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Comparison of Tailpipe and Dilution Tunnel Measurements

Nanoparticle artifacts: Comparison of tailpipe and dilution tunnel measurements of vehicle PM

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ABSTRACT

In the present paper the extent to which particle number/size distributions of motor vehicle exhaust may be modified by a standard dilution tunnel setup is analyzed. Steady state particle size distributions measured by sampling directly from the tailpipe using an ejector pump are compared to dilution tunnel measurements. It was found that size distributions from both methods compare well at low speed. However, at higher speed depending on the temperature of the transfer hose artificial high numbers of ultrafine particles were measured in the dilution tunnel which are absent in the tailpipe measurements. As shown below, this effect is due to evaporation of deposits from the transfer hose and subsequent condensation of new particles in the dilution tunnel. Sampling conditions can strongly influence the number size distribution of vehicle exhaust. Much further work is needed to define parameters which allow reliable measurements of vehicle exhaust particle size distributions so that real world atmospheric dilution is reflected.

EXPERIMENTAL SETUP

- Vehicles run on 122 cm single roll dynamometer
- THC, CO, NOx recorded pre and post catalyst
- Transfer of exhaust to tunnel:
  Dearborn: Heated/insulated corrugated stainless steel tube (~10 cm x 6 m)
  Cologne: unheated/uninsulated (5 m)
- Exhaust diluted to constant flow (10 - 30 m^3/min) with humidity and temperature controlled air (38 °C, -9 °C d.p.)
- Residence time: ~1 s to ~6 s
- Tailpipe sampling: Dekati Minidiluter (particle free N_2 or air)
- Dilution ratio: Tunnel: 10-30; Tailpipe: 8-10

RESULTS

Tunnel versus tailpipe (80 km h^{-1})

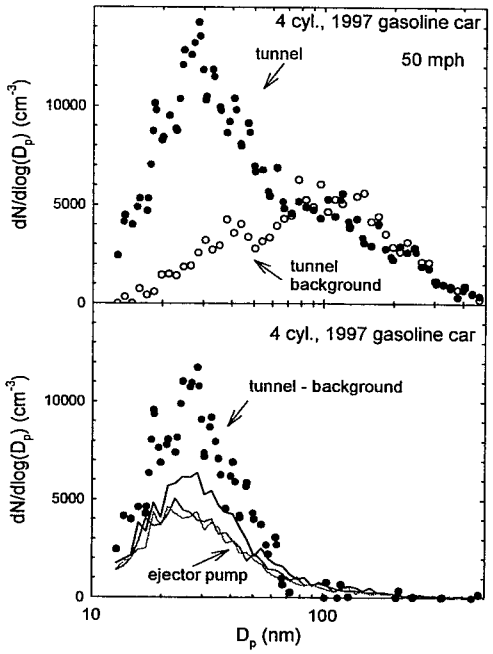

Figure 1. Top panel: Dilution tunnel particle size distributions recorded with and without vehicle exhaust. The uninsulated transfer tube is used to conduct the exhaust to the tunnel. Bottom panel: Comparison of ejector pump measurements of exhaust particle size with tunnel measurements after subtracting the background. All concentrations are converted to equivalent tailpipe concentrations.
(M.Maricq et al. SAE 1999-01-1461)

- **After subtraction of tunnel background: good agreement between tunnel and tailpipe**

