Quality Assurance Project Plan

Bethel Road Dust Study

Air Monitoring & Quality Assurance Program

State of Alaska
Department of Environmental Conservation
Division of Air Quality

555 Cordova Street
Anchorage, AK 99501

May 2025

This page intentionally left blank

1. QA Project Plan Identification & Approval

Title: **Quality Assurance Project Plan for the "Bethel Road Dust Study" Project**

The attached Quality Assurance Project Plan (QAPP) for the State of Alaska's "Bethel Road Dust Study" Project (Revision 1.0) is hereby recommended for approval. This document outlines the quality assurance and quality control procedures that will be followed to ensure the integrity and reliability of the data collected. By approving this QAPP, the Alaska Department of Environmental Conservation (ADEC) commits to adhering to the methodologies and protocols described herein, thereby ensuring that the project meets all regulatory and scientific standards. This QAPP has been prepared in accordance with the EPA's Quality Assurance Project Plan Standard (Directive No.: CIO 2105-S-02.0, March 2023).

Alaska Department of Environmental Conservation

Lydia Johnson, Project Manager
Air Monitoring & Quality Assurance Program
Phone: (907) 451-2130
Email: lydia.johnson@alaska.gov

Signature: ____________________ Date: 5/19/2025

Rochele Rodman, QA Manager
Air Monitoring & Quality Assurance Program
Phone: (907) 465-5344
Email: rochele.rodman@alaska.gov

Signature: ____________________ Date: 5/20/2025

Environmental Protection Agency

Cindy Fields, Regional QA Manager
US EPA Region 10
Phone: (206) 553-1893
Email: fields.cindy@epa.gov

Signature: CINDY FIELDS Digitally signed by CINDY FIELDS Date: 2025.05.20 10:48:06 -07'00' Date: ____________

Joey Richardson, Project Officer
US EPA Region 10
Phone: (206) 553-2928
Email: richardson.joey@epa.gov

Signature: JOSEPH RICHARDSON Digitally signed by JOSEPH RICHARDSON Date: 2025.05.20 09:49:09 -07'00' Date: ____________

2. Table of Contents

2.1. List of Tables

2.2. List of Figures

2.3. Acronyms, Terms, and Definitions

Abbreviation/Term	Definition
AAAQS	Alaska Ambient Air Quality Standards
DEC	Alaska Department of Environmental Conservation - The department of state government with primary responsibility for management and oversight of provisions of the Clean Air Act, including EPA's National Ambient Air Quality Standards.
Air Quality Index (AQI)	The AQI is an index for reporting daily air quality and what associated health concerns the public should be aware of. The AQI focuses on health effects that might happen within a few hours or days of breathing polluted air. The AQI rates the air quality in 6 steps from good to hazardous.
AMQA	Air Monitoring and Quality Assurance Program of ADEC - Responsible for coordinating all aspects (quality assurance, data collection, and data processing) with respect to ambient air quality and meteorological monitoring of the ADEC Division of Air Quality.
ANTHC	Alaska Native Tribal Health Consortium
AUTC	Alaska University Transportation Center
Criteria Pollutant	Any air pollutant for which the EPA has established a National Ambient Air Quality Standard for regulation under the Clean Air Act.
Coarse particulate matter - PM_{10}	Particulate matter less than or equal to 10 microns in size.
DAS	Data acquisition system
DC	Data completeness
DEC	Alaska Department of Environmental Conservation - The department of state government with primary responsibility for management and oversight of provisions of the Clean Air Act, including EPA's National Ambient Air Quality Standards.
DQO	Data quality objective
E-BAM	Met One Environmental Beta Attenuation Mass Monitor
EPA	U.S. Environmental Protection Agency
FEM	Federal equivalent method
FRM	Federal reference method
MQO	Measurement quality objective
NAAQS	National Ambient Air Quality Standards
Fine particulate matter - $PM_{2.5}$	Particulate matter less than or equal to 2.5 microns.
Particulate matter – PM_{10}	Particulate matter less than or equal to 10 microns.
Performance Audit	An audit of one or more monitors within a monitoring network using certified calibration standards to evaluate monitor accuracy. Performance audits are conducted by an independent auditor using calibration

