# Performance of a Scanning Mobility Particle Sizer at pressures between 500 - 780 mb

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## ABSTRACT

The scanning mobility particle sizer (SMPS) is widely used for measuring particle size distribution in the submicrometer range. For aircraft application there is concern that particle sizing may be flawed because the flows in the SMPS may be compromised due to pressure change at different altitudes. For an aircraft application we have tested the performance of a TSI SMPS model 3936L at various pressures using an altitude/temperature chamber. The sheath and aerosol flows were set at 10 l/min and 1 l/min respectively. The flows in the SMPS were found to be stable at the tested pressure range. Monodisperse aerosol was introduced into the chamber at various pressures and sized by the SMPS. The measured particle size at different pressures agreed within a few percent. One of the shortcomings of the present SMPS is the Aerosol Instrument Manager (AIM) software that controls and processes the data is initiated with a fixed mean free path and viscosity. These values depend on ambient pressure and temperature and thus change for aerosol sampling at different pressures and temperatures. The present instrument can be used since the pressure and temperature can be recorded with an additional serial connection to the classifier. However, this requires post processing.

## INTRODUCTION

Under normal operating condition the TSI AIM software is initialized with a fixed mean free ($\lambda$) path and viscosity ($\mu$). To use this SMPS under varying pressure and temperature as in an aircraft environment, one would need to monitor these variables and post process the data as the size distribution displayed by the AIM software would be incorrect. The object in this work was to test whether the set sheath flow in the SMPS are be maintained under varying pressure condition and whether the size distribution measured under these conditions can be obtained reliably with the correct $\lambda$ and $\mu$.

## METHOD

**Aerosol Generation:** Monodisperse aerosols were generated using a TSI 3940 aerosol generation system. A solution of NaCl dissolved in deionized filtered water (200 mg $l^{-1}$) was atomized, and the particles dried in a diffusion dryer, charge equilibrated and classified to obtain the desired particle size. The classified aerosol was subsequently neutralized with an Aerosol Dynamics Inc. (ADI) neutralizer (2 mCi $^{210}$Po source) and then directed to a buffer chamber from which it was distributed to the pressure chamber.

**Pressure Chamber:** To obtain the desired pressure and temperature a Tenney Environmental Chamber Model 26ST-SPL was used. It has a working volume of 26 $ft^3$, pressure range of few mb to sea level pressure and a temperature range of –70°C to 177 °C.

**Scanning Mobility Particle Sizer:** The SMPS being characterized is a TSI model 3936L. Under normal operating condition, the SMPS AIM software is initiated with a fixed mean free path ($\lambda$) and viscosity ($\mu$) computed from ambient pressure and temperature. A modified version of the AIM software (ver 5.2.0.2) was obtained from TSI to allow modification of the $\lambda$ and $\mu$.

**Experimental Design:** To simulate SMPS sampling of ambient air in a pressurized aircraft such as the King Air, an experimental setup shown in Figure 1 and 2 were used. Monodisperse aerosol was introduced into the chamber via two opposing critical orifices in the mixing chamber. Aerosol in the mixing chamber is sampled with the SMPS and exhaust of the CPC vacuum pump (GAST model DOA-V111-JK) is routed into the pressure chamber.

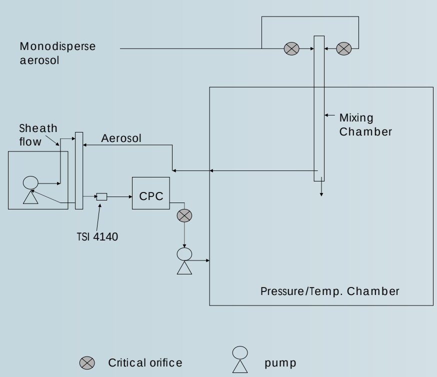


Figure 1

Figure 2

## RESULTS

**SMPS scan between 500 -780 mb:** First monodisperse aerosol generated with the classifier set for 100 nm particles were scanned with the SMPS at ambient (780mb) to give the results shown in Figure 3 with a mode at 98nm. Then the same size aerosol was introduced into the pressure chamber and scanned at ~500 mb giving the distribution in Figure 4 with a mode of 82nm. A size shift is noted because of inappropriate $\lambda$ and $\mu$ that was initialized at the start of the AIM software. The pressure and temperature monitored in the classifier was used to compute the correct $\lambda$ and $\mu$ and applied to the modified AIM program to give a size distribution shown in Figure 5 with the same mode of 98 nm. Figure 6 and 7 show measurements of the same aerosol made at 600 and 700mb and corrected for pressure and temperature.

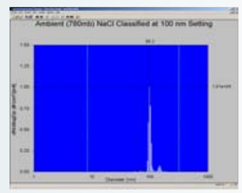


Figure 3

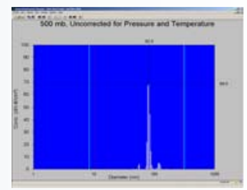


Figure 4

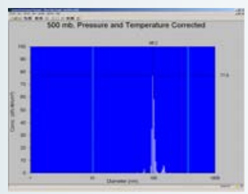


Figure 5

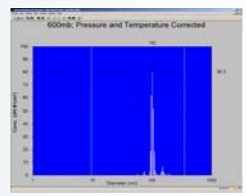


Figure 6

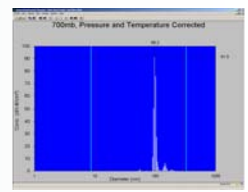


Figure 7

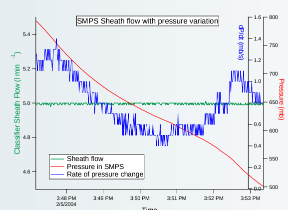


Figure 8

**Sheath flow under varying pressures:** For the SMPS to perform correctly under different pressures the sheath flow in the column must be maintained. The pressure in the SMPS was varied between 500 to 780 mb at a rate between 0.4 to 1.2 mb $s^{-1}$. The sheath flow under these conditions are plotted in Figure 8 and indicate the flow is well controlled with a mean value of 5 l $min^{-1}$ and a standard deviation of 0.005 l $min^{-1}$.

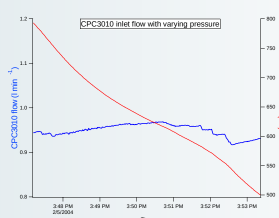


Figure 9

**CPC3010 flow Under varying pressures:** The flow at the inlet of the CPC was control via critical orifice and a vacuum pump and monitored with a TSI 4140 flow meter. The flow under various pressures are plotted in Figure 9. A mean flow of 0.95 l $min^{-1}$ with a standard deviation of 0.014 l $min^{-1}$ was observed.

## Discussion

The results presented here indicate that Model 3936L is capable of sizing particles correctly between 780 to 500 mb provided the pressure and temperature information are acquired and applied. With the modified TSI AIM software, correct size information requires post processing of the data manually for each scan. We are encouraging TSI to include the pressure and temperature acquisition in their SMPS AIM software so real time $\lambda$ and $\mu$ can be applied in the inversion program to obtain correct size distribution without the need for post processing.

## Summary

- With appropriate $\lambda$ and $\mu$, correct particles size distributions were obtained with the SMPS in the pressure range of 500 to 780 mb.
- The present TSI SMPS AIM software requires a fixed initial input of $\lambda$ and $\mu$ and therefore pressure and temperature variation cannot be accounted for.
- By attaching a second serial connection to the classifier in the SMPS, pressure and temperature in the classifier can be obtained and used for post processing the data to give correct size distribution.

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