Tunnel versus tailpipe (80, 96, 112 km h^{-1}); 8 cylinder, 1996 gasoline car

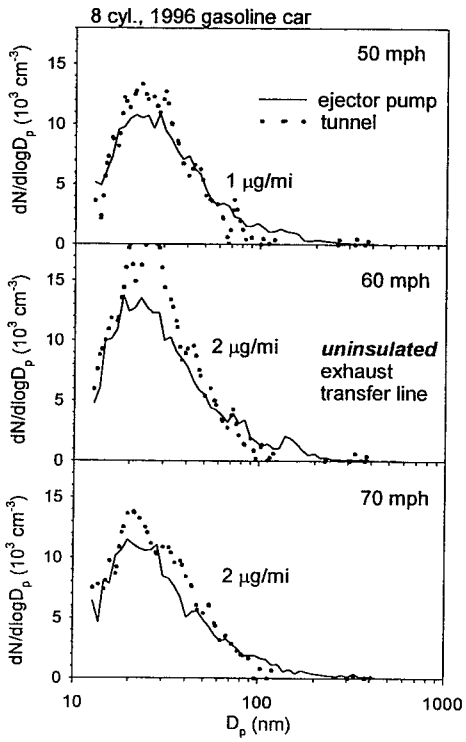

Figure 2. Comparison of ejector pump and dilution tunnel particle size distributions for the 8-cylinder gasoline car at 50, 60, and 70 mph when using the *uninsulated/unheated* transfer line. Note linear concentration axes. The tunnel background has been subtracted. Mass emission rates are estimated from the size distributions.
(M.Maricq et al. SAE 1999-01-1461)

- **Good agreement of tunnel and tailpipe measurement**

Tunnel versus tailpipe sampling; 4 cylinder, 1997 gasoline car

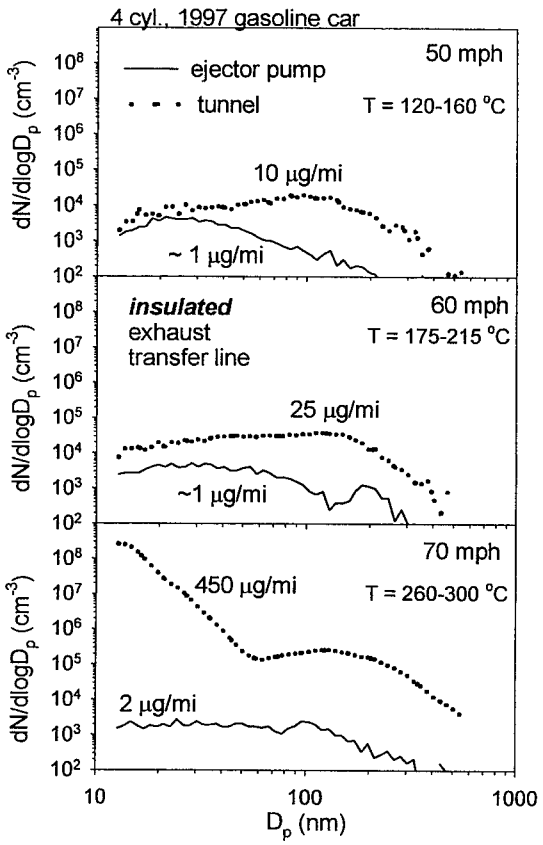

Figure 3. Comparison of ejector pump and dilution tunnel particle size distributions for the 4-cylinder, U.S., gasoline car at 50, 60, and 70 mph when using the *insulated/heated* transfer line.
(M.Maricq et al. SAE 1999-01-1461)

- **At high constant speed of 112 km h^{-1}: 10^3-10^4 x increased number concentration of particles smaller 20 nm are observed**

