Module 4: Automated Ambient Air Sampling Devices and Monitors

Objectives:
- PM10 and PM2.5
- Ozone (O3)
- Sulfur dioxide (SO2)
- Nitrogen dioxide (NO2)
- Carbon Monoxide (CO)

PM10 and PM2.5

- Filter-based systems
  - Gravimetric
  - Gravimetric and speciation

- Automated systems
  - Gravimetric

PM10 and PM2.5 Filter-based Systems

- Federal Reference Method (FRM) in the U.S.
- Gravimetric examples
  - R & P (Ruprecht and Patashnick/Thermo)
  - BGI
  - Andersen (Thermo)
- Gravimetric with speciation examples
  - MetOne
  - Thermo Electron
Typical Filter-based Gravimetric Sampler

Typical Filter-based Gravimetric Sampler

Typical Filter-based Gravimetric Sampler: WINS Impactor
Typical Filter-based Gravimetric Sampler: Sharp-Cut Cyclone

Typical Filter-based Gravimetric Sampler: Sequential Sampling
- Sequential (in sequence) samplers can be programmed to collect several samples over several days.
- They start and stop automatically; run information is stored for later download to computer or to notebook data sheet.
- In each run, a new filter is moved into place for use. The operator does not have to visit the site as often.
- The carousel-type moves a tray of filter cassettes in a circular manner.
- The cartridge-type use a piston arrangement to place and remove filter cartridges.

Typical Filter-based PM2.5 Gravimetric Sampler: Portable “Audit”
Programming a PM2.5 Sampler Run

- Enter start date and time (usually 12:00 midnight, 0:00)
- Enter end date and time (same date, usually 24:00 for a 24-hour sample)
- Sampling filter or module number
- Sample ID, Site ID
- Activate system

Typical Filter-based PM2.5 Sampler Data Displays and Records

- Flow rate (average and coefficient variance)
- Flow rate (out of specifications for more than 5 minutes)
- Sample volume, total
- Temperature (minimum, maximum, average)
- Barometric pressure (minimum, maximum, average)
- Times: start, end, elapsed, out of specification
- Others

Typical Filter-based Speciation Sampler
Filter-based Speciation Sampler (R & P, Thermo System)

SSI PM10 Sampler Cut-Away View

Filter-based PM10 SSI Sampler Basic Laboratory Needs and Requirements

- Clean room for sample filter preparation and analysis
- Desiccators to condition PM10 filters or controlled temperature/relative humidity room
- Balance with a minimal resolution of 0.1 mg
- Calibration weights
- Laboratory notebook
- Filters
- Filter transporting bag with label
Set Up for Weighing 8 by 10-inch PM$_{10}$ Filter

Clean Room or Weighing Room Requirements
- Positive air flow preferred (positive pressure)
- Temperature Control (20 to 22° C ±2°C in 24 hours)
- Relative Humidity (30 to 40% ± 5% in 24 hours)
- Keep room dust-free
- Use lab coat and powder-free gloves

PM10 and PM2.5 Automated Systems
- Tapered element oscillating microbalance (TEOM)
- Beta gage attenuators
Tapered Element Oscillating Microbalance (TEOM)

Principle of operation
Tapered Element Oscillating Microbalance (TEOM)

Other Uses

- Particles caught on the TEOM filter can be analyzed further for ions and metals
- Optional Automatic Cartridge Collection Unit (ACCU) can be attached to the bypass flow line to collect additional samples
- Sampler can be set up to sample only at certain times during the day or only under certain meteorological conditions (when linked to a wind speed or direction sensor)

Example of Results Using a TEOM Sampler

Example of Three TEOM Samplers

Comparison of PM-10 Data from Three TEOM Monitors and Wind Speed
Birmingham, Alabama, 16 April 1990
Beta Gage Attenuators

"Smart Heater": This is a canister style heater on the inlet tube.

Beta Gage Attenuators

Met One Beta Attenuation Monitor (BAM) Model 1020

Radioactive Source ¹⁴C (Carbon-14) (less than 60 uCi)

The mass density of particulate on the filter is calculated from the measured reduction in the number of beta particles passing through the filter.

The BAM 1020 is a reference instrument for PM10.

Tape rolls last approximately two months.