	standards provided by the auditor rather than those that are used for routine precision and accuracy checks. The ADEC QA Officer performs regular performance audits for each criteria pollutant monitored by ADEC.
NAAQS	National Ambient Air Quality Standards
ONC	Orutsararmiut Native Council
QA	Quality assurance
QAPP	Quality Assurance Project Plan- A plan which identifies data quality goals and identifies pollutant-specific data quality assessment criteria.
QC	Quality control
QMP	Quality Management Plan - A plan which describes the roles and responsibilities for maintaining a Quality System within a program or organization.
SLAMS	State and Local Monitoring Station - SLAMS consist of a network of roughly 4,000 monitoring stations nationwide. Distribution depends largely on the needs of the State and local air pollution control agencies to meet their respective State Implementation Plan (SIP) requirements. The SIPs provide for the implementation, maintenance, and enforcement of the NAAQS in each air quality control region within a state. The State of Alaska monitoring network currently has eight SLAMS sites for carbon monoxide and PM.
SPMS	Special Purpose Monitoring Station - Special purpose monitoring stations are not permanently established and can be adjusted to accommodate changing needs and priorities for special studies needed by the State and local agencies. The SPMS are used to supplement the fixed monitoring network as circumstances require.
$\mu g/m^3$	Micrograms per cubic meter
$\mu g/sm^3$	Micrograms per standard cubic meter
VSCC	Very sharp cut cyclone
YKHC	Yukon-Kuskokwim Health Corporation

3. Distribution List

A hardcopy of this Quality Assurance Project Plan (QAPP) for the Bethel Road Dust Study has been distributed to the individuals listed in Table 1. An electronic version is available on the Alaska Department of Environmental Conservation's Air Monitoring & Quality Assurance Program (AMQA) website (https://dec.alaska.gov/air/air-monitoring/guidance/data-summaries/bethel-dust-study/).

Table 1: Distribution List

Name	Position	Division/Office	Contact Information
Lydia Johnson	Program Manager/Project Lead	Alaska Department of Environmental Conservation	lydia.johnson@alaska.gov (907) 451-2130
Ayla Crosby	Environmental Program Specialist 3	Alaska Department of Environmental Conservation	Ayla.crosby@alaska.gov (907) 269-7550
Grace Carico	Environmental Program Specialist 3	Alaska Department of Environmental Conservation	grace.carico@alaska.gov (907) 451-2164
Rochele Rodman	QA Manager	Alaska Department of Environmental Conservation	rochele.rodman@alaska.gov (907) 465-5344
Lori Strickler	City Manager	City Of Bethel	Citymanager@cityofbethel.net (907) 543-1373
Brian Lefferts	Director, Public Health	Yukon-Kuskokwim Health Corporation	Brian_lefferts@ykhc.org (907) 543-6423
Alyssa Leary	Environmental Health Services Manager	Yukon-Kuskokwim Health Corporation	Alyssa_leary@ykhc.org (907) 545-0150
Mary Herrera-Matthias	Natural Resources Director	Orutsararmiut Native Council	mmatthias@nativecouncil.org (907) 543-0516
Christina Miller	Grants Officer, Region 10	U.S. Environmental Protection Agency	miller.christina@epa.gov
Cindy Fields	Regional QA Manager, Region 10	U.S. Environmental Protection Agency	fields.cindy@epa.gov (206) 553-1893
Joey Richardson	Senior Air Monitoring Specialist, Region 10	U.S. Environmental Protection Agency	richardson.joey@epa.gov (206) 553-2928

4. Project/Task Organization

Road dust is a main air quality issue in rural Alaska. Many communities conduct survey-style road dust monitoring with portable particulate matter monitors like the DustTrak™. Road dust has been monitored in Bethel off and on over the last 20 years. The latest monitoring study was conducted by the Yukon Kuskokwim Health Corporation Public Health Division (YKHC). Measurements conducted by YKHC showed high concentrations of PM_{10} and $PM_{2.5}$. Since the DustTrak does not meet the quality assurance (QA) requirements for comparison to the National Ambient Air Quality Standards (NAAQS), the Alaska Department of Environmental Conservation (DEC) decided to design a study that will help determine the levels of PM_{10} and $PM_{2.5}$ in a residential area of Bethel. Funding for the study is provided through grants from the U.S. Environmental Protection Agency (EPA). DEC will work with partners in Bethel, mostly with the City of Bethel, the Orutsararmiut Native Council (ONC), and the YKHC Public Health Department.

