Beyond Counting– Applications of Condensation Systems to Particle Collection and Charging

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Since the pioneering work of Aitken in the nineteenth century, condensational growth has been a key tool for aerosol scientists. Initially used to determine particle number concentrations, condensational particle counters continue to be a mainstay of aerosol research laboratories. Yet there are many additional types of aerosol measurement that are enabled through condensational growth as well.

As early as the 1970s, steam-injection methods were used to enlarge and capture submicrometer particles for on-line determination of chemical composition. In the 1990s condensational growth was applied to concentration systems for enriching the numbers of ultrafine particles in an air flow. It has been explored as a means to enhance the level of electrical charging. And it has been exploited to enable ultrafine particle imaging. This presentation will explore some of these applications beyond particle counting, namely collection, concentration, charging, and imaging. We focus on applications of a "moderated" approach for water-based condensation in a laminar flow that enables creation of water vapor supersaturation with relatively low water content and temperature in the output flow.

Moderated Water Condensation Growth Tube: Illustrated in Figure 1, the moderated water condensation method passes flow through a wet-walled tube, the middle portion of which is warmed. Within the warm section water vapor from the walls diffuses into the flow more quickly than it warms, creating a supersaturated flow. The cooler walls downstream remove water vapor and reduce the temperature, while maintaining the supersaturation (Hering et al., 2014) This three-stage, "moderated" approach activates particles at sub-10nm sizes without elevated temperature or water content in the output flow.

Collection: The moderated water condensation approach enables the capture of ultrafine particles as a dry, 1-mm diameter spot. Collection efficiencies are above 90% for particles larger than 8 nm. The concentrated collection interfaces readily with laboratory systems for automated sample extraction and analysis. The system has been implemented as a sequential sampler for time-resolved monitoring of inorganic ions and for polycyclic aromatic hydrocarbons, with comparable results to filter collection. The approach may also be used for the concentrated deposition of particles into liquid, capturing both soluble and insoluble fractions.

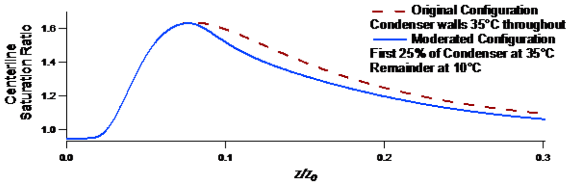

Figure 1. Saturation ratio along the flow centerline for wet-walled growth tubes operated with walls at 35°C throughout, or with walls starting at 35° and decreasing to 10°C. Entering flow is 5°C, 50%RH. z = axial distance; $z_o = Q/D$ (where Q=volumetric flow; D=water diffusivity).

Concentration: Using aerodynamic focusing as introduced by Fernandez de la Mora (1988), the droplets formed through condensational growth pass through a nozzle that focuses the droplets into the central 10% of the flow. The outer 90% of flow is removed through an annular slit in the wall of the nozzle, providing a 10:1 enrichment in particle concentration. Measured enrichments are 85-90% of the flow split for particles above 8 nm.

Charging: Many measurements of nanometer sized particles rely on size selection by electrical mobility, but charging efficiencies below 20 nm is poor, even with unipolar charging. Ion attachment is greatly increased by introducing ions along with the aerosol into a condensation growth tube. Multiple charging may be minimized through use of an ion scavenger immediately following the point of activetion, or by rapidly evaporating the droplets once formed. This approach has been combined with aerodynamic focusing to provide a 30-40 enrichment in the charging of particles at 10nm.

Imaging: Kulkarni and Wang (2006) developed a system for rapid measurements of particle size distributions through condensational growth and imaging of particles within a parallel plate mobility size separator. The original systems used an alcohol-laden sheath flow and cooled condenser to create this growth. This has now been accomplished using water condensation, wherein the water is introduced downstream of the mobility separation.

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