Beta Gage Attenuators

Beta Gage Attenuators
PM10 and PM2.5 Automated Systems

- **Advantages**
  - Provide continuous or continual measurements of PM concentration
  - Can operate for days or weeks without attention
  - Can relay results electronically to a central location
  - Does not require a laboratory to weigh filters
  - Filters may be analyzed later for metals, etc
  - Can be used to measure TSP, PM10, and PM2.5 with proper inlet

- **Disadvantages**
  - Effects of moisture on sample demands careful control of temperature
  - TEOM filter can overload in highly polluted areas and affect accuracy
  - Beta ray gage has a radioactive source

Ozone (O3) Ultraviolet Photometry Method

Ultraviolet Photometry Method
- Principle of operation
- Instrument description
- Installation
- Calibration and operational checks
- Operation
- Data displays and output
**Ozone (O3) Ultraviolet Photometry Method**

**Principle of Operation**

- Ultraviolet light signal passes through a cell containing sampled air
- Ultraviolet light is absorbed in proportion to the amount of ozone present (Beer-Lambert Law)
- Air sample, scrubbed of ozone, provides an absorption “blank” reading

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**Example of Ozone (O3) Analyzers**

![Ozone Analyzer Image]

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**Ozone (O3): API Schematic**

![Ozone Schematic Image]
Ozone (O3): Installation

- Monitor is installed in a temperature controlled shelter, building, or mobile laboratory
- Sample from the outside ambient air must pass through Teflon or glass tubing. In-line glass catch bottle to trap bugs and water may be needed
- Source of clean, dry air needed for calibration and zero/span check system
- Ozone monitor zero/span check and data output can be automated
- Siting criteria must be followed

Ozone (O3): Calibration and Operational Checks

- Conduct a zero/span check every week
- Perform a calibration check of zero/span every 3 months
- Perform a flow check every 6 months

Ozone (O3): Operation of Continuous Monitor

- As part of the workshop, participants may be shown the operation of an ozone monitor
Ozone (O3): API Data Display and Input

- Ozone concentration displayed in ppm or ppb.
- Updated every few seconds
- Data can be stored and averaged by data acquisition systems as hourly, etc
- Example graph of daily average ozone concentration profile, Los Angeles, CA
- Graph to be scanned

Diurnal Plot of Ozone

Sulfur Dioxide (SO2): Pulsed Fluorescence Method

Pulsed Fluorescence Method
- Principle of operation
- Instrument description
- Installation
- Calibration and operational checks
- Operation
- Data displays and output
Sulfur Dioxide (SO2): API

Principle of Operation: Detection method is based on a 3-step process

- SO2 + UV light pulse to excite the molecule
- SO2 absorbs UV energy to go to SO2*
- SO2* decays to SO2 and emits fluorescence light, detected by PMT

Example of Sulfur Dioxide (SO2) Analyzers

![Example of Sulfur Dioxide (SO2) Analyzers](image)

Sulfur Dioxide (SO2): API Schematic

![Sulfur Dioxide (SO2) API Schematic](image)
Sulfur Dioxide (SO2): Installation

- Monitor is installed in temperature-controlled shelter, building, or mobile lab
- Sample from outside air must pass through Teflon/glass tubing
- Source of clean, dry air needed for zero check and for dilution of cylinder gas to produce span gas
- Zero/span and data output can be automated

Sulfur Dioxide (SO2): Calibration and Operational Checks

- Conduct a zero/span check every week
- Perform a calibration check of zero/span every 3 months
- Perform a flow check every 6 months

Sulfur Dioxide (SO2): Operation of Continuous Monitor

- As part of the workshop, participants may be shown the operation of a sulfur dioxide monitor
Sulfur Dioxide (SO2): API Data Display and Input

- Sulfur dioxide concentration displayed in ppb or ppm. Updated every minute or so.

- Data can be stored and averaged by data acquisition systems as hourly average, etc.

- Rapid changes in SO2 concentrations in the air may not be fully detected. Auto-ranging helps detect high values.

Nitrogen Dioxide (NO2): Chemiluminescence Method

Chemiluminescence Method

- Principle of Operation
- Instrument description
- Installation
- Calibration and operational checks
- Operation
- Data displays and output

Nitrogen Dioxide (NO2):

- Principle of Operation

- NO2 determined by indirect photometric measurement of light intensity when nitric oxide (NO) reacts with ozone (O3) to form NO2 and give off light (chemiluminescence).