<u>Alaska Department of Environmental Conservation</u>:

- **Jason Olds** is the DEC Division of Air Quality Director.
- **Rochele Rodman** is the QA Manager for the AMQA program. This position provides QA oversight for the Division of Air Quality. Rochele Rodman reports QA matters to Jason Olds.
- **Lydia Johnson** is the Program Manager for the AMQA Data Management Section and Project Manager for this study. Responsible for overseeing the project, coordinating with partners, and ensuring the project meets its objectives. Is responsible for maintaining the project QAPP.
- **AMQA Data Management Section staff** will conduct site installations, calibrations, quality control (QC) checks, data analysis, and reporting.

<u>City of Bethel:</u>

- **Lori Strickler** is the City Manager. Supports the project with technical assistance for site selection, logistics, and communicating the purpose and monitoring results of this road dust study to the community.

<u>Yukon Kuskokwim Health Corporation (YKHC):</u>

- **Brian Lefferts** is the Public Health Director for YKHC.
- **Alyssa Leary** is the Environmental Health Services Manager for YKHC.
- **YKHC staff** will support the project with technical assistance for site selection, logistics, and communicating the purpose and monitoring results of this road dust study to the community.

<u>Orutsararmiut Native Council (ONC)</u>

- **Mary Herrera-Matthias** is the Natural Resources Director for ONC. Supports the project with technical assistance for site selection, logistics, and communicating the purpose and monitoring results of this road dust study to the community.

<u>EPA Region 10:</u>

- **Joey Richardson** is a Senior Air Monitoring Specialist and project officer.
- **Cindy Fields** is the EPA Region 10 QA Manager. Coordinates quality assurance matters at the regional level with state, local agencies, and Tribes.

