissions are in the real world. The TSI Engine Exhaust Particle Sizer™ (EEPS™) spectrometer was designed primarily to measure engine exhaust emission transients in a laboratory setting. A study was done to see if the EEPS could be used in a mobile lab environment.

The mobile measurement environment has a number of distinct features that make it difficult for instrumentation in general. Power requirements are one issue for instrumentation that uses the abundant AC power of the laboratory or test cell. Vibration is a problem for many instruments but is a particularly difficult one for an instrument such as the EEPS that uses electrometers that are sensitive to vibration. The vibration from road noise leads to increased noise in the baseline signal of the instrument. Therefore, using the EEPS in a vehicle to measure on-road exhaust emissions presents a challenge.

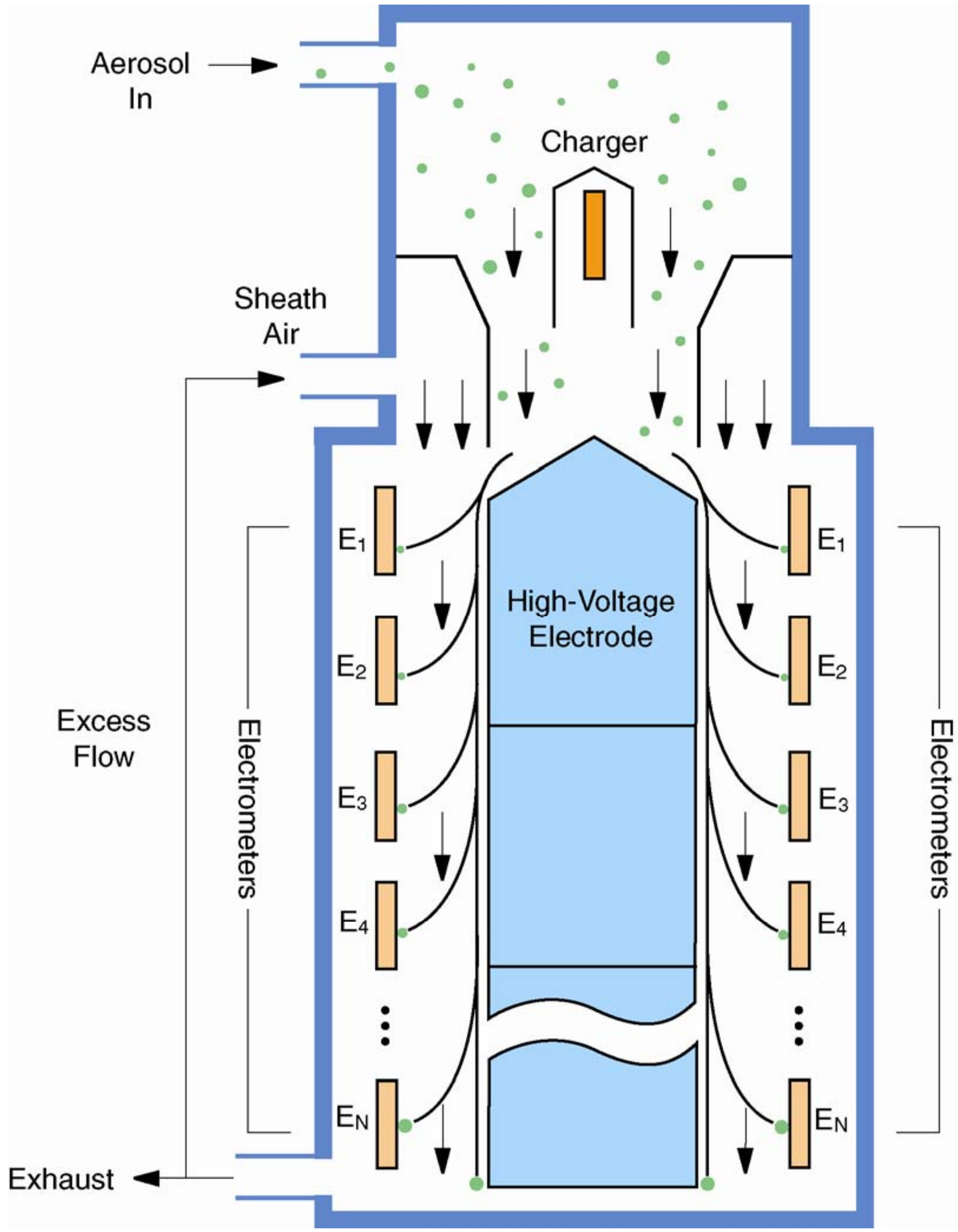
To determine the usefulness of the instrument for this application, a test vehicle was assembled using a minivan as a platform for on-highway chase tests. A probe was mounted on the roof of the van and tubing brought the air sample to a TSI 3090 EEPS and a TSI 3022A CPC. The instruments were strapped down to the floor of vehicle for stability during vehicle motion. A video and still camera were used to record for correlation purposes and a laptop was used to collect data. An inverter was used to provide AC power to the instrumentation during the tests.

