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Ambient Pressure Impact on Particle Sizing with SMPS

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Introduction

Using a Scanning Mobility Particle Sizer (SMPS) the ambient conditions affect the particle size measurement. This means that air pressure and temperature change the internal flow for sheath and aerosol air, the air viscosity, and the particle size cutoff at the entry. This impact is important, if the SMPS is not used under constant ambient conditions in a laboratory, but for field measurements on various altitudes and at various ambient pressures.

The Differential Mobility Analyzer (DMA) selects particles in the SMPS due to their electrical mobility. The electrical mobility can be assigned to an equivalent diameter D_p, if the viscosity μ (Rasmussen 1997), the mean free path of air λ (Willeke 1976), and the particle slip correction factor $C(\lambda, D_p)$ are known (Hinds 1982, Kim 2005). The viscosity of air is mainly a function of temperature T, but also a function of pressure p and humidity H. The mean free path of air depends on temperature T and pressure p.

The Aerosol Instrument Manager (AIM, control software, TSI 2004) allows the user to enter values for μ and λ before the measurement and defines the DMA settings (Figure 1). The AIM calculates the particle sizes after the measurement.

In the present experiment the influence of ambient pressure on the SMPS particle diameter analysis is investigated using constant and adjusted values for the viscosity $\mu(T, p_a, H)$ and the free mean path $\lambda(p_a, T)$.

Materials and Method

The measurements were performed in a accessible pressure chamber (Figure 2). This chamber allows the setting of the ambient pressure and temperature. The instruments were installed in the chamber, but they were controlled by the computer from outside. Various aerosols with polystyrene spheres (PSL with diameters 71, 95, and 175 nm) were generated with an Atomizer (TSI 3079). The instruments were run during 6 hours continuously with the same aerosol (Figure 3).

The pressure p_a in the chamber was changed stepwise from 950 hPa (ambient) to 900, 850, 900, 950, 1000, and back to 950 hPa. At each ambient pressure the flows (DMA: sheath air, CPC: aerosol air) are measured with thermal mass flow meters, the DMA parameters were recorded. Finally the PSL particle size was measured with a SMPS at 950 hPa and adjusted settings (Table 1).

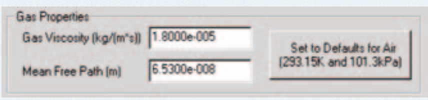

Figure 1: Input box in AIM (TSI) for viscosity and mean free path.

T (°C)	22	22	22	22
p_a (hPa)	850	900	950	1000
μ (10^{-5} Pa s)	1.8223	1.8224	1.8225	1.8226
λ (nm)	79.246	74.843	70.904	67.359

Table 1: Constants used in experimental Setup. Pressure 950 hPa was the default value (L'Air Liquide 1976, Rasmussen 1997)

Figure 2: View on the accessible pressure chamber.

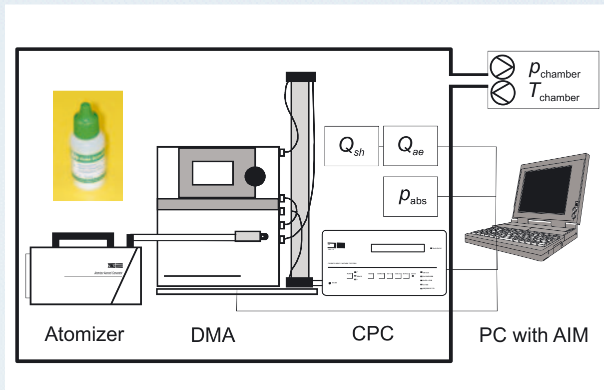

Figure 3: Experimental setup for the size analysis of PSL-aerosol in a climate chamber: atomizer (TSI 3079), DMA (TSI 3080), CPC (TSI 3022), Sofware (AIM from TSI), and external references

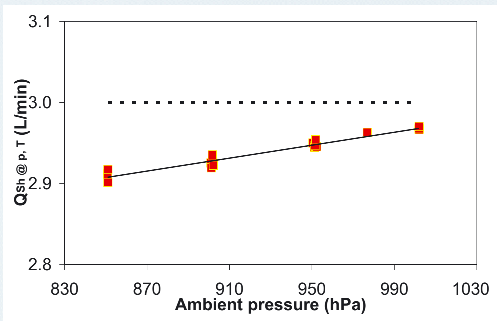

Figure 4: DMA sheath air flow (dashed line: constant (correct) flow, red sqares: measured flow)

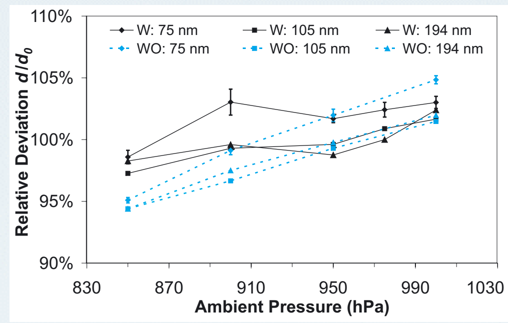

Figure 5: The influence of ambient pressure on SMPS particle sizing with (W) and without (WO) adjusted μ and λ.

Results and Discussion

The ambient pressure p_a measured with the DMA deviated up to 30 hPa from a calibrated external reference. This influences the control of the sheath air flow (Figure 4). Since DMA did not allow the user to adjust the absolute pressure sensor this bias cannot be eliminated.

The PSL diameter measured with the SMPS is influenced by the ambient pressure. The deviation of the results are much smaller when μ and λ are adjusted according to the ambient pressure (Figure 5).

With adjusted internal absolute pressure measurement and correct flow control the results would be even better.

Conclusions

Particle size measurements with SMPS needs correct settings for the actual ambient conditions. The manufacturer gives some tools to the user with the input boxes for viscosity and mean free path length. Further improvement of the particle sizing would be possible by allowing the adjustment of the ambient pressure sensor.

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