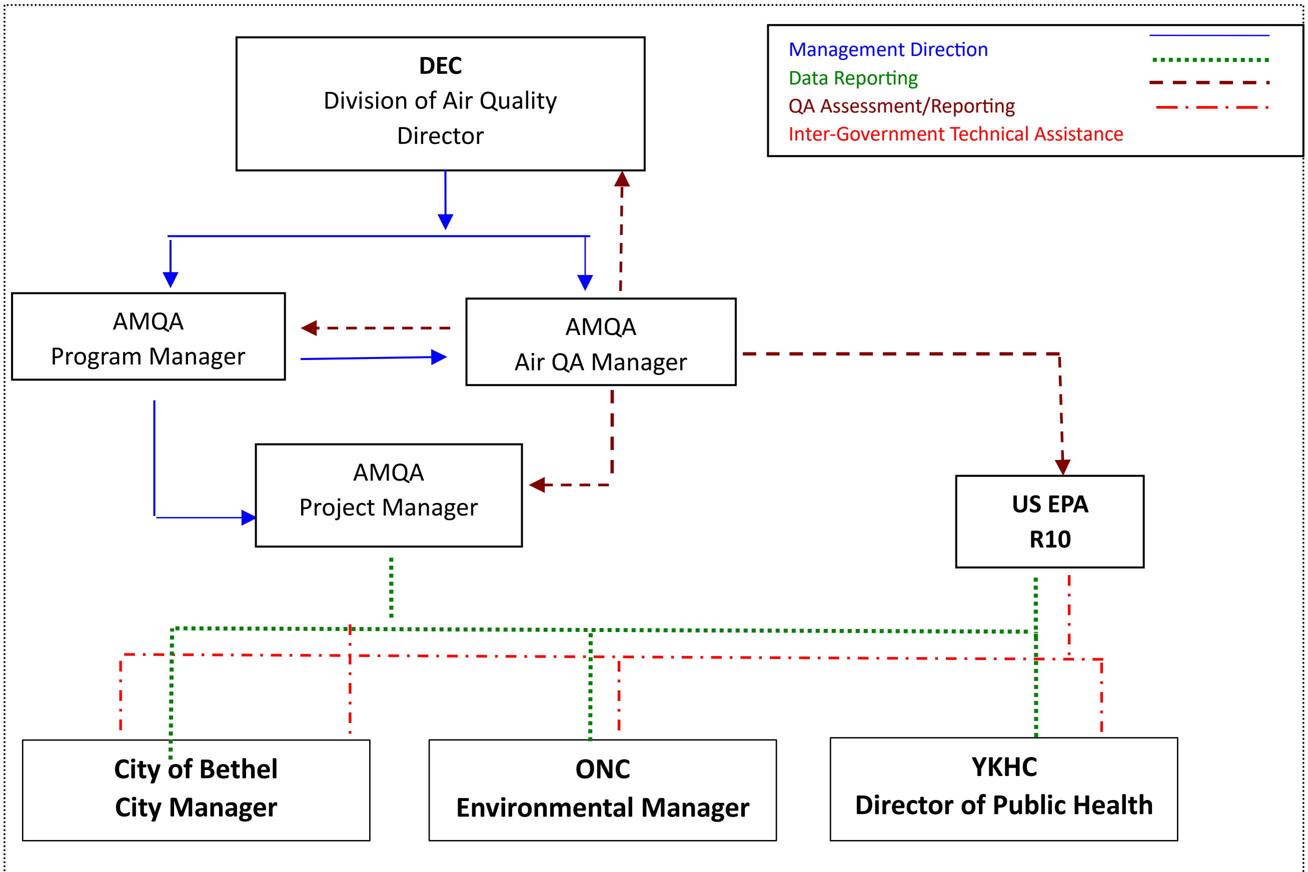


Figure 1. Project Organizational Chart

5. Problem Definition and Background

Road dust is the main air quality concern statewide. Various surveys have indicated that road dust impacts exist in all ecoregions of the state. For years road dust has been identified as the main air quality concern in many communities. Even Alaska's metropolitan areas like the Municipality of Anchorage deal with road dust issues annually. Road dust is measured as particulate matter with an aerodynamic diameter of less than 10 micrometer (PM_{10}). The U.S. Environmental Protection Agency (EPA) has established a health-based standard for PM_{10} due to its adverse health effects, including respiratory and cardiovascular issues.

To better understand the road dust impacts, the Department of Environmental Conservation (DEC) Air Monitoring and Quality Assurance Program (AMQA) conducted air monitoring in several communities between 2003 and 2005. At the time, monitoring projects used available Federal Reference Method monitors. This method involves laboratory analysis of filters before and after the sampling event, which is labor intensive and expensive. Additionally, information about the sampling is often not available for several weeks, as samples must be shipped back to the lab for weighing. Due to the high cost of these monitoring project, few occurred in recent years.

Over the past decade, low-cost sensor technology has offered an alternative path to estimating impacts of road dust. Low-cost technology is easier to use and reduces the cost of monitoring significantly but comes at the cost of accuracy and precision. The technology is still very useful for collecting information on trends and to identify potential sources of PM emissions. However, it is not suitable for comparing results to the National Ambient Air Quality Standards (NAAQS).

As a training tool and for survey purposes, the EPA and the Alaska Native Tribal Health Consortium (ANTHC) have used the TSI DustTrak[1] for road dust studies in rural Alaska. Results in many communities have identified a significant portion of PM_{10} as $PM_{2.5}$. Health risks associated with $PM_{2.5}$ are more severe than for PM_{10}, and DEC wants to better understand the accuracy of these measurements.

The Yukon Kuskokwim Health Corporation's Environmental Health Program (YKHC) conducted studies in Bethel using a DustTrak. Results indicated that a large portion of the sample was in the size range of fine particulate matter ($PM_{2.5}$). Since the last road dust study DEC supported was in the 2015 Ruby Road Dust Study[2], DEC has decided to conduct a new study. DEC is working with YKHC, the City of Bethel, the Orutsararmuit Native Council (ONC) and the Alaska University Transportation Center (AUTC).