How the 3090 EEPS works

- It uses a diffusion charger to create Ions which charge the particles
- Particles mix with the ions and produce a predictable charge level versus particle size
- Particles are surrounded by sheath flow and flow down between a central rod and outer cylinder
- A high voltage on the central rod creates an electric field which repels the particles outward from a central column.
- Charged aerosol particles are detected on a column of electrometers

Problem with vibration

- Movement between the electrometer rings and the High-Voltage Electrode creates currents which adds to the noise level



Test Setup

The following equipment was used in the experiment.

- A TSI model 3090 EEPS (Engine Exhaust Particle Sizer) and a TSI model 3022A CPC (Condensation Particle Counter).
- A digital still camera and an analog Hi8 video camera.
- A 400W power inverter that converted 12 VDC to 120 VAC.
- A laptop computer

A Toyota Sienna minivan was used as the test vehicle. Modifications included the following.

- Power was supplied to a camera, laptop and instruments using the power inverter. The inverter was sufficient to run all the equipment during the tests.
- The back seat was removed and a plywood platform was installed. The Instruments were secured to the platform using tie-downs for stability during vehicle motion. No additional vibration isolation was employed.
- A 12mm conductive sampling probe was attached to the roof rack. It protruded about 50cm in front of the roofline to sample undisturbed aerosol samples. The

sampling probe allowed aerosol to be sampled through an open back window into a flow splitter and subsequently into the instruments.

- Conductive flexible tubing was used to bring the air sample to a flow splitter and from there to the instruments.
- Data was collected from the instruments using standard software running on a laptop. Particle burst events were correlated using the Video camera with a time stamp on each frame. The camera recorded traffic conditions through the front window of the van.
- Baseline levels of noise were measured by switching a HEPA filter into the sampling line while operating the vehicle over a bumpy road.

Test Results:

On Road testing was done by driving on some of the freeways in the Minneapolis/St. Paul area as well as driving around the University of Minnesota Campus. The driver attempted to get behind some large diesel vehicles such as those shown below.

Test results for total concentration on the EEPS and the CPC were compared to see how they compare. Figure 1 shows data from over an hours worth of driving. Figure 2 shows a smaller portion of the drive enlarged to see more detail. The slower response time of the 3022A CPC results in peaks that do not go as high as the EEPS. The 3022A CPC also doesn’t detect particles as small as the EEPS which results in lower concentrations.

