

Experimental Determination of the Collection Efficiencies of the Aerodynamic Lens in the Aerodyne Aerosol Mass Spectrometer (AMS)

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INTRODUCTION

One of the key issues for the successful interpretation of AMS data is knowledge of the aerodynamic lens collection efficiency (CE), required for quantifying size-resolved mass composition. Numerical calculations of the CE have been performed but measurements to verify the numerical calculation have been limited. Presented here are new results which extend the measurements to larger and smaller particle sizes. The CE of the aerodynamic lens in the vacuum aerodynamic size range of 43 – 721nm, using ammonium nitrate particles, has been recently measured. These results allow us to quantify the CE of the AMS with greater certainty for comparison with numerical calculation. Future experiments will be extended to particles of different densities and morphologies to further investigate the aerodynamic focusing properties of this lens system.

The principal experimental difficulties are invariably associated with the ability to generate monodisperse test aerosols in an appropriate size range (20 to 2500nm) and at high enough concentrations to provide sufficient detectable mass to yield a reasonable signal at small particle sizes. Also important is the ability to correctly reference the number concentration, particularly for <80nm particles. In this regard, the results from a previous study (Liu and Deshler, 2003) which discusses losses of <80nm particles in the Condensation Particle Counter (TSI CPC3010) and techniques to minimize these losses, are particularly relevant.

METHODS:

Aerosol generation: Monodisperse aerosols were generated using TSI 3940 aerosol generation system. A solution (1 to 10 g/L depending on size generated) of NH_4NO_3 dissolved in deionized filtered water is atomized, dried in a diffusion dryer, charge equilibrated and classified with an appropriate voltage setting to obtain the the desired particle size. The classified aerosol was neutralized with an Aerosol Dynamics Inc., neutralizer (ADI) (2 mCi ^{210}Po source) as earlier study (Liu and Deshler, 2003) reported significant losses of classified charged particles in the CPC3010. The neutralized aerosol is directed to a buffer chamber where it is distributed to the various instruments.



Fig.1. Aerosol generation system

Aerosol size distribution: The aerosol size distribution of the generated aerosol were scanned with a TSI 3936L10 scanning mobility particle sizer (SMPS) to give the size distribution.

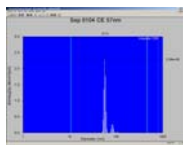


Fig.2. Example of a SMPS scan of classified 57nm aerosol

Aerosol concentration: Reference aerosol concentration was measured with a TSI CPC3010 operated at a differential temperature of 21°C to ensure activation of smaller particles.

Collection Efficiency Experimental Design:

Reference: AMS 100% CE is determine with particles size that are collected 100% by the AMS and CPC. Here we used vacuum aerodynamic diameter $D_{va} \approx 270\text{nm}$. From the 270nm particles measurement we obtain:

- The mass concentration of the singly charged particles from the CPC and SMPS measurements, $CPC(d250)$ are determined using density of NH_4NO_3 and Jayne shape factor of 0.8.

- The mass concentration of singly charged particles from the AMS measurement, $AMS(d250)$ are determined by integrating all TOFs signal for the first peak measured by the AMS.

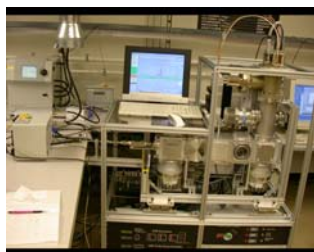


Fig.3. Experimental setup

$$Reference = \frac{CPC(d250)}{AMS(d250)}$$

Collection Efficiency: Similar AMS, CPC and SMPS measurements were obtained for a range of D_{va} from 43nm to 721nm to determine the AMS mass concentration, $AMS(x)$ and CPC mass concentration, $CPC(x)$ of the singly charged particles. The collection efficiency for size x is determined by:

$$CE(x) = \frac{CPC(d250) \times AMS(x)}{AMS(d250) \times CPC(x)}$$

RESULTS

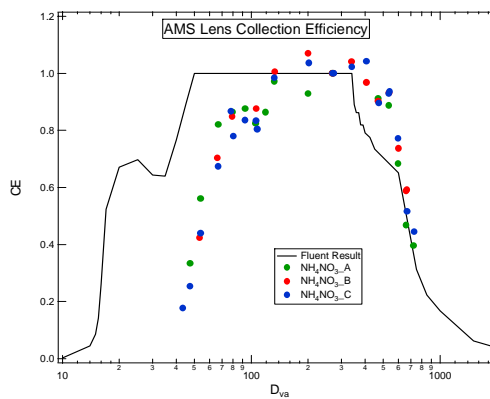


Fig.4. CE results of NH_4NO_3

Issues with large NH_4NO_3 particles: Smaller size tail measured by AMS and not with SMPS (Fig.5). Speculate that large particles are fracturing at the inlet orifice or focusing lens.

CE obtained from number count mode with mass integrating mode higher (Fig.6) suggesting fracturing of large particles

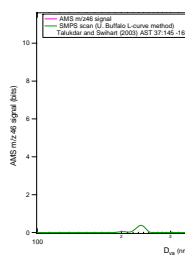


Fig.5.

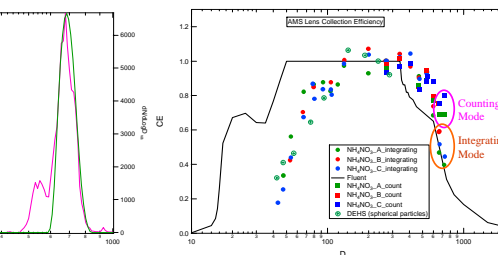


Fig.6.

Experiment with $\text{Pb}(\text{NO}_3)_2$: Attempt was made to extend to larger D_{va} using denser material such as $\text{Pb}(\text{NO}_3)_2$ that has a density of $4.53\text{g}\cdot\text{cm}^{-3}$. Could not obtain a reference which maybe due to lack of focusing or bounce at vaporizer. Further experiment will be conducted with beam width probe to determine the cause.

Experiment with Di-ethyl hexyl sebacate (DEHS): Further experiments with spherical particles were conducted. Similar results were obtained for $D_{va} < 300\text{nm}$ (Fig.6). Results for larger particles indicated the AMS to CPC count ratios > 1 suggesting droplets may be shattering.

Summary:

- Extended NH_4NO_3 CE results to cover wider size range $-D_{va}$ 43 – 727nm
- Obtained similar results with DEHS (spherical) $D_{va} < 300\text{nm}$ particles
- Evidence to suggest that large NH_4NO_3 particles fracturing and large DEHS drops breaking into smaller drops
- $\text{Pb}(\text{NO}_3)_2$ requires more work (Beam width probe)
- Experimental results differ from Fluent model calculations
- Experimental results indicate less efficient focusing for the $< 100\text{nm}$ compared to Fluent model calculation

Reference: Liu P.S.K and Deshler T. (2003) Causes of concentration differences between a scanning mobility particle sizer and a condensation particle counter, *Aerosol Sci. Technol.* 37:916-923.