[1] https://tsi.com/products/aerosol-and-dust-monitors/aerosol-and-dust-monitors/dusttrak%E2%84%A2-ii-aerosol-monitor-8530
[2] https://dec.alaska.gov/air/air-monitoring/guidance/data-summaries/

6. Project/Task Description

The goal of the study is to document road dust on a typical residential street in Bethel to determine the amount of PM_{10} and $PM_{2.5}$ particles in the ambient air. The study will employ five Met One E-BAMs; three E-BAMs measuring $PM_{2.5}$ and two E-BAMs measuring PM_{10}. One $PM_{2.5}$ E-BAM will be set up away from the study area as the quality control instrument, while the other four E-BAMs will be placed on each side of the residential roadway; two E-BAMs, one measuring $PM_{2.5}$ and one measuring PM_{10}, will be placed on each side of the roadway.

The E-BAM is not currently designated as an EPA federal equivalent method (FEM) for continuous PM_{10} or $PM_{2.5}$ monitoring, but the unit is designed to accurately predict federal reference method (FRM) or FEM concentration measurements. DEC will apply the QA requirements for the FEM BAM 1020 sampler, which is very similar to the E-BAM in function and performance.

6.1. Workplan Activities and Schedule

Discussions surrounding a potential road dust study in Bethel started in 2023. Plans for a spring study in 2024 had to be postponed due to DEC staff shortages. In January 2025, DEC held a planning meeting in Bethel. Based on discussions with the Bethel project partners, road dust is anticipated to begin in early June. DEC plans to be ready to install sampling equipment by the end of May 2025. Table 2 summarizes the major milestones of the project.

Table 2. Workplan Timeline

Milestone Date	Workplan Activity	Description
January 30, 2025	Planning Meeting in Bethel	Meet with YKHC, City of Bethel, ONC, AVCP staff, and other stakeholders in Bethel
April 30, 2025	Site Reconnaissance	Preliminary review of potential monitoring site locations in coordination with stakeholders
April 30 2025	Equipment Testing	Test E-BAM analyzers in Anchorage prior to deployment
April 30 2025	Instrument update	Telemetry system AirSis returned to manufacturer for update/repair
April 30, 2025	Site Selection	Finalize monitoring site selection
May 15, 2025	QAPP development	Develop QAPP including siting information
May 30, 2025	Site Installation	Install sites in Bethel as dry, road dust season starts
May/June 2025	Data Collection	Monitor for 4 to 6 weeks depending on weather and dust events for sufficient data capture
August 30, 2025	Data Analysis	Analyze PM_{10} and $PM_{2.5}$ data and share preliminary findings with stakeholder.
November 15, 2025	Draft Report	Develop draft report and share with stakeholders for review and commenting
December 31, 2025	Final Project Report	Finalize Final Project Report

7. Quality Objectives and Criteria

7.1 Data Quality Objectives (DQOs)

DQOs are qualitative and quantitative statements derived from the DQO process that:

- Clarify the monitoring objectives.
- Define the appropriate type of data.
- Specify the tolerable levels of decision errors for the monitoring program.

By applying the DQO process to the development of a quality system, the Air Quality Program guards against committing resources to data collection efforts that do not support a defensible decision.

The main study objectives are to:

1. Measure hourly and daily PM_{10} concentrations from road dust during dusty season, and
2. Simultaneously measure hourly and daily $PM_{2.5}$ to determine the fine particulate matter content of road dust in Bethel.

The DQOs were subsequently translated into the measurement quality objective (MQO) for each parameter (Table 3).

7.2 Data Quality Indicators (DQIs)

Once a DQO is established, the quality of the data must be evaluated and controlled to ensure that it is maintained within the established acceptance criteria. DQIs and MQOs are designed to evaluate and control various phases (sampling, preparation, and analysis) of the measurement process to ensure that total measurement uncertainty is within the range prescribed by the DQOs. DQIs and MQOs are defined in terms of *precision, bias, representativeness, detectability, completeness, and comparability*.

Bias – Bias is the systematic or persistent distortion of a measurement process that causes uncertainty in one direction (e.g., results are either higher than or lower than they should be). Bias is estimated by evaluating the instrument-measured result against a known standard used as the "true" value. It is expressed as a positive or negative percentage of the "true" value. In this program, manual QC checks with a known standard concentration are performed at least every two weeks for gaseous pollutants and monthly for particulate pollutants. These checks will be the primary method for estimating bias on an ongoing basis. Performance audits will provide another estimate of bias. These audits will be conducted by personnel using equipment and standards that are completely independent from those used to calibrate the monitoring equipment and the personnel responsible for site operations. In this program, bias is estimated using the calculations found in Table 7.