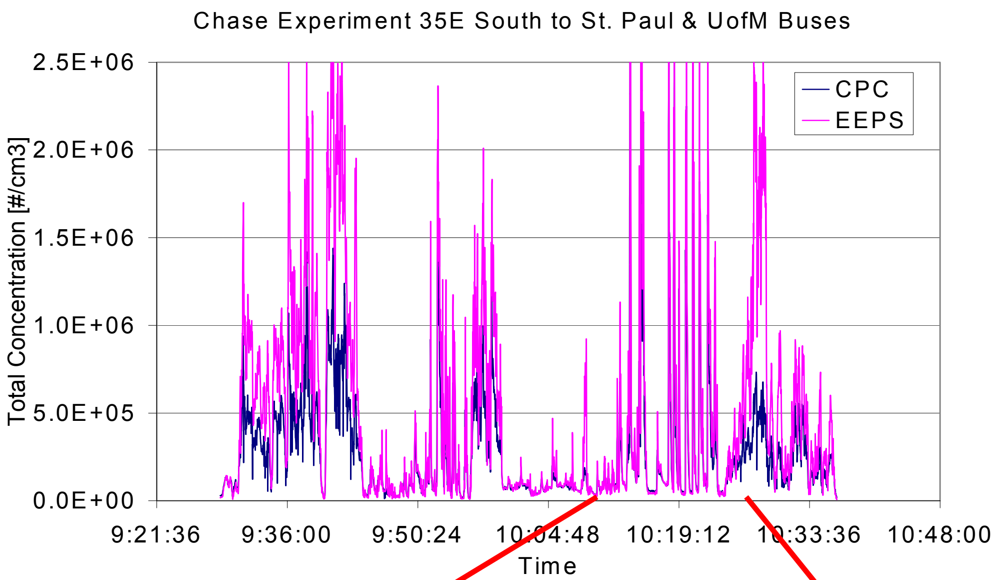


Figure 1

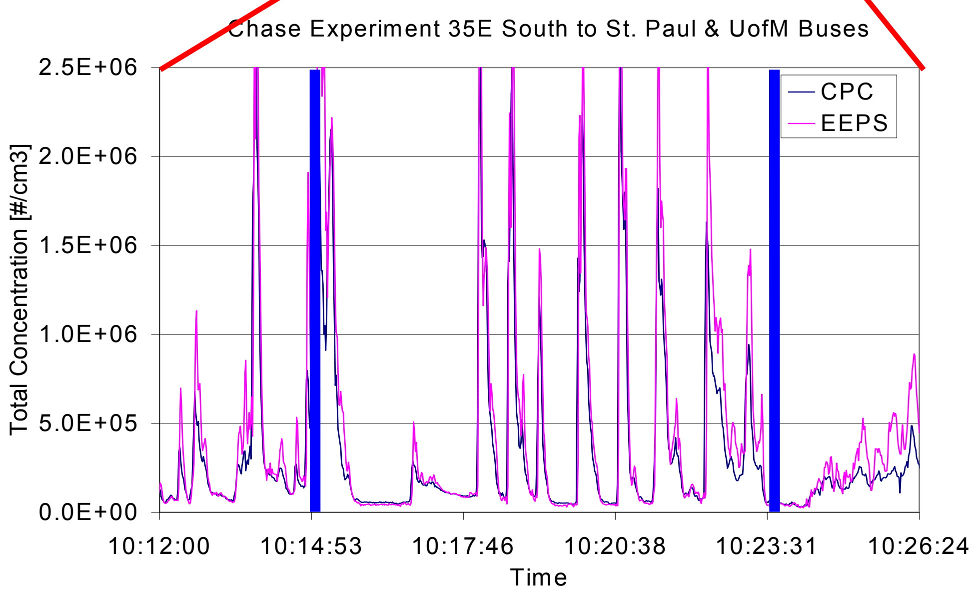
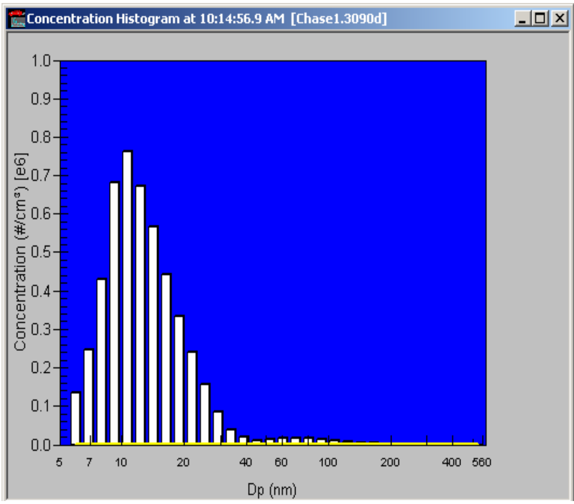


Figure 2

The data shown in Figures 3 and 4 shows typical data taken during sampling from a diesel plume. Figure 3 shows concentration in a linear scale and Figure 4 shows the same data in a log scale. The yellow line shows the typical RMS noise level for the EEPS (under laboratory conditions). The time at the top of the graphs indicates when the data was taken. In Figure 2 the left blue line indicates the time when the size distribution was taken for Figures 3 and 4. Figures 3 and 4 were with 0.1 second averaging on the EEPS.