4 cylinder gasoline car; 100 km h^{-1}

- Dilution tunnel measurement

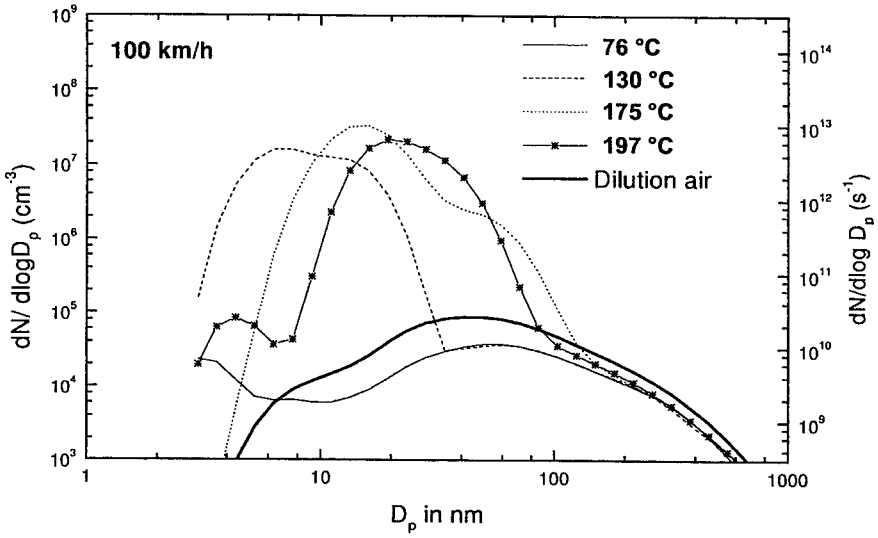

Figure 4.
Data in collaboration with
B. Wehner, A. Wiedensohler, IFT Leipzig

- Tailpipe measurement

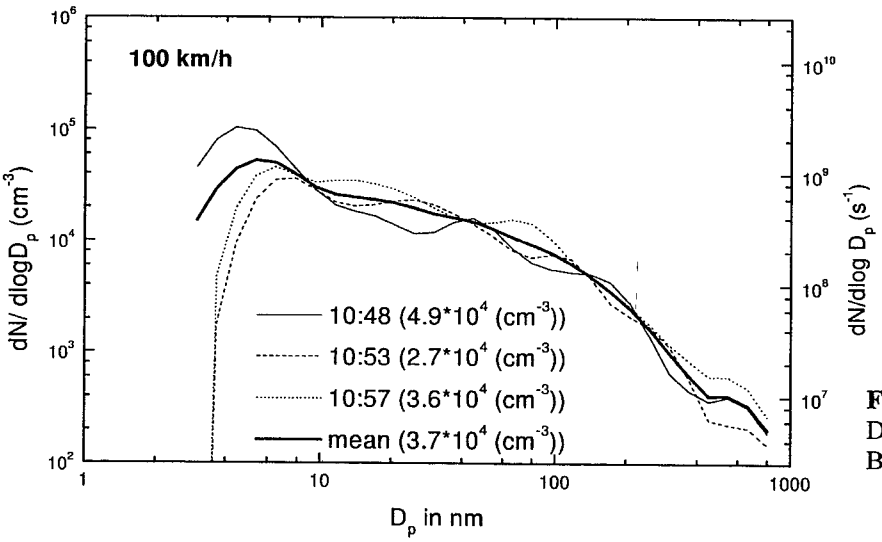

Figure 5.
Data in collaboration with
B. Wehner, A. Wiedensohler, IFT Leipzig

- **Increase of temperature inside of 5 m transfer hose leads to high number of artificial particles which are absent in the tailpipe measurement**