Precision - Precision is a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions, or how well side-by-side measurements of the same thing agree with each other. It is important that the measurements be as similar as possible, using the same equipment or equipment as similar as possible. Precision represents the random component of uncertainty. This random component is what changes randomly high or low and cannot be controlled with the equipment and procedures used. Precision is estimated by various statistical techniques using the standard deviation or, if you only have two measurements, the percent difference.

Representativeness - Representativeness is defined as a measure of the degree to which data represents some characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The representativeness of measurements in this program is ensured by adhering to EPA siting guidelines.

Detectability – Defined as the lowest value that a method's procedure can reliably discern a measured response above background noise. In other words, detectability is the level at which the instrument can reliably distinguish a signal from zero. Because there is inherent variation in any measurement process (precision uncertainty), the level of detectability depends on the amount of precision error present. Detectability is determined by the manufacturer's specifications.

Completeness - Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. It is expressed as a percentage of the valid data collected relative to the total data expected.

Comparability – Comparability is a measure of confidence with which one set of data can be compared to another. This is crucial for ensuring that data sets from different locations or timeframes can be reliably compared.

References to Regulatory and Guidance Documents:

This QAPP has been prepared in accordance with the following regulatory and guidance documents:

- EPA's Quality Assurance Project Plan Standard (Directive No.: CIO 2105-S-02.0, March 2023)
- EPA's Guidance for Systematic Planning Using the Data Quality Objectives Process (QA/G-4, February 2006).

Table 3: Monitoring Measurement Quality Objectives

Table 3. Monitoring MQOs							
Parameter	**Comparability**		**Completeness**		**Bias**	**Representativeness**	
	Equipment	**Reference/ Method**	**Hourly**	**Daily**		**Sampling Frequency**	**Siting**
$PM_{2.5}$ and PM_{10} Continuous Methods	Met One E-BAM	DEC AMQA Met One E-BAM SOP EPA QA guidance criteria for continuous PM	≥75 %	≥ 75% aggregate hours/day	**Flow audit** $PM_{2.5}$ & PM_{10} Design Flow: ≤ ±5.1% Δ (16.7 lpm) PM_{10} & $PM_{2.5}$ Accuracy Flow: ≤ ±4.1% Δ	Continuous, hourly average,	EPA siting guidelines for PM_{10} and $PM_{2.5}$

8. Special Training and Certification

Air monitoring personnel will be recruited and screened to ensure they are experienced and qualified. Air monitoring personnel will meet the educational, work experience, responsibility, personal attributes, and training requirements for their respective positions. Training will be available to employees supporting the AMQA Program, commensurate with their assigned duties and sufficient to contribute to the reporting of complete and high-quality data.

Primary responsibility for training will rest with the individual's supervisor. Records on personnel qualifications and training will be maintained in personnel files. Training may consist of courses, workshops, classroom lectures, teleconferences, and on-the-job training. The following groups provide training: U.S. EPA's Air Knowledge (https://airknowledge.gov/), U.S. EPA Quality Assurance Division (QAD), U.S.EPA Office of Air Quality Planning and Standards (OAQPS).

Training Plan:

The training plan will include specific programs, courses, and certifications required for personnel. This will ensure that all personnel are adequately trained to perform their duties effectively.

Documentation and Assurance:

Training will be documented and assured through a systematic process. Training records will be verified and updated regularly to ensure accuracy and completeness. This process will include regular audits and reviews to ensure compliance with training requirements. Training records are stored on DEC's internal server.

Specialized Training:

Specialized training and certifications will be identified and provided to personnel as needed. This may include training on specific equipment, procedures, or regulatory requirements relevant to the project.

9. Documentation and Records

DEC will maintain a logbook documenting operational and maintenance activities with each E-BAM unit used in the study. The logbook will be used to document quality control checks (calibration, temperature, pressure, flow, etc.), maintenance, and equipment changes and moves. The logbook will also include records of problems encountered and corrective actions taken.