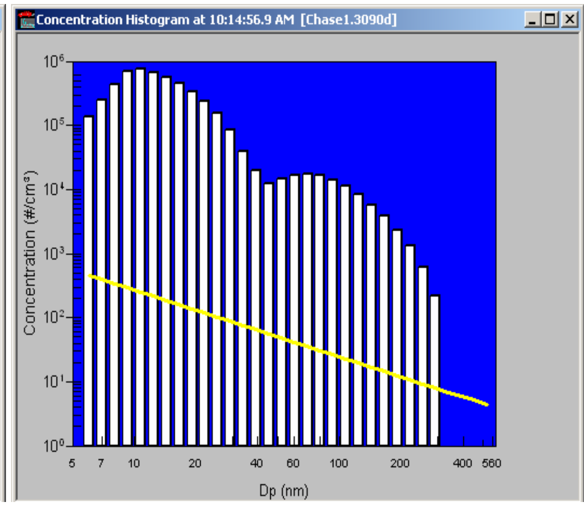
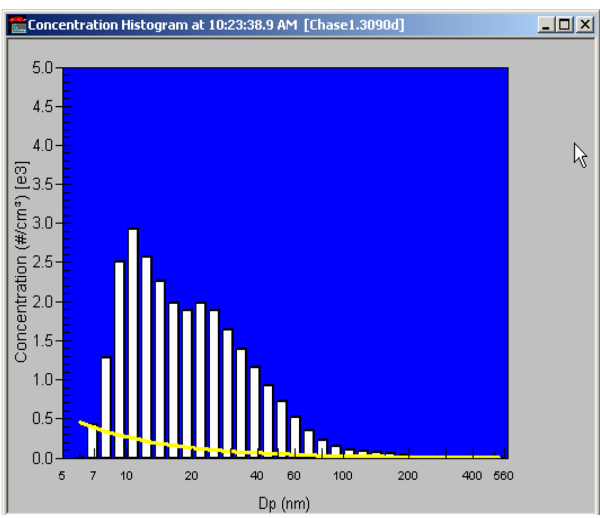


Figure 3 **Figure 4**

The data shown in Figures 5 and 6 shows typical data taken when the traffic ahead of the test vehicle didn't have a significant particle emitter in front of it (right blue line on Figure 2). While the signal is much closer to the noise level it is still significantly above the noise level. This data was also taken with 0.1 second averaging with the EEPS.



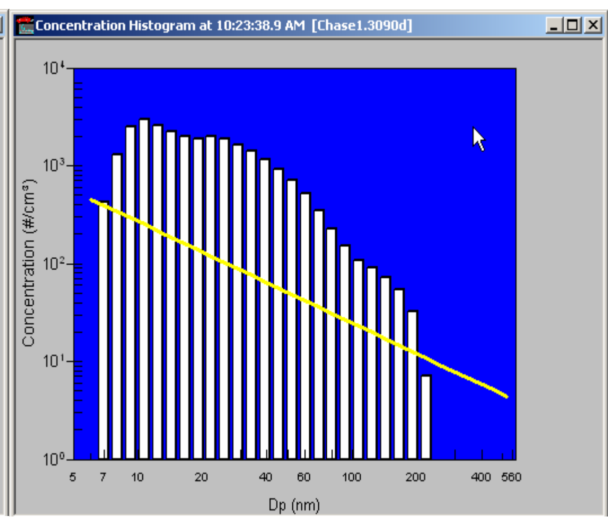


Figure 5 **Figure 6**

Baseline noise On Road:

Baseline noise levels were measured by collecting data with a high efficiency filter in the sampling line while operating the vehicle over a bumpy road. Results showed that although the baseline RMS noise for bumpy road conditions is considerably higher the bench top levels, there is sufficient signal to noise to clearly show particle burst events from most diesel sources (i.e. trucks, buses, semi-trailers). The scale in Figure 7 is 1/10 that of Figures 1 and 2. The RMS noise on road was approximately 3 times that of the same instrument in the laboratory. The average on road signal was approximately 50 times the on road noise level. This gives us sufficient signal to noise for this urban roadway example.