- First, NO2 is quantitatively reduced to NO by a converter.
Nitrogen Dioxide (NO2): (Cont’d)

- **Principle of Operation**
  - Second, NO from NO2 reduction and NO already present in air react with O3 generated inside the monitor. Concentration is total oxides of nitrogen (NOx).
  - Third, NO already present in air is detected.
  - Fourth, NOx concentration minus NO concentration equals NO2 concentration.
Nitrogen Dioxide (NO2): API Installation

- Monitor is installed in temperature-controlled shelter, building, or mobile lab
- Sample from outside air must pass through Teflon/glass tubing
- Source of clean, dry air needed for zero check and for dilution of cylinder gas to produce span gas
- Zero/span and data output can be automated

Nitrogen Dioxide (NO2): Calibration and Operational Checks

- Conduct a zero/span check every week
- Perform a calibration check of zero/span every 3 months using a gas phase titration system
- Perform a flow check every 6 months
- Check the efficiency of the NO2 catalytic converter every 3 months

Gas Phase Titration System for NO2
Nitrogen Dioxide (NO₂): Operation of Continuous Monitor

- As part of the workshop, participants may be shown the operation of a nitrogen dioxide monitor.

Nitrogen Dioxide (NO₂): API Data Display and Input

- Oxides of nitrogen concentrations are displayed in ppb or ppm. Updated about every 2 minutes depending on monitor.
- Concentrations expressed as NOx, NO, and NO₂.
- Data can be stored and averaged by data acquisition systems as hourly average, etc.
- Rapid changes in NO/NO₂ ambient concentrations may result in erroneous values as cycle proceeds.

Carbon Monoxide (CO): Gas Filter Correlation Method

Gas Filter Correlation Method
- Principle of operation
- Instrument description
- Installation
- Calibration and operational checks
- Operation
- Data displays and output
Carbon Monoxide (CO):

- **Principle of operation**

- Infrared (IR) light is absorbed by CO in the ambient air sample.
- The absorption of IR light by CO in air is compared to absorption of a reference gas contained in a gas filter wheel within the monitor.
- IR energy loss through the sample cell is compared to span reference signal from filter wheel and concentration of CO computed by Beer-Lambert Law relations.

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Example of Carbon Monoxide (CO) Analyzers

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Schematic Diagram of a CO Instrument with Optional Converter
Carbon Monoxide (CO): API Installation

- Monitor is installed in temperature-controlled shelter, building, or mobile lab
- Sample from outside air must pass through Teflon/glass tubing
- Source of clean, dry air needed for zero check and for dilution of cylinder gas to produce span gas
- Zero/span and data output can be automated

Carbon Monoxide (CO): Calibration and Operational Checks

- Conduct a zero/span check every week
- Perform a calibration check of zero/span every 3 months
- Perform a flow check every 6 months

Carbon Monoxide (CO): Operation of Continuous Monitor

- As part of the workshop, participants may be shown the operation of a carbon monoxide monitor
Carbon Monoxide (CO): API Data Display and Input

- CO concentrations are displayed in ppm
- Range is user selectable; 0 to 1 ppm up to 0 to 1,000 ppm
- Data can be stored internally and expressed later as hourly averages, etc
- Remote control and access of the displayed data is available

Example of Automated Air Sampling Devices in Holding Rack

Approximate Costs for Automated or Continuous Monitors

- PM10 or PM2.5 FRM Sampler: US $8000
- PM10 or PM2.5 Speciation Sampler: US $10000
- Ozone Chemiluminescent Monitor: US $9400
- Sulfur Dioxide Fluorescence Monitor: US $9500
- Nitrogen Dioxide Monitor: US $10000
- Carbon Monoxide: US $10800
- Clean Air Supply: US $4000
- Dynamic Calibrator: US $5000
- Shelter, Temperature Controlled: US $5000
Module 4 Review

Our Objectives for Module 4 were to give information about automated methods for measurement of these particulate and gaseous air pollutants:

- PM10 and PM2.5
- Ozone (O3)
- Sulfur dioxide (SO2)
- Nitrogen dioxide (NO2)
- Carbon Monoxide (CO)