Installation of the Model 5012 Multi-Angle Absorption Photometer (MAAP) for Real-time Black Carbon Monitoring

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Outline

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- Measurement Principle
- Setup
- Operation
- Maintenance
- Applications
Background

• “Elemental” Carbon
  – *Major component of PM2.5*
  – *Typically 25-50% of PM2.5 (as much as 70%)*
  – *Anthropogenic origin*
    • mobile sources
    • products of incomplete combustion
“Black” Carbon

- Surrogate for “elemental carbon” – not a chemical measure
- Measured continuously via
  - Optical (aerosol light absorption),
  - Thermal, and
  - Photoacoustic methods
Measurement Principle

- **Filter-based Aerosol Absorption Measurement Methods**
  - Sampling of particles on a fibrous filter matrix.
  - Measurement of the modified optical properties by the collected aerosol layer.

\[
\begin{align*}
\sigma_0^{(TRANS)} &= \frac{A}{V} \ln \left( \frac{T_0}{T} \right) \\
\sigma_0^{(REF)} &= \frac{A}{2V} \ln \left( \frac{R_0}{R} \right) \\
\sigma_0^{(MAAP)} &= (1 - SSA_L) \times LOD \times \frac{A}{V}
\end{align*}
\]

where,
\( \sigma_o = \) mass absorption efficiency, \( A = \) filter surface area, \( V = \) sampled volume, \( T = \) transmitted light, \( R = \) reflected light, \( SSA_L = \) single scattering albedo of filter aerosol layer, and \( LOD = \) layer optical depth.
Measurement Principle

Based on the 2002 Reno Aerosol Optical Study using kerosene soot and sulfate particle mixtures:

- **Filter transmittance method**
  - required correction of filter loading and aerosol scattering

- **Filter reflectance method**
  - required correction of filter loading

- **Multi-Angle Absorption Photometry**
  - required no correction of filter loading or aerosol scattering effects
Interaction of Aerosol, Filter Matrix, and Incident Radiation

Filter Matrix Effects (both positive and negative bias possible)

+ Multiple scattering of light by filter fibres and light-scattering aerosol particles tends to overestimate the absorption coefficient.

- ”Shadowing” of collected particles inside the fibre matrix tends to underestimate the absorption coefficient.
Measurement Principle

Model 5012 MAAP  Continuous Black Carbon Monitor:
*Multi-Angle Absorption Photometer*
Setup

• Standard 19” rack mounted (top rack)
• 110/220 VAC
• 8 – 20 L/min volumetric flow control
• Single point sensor and flow calibrations
• Compatible with USEPA 10-micron inlets and PM$_{2.5}$ sharp-cut cyclones.

• Indoor or outdoor shelter options
• Report in µg/m$^3$ or ng/m$^3$
• > 1-year tape supply
• Auto-filter advance (loading, cycle time, and hour of day)
Setup

- Front and rear door access
- -20 to 60 deg C
Operation

• Dual Serial Port Communications @9600 baud rate
• Front and rear scalable analog output (mA or VDC)
• Continuous Operation w/minimal maintenance
• Calibrate with FRM Calibration kits (NIST traceable flow transfer standard, thermometer, and barometer).
• 1 – 30 minute internally stored averages
• Internally logged calibration changes
• Internally logged instrument status
Annual Maintenance

• Sensor and flow calibration
• Cleaning of photo-detectors
• Vacuum pump maintenance
• O-ring replacements
• Filter tape replacement
Quarterly Maintenance

- System Audit
  - *flow rate, temps, pressure, optical check*
- PM$_{10}$ inlet and cyclone cleaning (w/optional inlets)
- Check filter tape supply
Monthly Maintenance

- Flow checks (control chart)
- Temp and Barometric check (control chart)
- Cyclone cleaning (w/optional inlet)
- Check filter tape supply
Applications

Bench Studies

*Reno Aerosol Optics Study June 2002 – accurate measure of aerosol absorption*

\[ \sigma_{ap(\text{MAAP})} = 1.04 \cdot (\sigma_{ap(\text{REF})}) + 1.0, \quad r^2=0.99 \]
Applications

Ambient Precision Studies

Franklin, MA Collocated Precision Evaluation June 2003

Collocated MAAPs w/PM2.5 Inlet - Field Calibrated for Ta, Pa, and Qa
Overnight Collocation at Franklin, MA Shelter June 17-18th, 2003 : 30 Minute Data Points
Applications

Ambient Accuracy Studies
Fresno, CA Supersite EC Data Comparison \[ y = 0.95x - 0.04; R^2 = 0.97 \]
Applications - 3 studies cited

Reno Aerosol Optics Study - Desert Research Institute, June 2002
Sheridan et al., Aerosol Sci. Technol, 2004
Test aerosols: kerosene flame soot, graphite particles, amm. sulphate
Reference methods: long-path extinction cell, integrating nephelometer

Optical properties of biomass burning - MPI Chemistry Mainz, February 2003
Schnaiter et al., Aerosol Sci. Technol., submitted
Test aerosols: combustion aerosol from corn stem burning
Reference methods: long-path extinction spectrometer, integrating nephelometer

AIDA SOOT 03 Study - Research Centre Karlsruhe, November 2003
Schnaiter, Schmid, Petzold, Kaminski, Weingartner, Saathoff et al.
Test aerosols: Diesel particles, PALAS spark discharge generator particles
Reference methods: long-path extinction spectrometer, integrating nephelometer
Long-term measurements at Jungfraujoch High Altitude Research Station (11,745 feet amsl) Operational since March 2003
NASA Aircraft Particle Emissions Experiment
APEX April 2004 - in collaboration with Aerodyne Research Inc.,

1 Hz data resolution
“… The IMPROVE EC versus MAAP BC comparison almost meets the equivalence criteria in summer except for a lower slope (0.94 ±0.06).”

The MAAP demonstrated an insignificant amount of seasonal variation during this study.
Ambient

- Air Toxic Monitoring
- AQ Index Reporting
- Fenceline Monitoring
- Air shed Characterization
- Visibility research
- Tropospheric Carbon Studies
For Questions or more Information

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