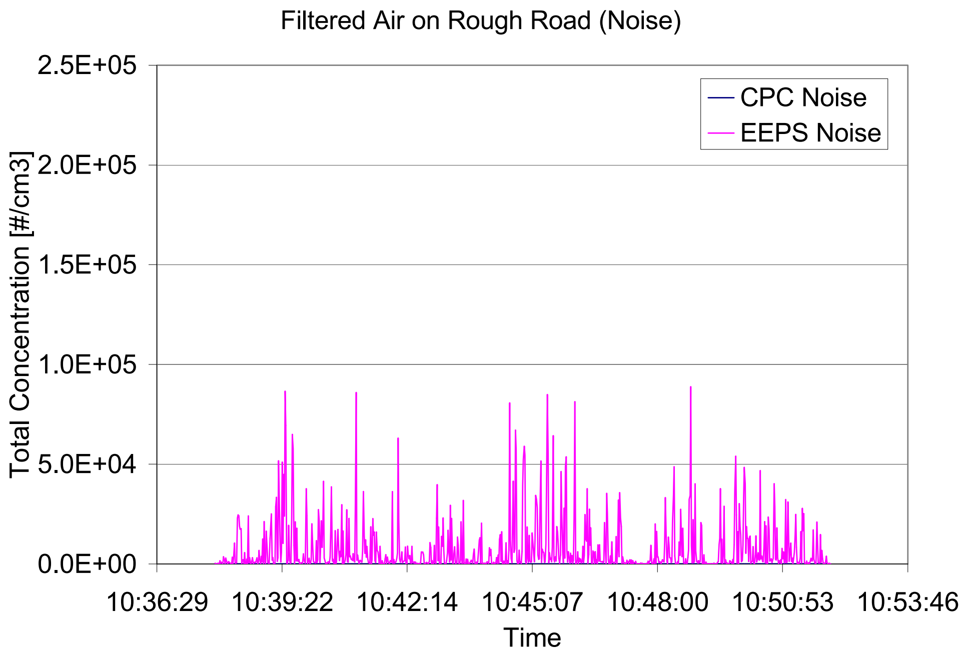


Figure 7

Figures 8 and 9 show typical size distribution results during the On Road baseline readings. This data was also taken with 0.1 second averaging with the EEPS. Longer averaging times would lower the noise level.

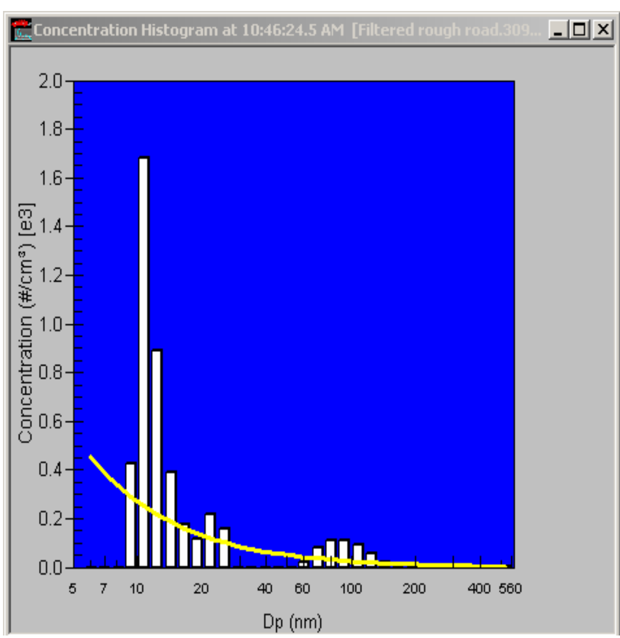


Figure 8

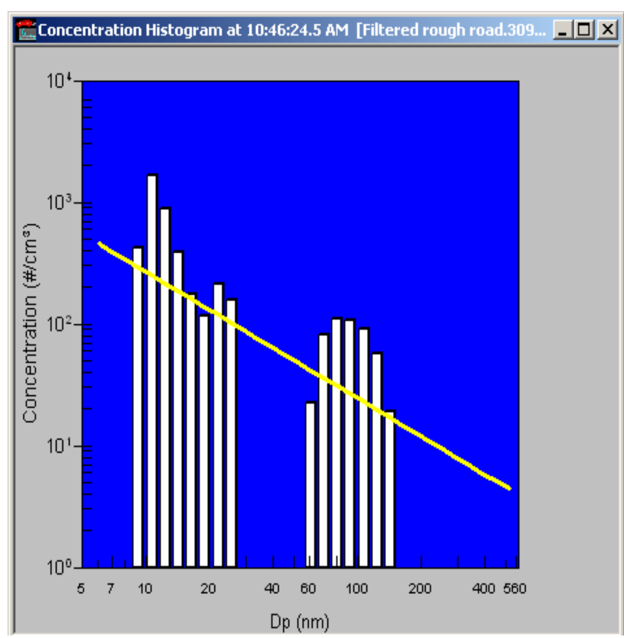


Figure 9

Summary of Data:

The data shows that the EEPS is usable for mobile measurements in urban environments. Away from urban sources the background may not be sufficiently high to be seen above the higher noise level that occurs due to the vibration.

Conclusions:

Results showed that although the baseline RMS noise for bumpy road conditions is more than 3 times the bench top levels, there is sufficient RMS signal to noise (50:1) to clearly show particle burst events from most diesel sources (examples: trucks, buses, semi-trailers).

In addition, the EEPS total concentration closely matched the CPC concentrations and correlated very well with particle bursts. Therefore, based on the test results, the EEPS should prove to be a valuable tool for mobile on-road chase experiments.