Quantifying Aerosols: A Characterization of the Transmission and Collection of an Aerodyne Aerosol Mass Spectrometer

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Interesting Questions

• Why study aerosols?
• What is an Aerodyne Aerosol Mass Spectrometer (AMS)?
• How does changing the porosity and shape of the vaporizer affect the collection efficiency of the AMS?
• What factors influence the transmission efficiency of the lens system?
Introduction to the AMS

Animation Credit: Matt Thyson (Lexington, Massachusetts)

Light Scattering Module
Experimental Setup

Aerosol Source
Atomizer

Size Selection
Differential Mobility Analyzer (DMA)

Input
Condensation Particle Counter (CPC)

Detection
Aerosol Mass Spectrometer (AMS)

Detection Ratio = \frac{\text{Mass Detected}}{\text{Mass Input}} = \frac{\# \text{ Detected}}{\# \text{ Input}}
Collection of the Vaporizer
• Light scattering signal agrees well between NH$_4$NO$_3$ and (NH$_4$)$_2$SO$_4$
• MS mass and MS count detection higher for NH$_4$NO$_3$ than (NH$_4$)$_2$SO$_4$
Characteristics of the Vaporizer

- Tungsten vaporizer
- Porosity not uniform, pockets of air
- Conical or flat shape

80% Dense  62% Dense  50% Dense
Porosity of the Vaporizer: Nitrate

- Good agreement between LS counts, MS mass, and MS counts with all three vaporizers
Porosity of the Vaporizer: Sulfate

- LS signal higher than MS counts or MS mass due to bounce
- Slight improvement with less dense vaporizers
Vaporizer Shape: Nitrate

- Good agreement between LS counts, MS mass, and MS counts with both vaporizers
Vaporizer Shape: Sulfate

- LS signal higher than MS counts or MS mass
- Improvement with conical vaporizer over flat vaporizer
  ~15%
Transmission of the Lens System
Lens System

Variables Included:
• Orifice size- 120 µm, 100 µm
• Valve body geometry- constant bore valve, standard valve
• Aerodynamic lens geometry-high pressure lens, standard lens
Particle Focusing in the Lens

Calculated Particle Trajectories
100 nm Diameter Unit Density Spheres
(Fluent ver 4.47)

J. T. Jayne, et. al.
Particle Focusing Before the Lens

Standard Lens

760Torr → Orifice → 2 Torr → Lens → 0.1 Torr → Mass Spec

1000nm

High Pressure Lens

760Torr → Orifice → 20 Torr → Lens → 0.1 Torr → Mass Spec

1000nm

Courtesy of Rensheng Deng and Leah Williams
High Pressure Lens: 120 µm Orifice

- Narrower transmission efficiency than calculation predicts
- Slightly better transmission for large particles than standard lens
High Pressure Lens: 100 µm Orifice

- Much better transmission efficiency for large particles (350nm-2µm)
- Still not as good as calculated values
High Pressure Lens: Different Valves

- Constant bore valve has better transmission efficiency than the standard valve for large particle sizes.
- Standard valve on high pressure lens looks very similar to standard valve on standard lens.
• Valve does not have a large effect
• Good agreement with data collected last summer
Conclusions

Vaporizer:
- The density of the vaporizer might have a slight impact on the collection efficiency.
- The shape of the vaporizer can change the collection efficiency by ~15%.

Lens System:
- The high pressure lens has a better transmission efficiency for larger particles than the standard lens.
- There are many variables which impact the transmission of particles through the lens, including the size of the orifice and the valve and lens geometry.
Thank You!

• Leah Williams
• Everyone at Aerodyne, especially Manjula Canagaratna, John Jayne, Tim Onasch, Achim Trimborn, Dagmar Trimborn, and Doug Worsnop
• Jeff Gaffney and Milton Constantin from the DOE OBER GCEP SURE program
Aerosols

- Particulate matter suspended in the air
- Size range (10 nm- 10 µm)
- Origins: volcanic, dust, fires, sea spray and human
- Health effects
- Scatter/absorb light radiation
- Cloud formation and structure
- Climate change impacts
Introduction to the AMS

Particle Inlet

Aerodynamic Lens

Chopper

Quadrupole Mass Spectrometer

Thermal Vaporization & Electron Impact Ionization

Turbo Pump

Turbo Pump

Turbo Pump
100 µm pinhole has best transmission efficiency for both the large and small particle sizes.
High Pressure Lens, Different Inlets

- Good agreement between new and standard inlets on the high pressure lens with the 120 um pinhole
- Standard inlet might actually give slightly better transmission for large particles
Standard Lens, Different Inlets

• Not a large difference between the new and standard inlets
Velocity Calibration, High Pressure Lens and Constant Bore Inlet

![Graph showing velocity calibration with pressure and pinhole size.](image-url)
Solid Pb(NO3)2 Data graphed against classical aerodynamic diameter, Open circles are graphed against vacuum aerodynamic diameter.
Pressure Inlet Experiments, High Pressure Lens, Constant Bore Inlet

![Graph showing detection ratio vs. Dva (nm) for different lens configurations and pinhole sizes.](image-url)
Thank You!

• Leah Williams
• Everyone at Aerodyne especially the CACC group
• Department of Energy Global Change Education Program