Effect of silicone coupler

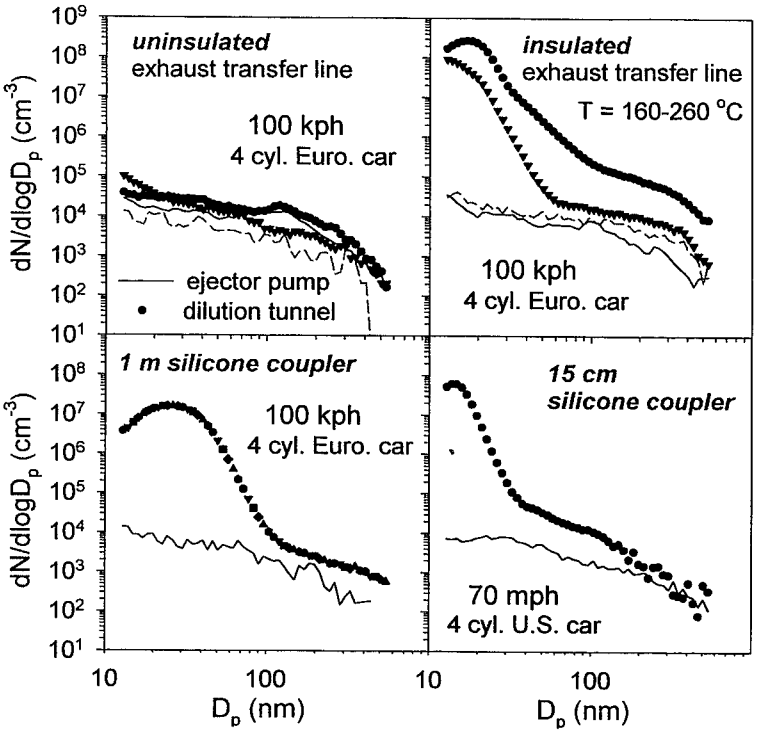

Figure 6. Comparison of particle size distributions for the 4 cylinder European gasoline car taken by ejector pump versus dilution tunnel when using a 1) *uninsulated* transfer line, 2) *insulated* transfer line, 3) *uninsulated* transfer line plus a 1 meter silicone rubber coupler, and 4) *uninsulated* transfer line plus a 15 cm silicone rubber coupler. In the top two panels, two sets of data are compared. Mass emission rates are estimated from the size distributions. (M.Maricq et al. SAE 1999-01-1461)

- **Pyrolysis/desorption of silicone and subsequent condensation results in high artificial particle numbers measured in the tunnel**

PM Size distribution of a Diesel vehicle

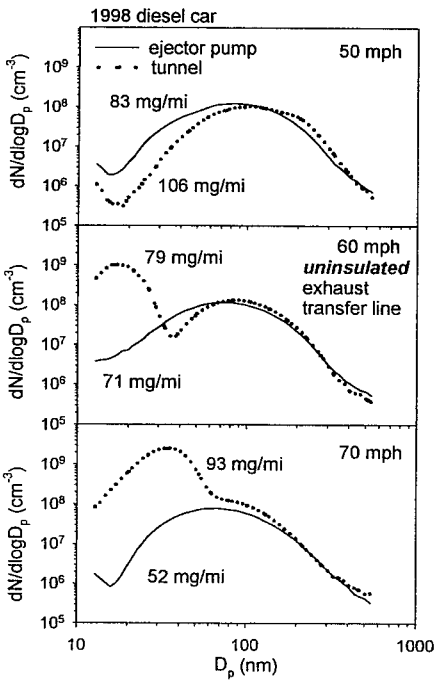

Figure 7. A comparison of diesel vehicle exhaust particle concentration taken with the ejector pump versus dilution tunnel when using the *uninsulated/unheated* transfer line. (M.Maricq et al. SAE 1999-01-1461)

- **Similar effect as observed for gasoline car: Evaporation of transfer hose deposits and subsequent condensation results in artificial particles**

Atmospheric measurements of PM

Figure 8. Ford Mobile Laboratory. The instrumentation includes APS, SMPS, TEOM, EC/OC Analyzer, MOUDI, Dichotomous sampler for PM2.5/PM10; Gas analyzers: NO_x, O_3, CO

- **The Mobile Laboratory is utilized to measure PM size distributions (and many other data) under real atmospheric dilution conditions**

SUMMARY AND CONCLUSIONS

- **Heating of transfer line by the exhaust gas results in evaporation of deposits which may condense and form artificial high numbers of particles.**
- **Tunnel, transfer hose, and sampling probes should be kept clean**
- **Temperature of the transfer hose should be monitored and kept sufficiently low to avoid artifacts**
- **Avoid use of silicone rubber, or similar material in the transfer line**
- **Formation of condensed particles in the real atmosphere? Are they of importance?**

LITERATURE

M.M. Maricq, R.E.Chase, D. H. Podsiadlik, R. Vogt: "Vehicle exhaust particle size distributions: A comparison of tailpipe and dilution tunnel measurements". *SAE series 1999-01-1461 (1999)*