Study data will be housed on DEC's internal server; DEC's server is backed up nightly. The data will include raw data, field and logs, results of calibration and QC checks, audit results, problems and corrective actions/resolutions, QAPP revisions, and the final project report.

Written and electronic data reports (CD/DVD/email) will be provided by DEC. The retention time for all records and reports will be a minimum of 10 years, and they will be stored on DEC's internal server.

10. Sampling Process Design

DEC, with input from the local stakeholders, selected a location along a gravel road which experiences frequent and busy pedestrian traffic. The final locations will be determined by the need for power and the ability to place the monitors next to the roadway at a safe distance. Final locations will be reported in the final project report. Two E-BAMs will be placed on each side of the road. Each site will have one E-BAM measuring PM_{10}, and the second one will use a very sharp cut cyclone (VSCC) to measure $PM_{2.5}$. A fifth E-BAM will be set up in a location away from the road area to measure the communities background $PM_{2.5}$ concentrations.

DEC has three Airsis systems for communicating the data in real-time via satellite connection. Each $PM_{2.5}$ E-BAM will be equipped with an AirSis unit. The E-BAMs collect hourly averaged PM data, which will be averaged into 24-hour averages. The E-BAMs will be calibrated at the sampling location prior to the study. Flow checks will be conducted prior to and at the end of the study. If the study extends for more than 30 days, another flow check will be conducted around the 30-day mark.

11. Sampling Methods

This study will use Met One E-BAM technology, which automatically measures and records airborne PM_{10} or $PM_{2.5}$ particulate concentration levels using the principle of beta ray attenuation. This method provides a simple determination of concentration in units of milligrams of particulate per cubic meter of air [3]. A vacuum pump within the instrument pulls a measured amount of air through filter tape, and the mass concentration is read on the filter tape.

<u>Sample Collection Procedure and Methods:</u>

- Samples will be collected continuously using an E-BAM, with hourly averages recorded. The E-BAMs collect hourly averaged PM data, which will then be averaged into 24-hour averages.
- The sampling process will follow the procedures outlined in DEC's Environmental Beta Attenuation Monitor Standard Operating Procedures document, located in Appendix A, which details the steps for setting up the E-BAM, calibrating the instrument, and collecting samples.

<u>Compliance with Reference Method Requirements:</u>

- Although the E-BAM is not currently designated as an EPA FEM for continuous PM_{10} or $PM_{2.5}$ monitoring, it is designed to accurately predict FRM or FEM concentration measurements.
- The study will apply the QA requirements for the FEM BAM 1020 sampler, which is very similar to the E-BAM in function and performance.

<u>Calibration and Maintenance Procedures:</u>

[3] Met One, *E-BAM Particulate Monitor Operation Manual*, 2021.

- Calibration of the E-BAM will be performed before each sampling event using a certified calibration standard. The calibration procedures are detailed in DEC's Environmental Beta Attenuation Monitor Standard Operating Procedures document, located in Appendix A.
- Routine maintenance, including filter tape replacement and vacuum pump inspection, will be conducted per the manufacturer's guidelines and documented in the maintenance log.

Performance Requirements:

- Performance requirements for the E-BAM include a precision of ±5%, an accuracy of ±10%, and a detection limit of 0.1 mg/m^3. These requirements are detailed in the instrument manual (Appendix B).
- Method-specific data validation tables (DVTs) will be used to present these performance requirements. The DVTs will include precision, accuracy, and detection limits for each parameter measured. DVTs are located in Appendix C.

12. Sample Handling and Custody

This project does not require the traditional sampling or analysis of physical samples. Instead, it utilizes Met One E-BAM technology for real-time measurement and recording of airborne PM_{10} and $PM_{2.5}$ particulate concentration levels. As such, there are no specific sample handling, labeling, collection, or transportation requirements. However, all data collected by the E-BAMs will be managed and documented according to the procedures outlined in DEC's Environmental Beta Attenuation Monitor Standard Operating Procedures document, located in Appendix A.

13. Analytical Methods

DEC has reviewed section 2.2.4, "Analytical Methods", of the EPA's Guidance for Quality Assurance Plans. It has been determined that this section does not apply to the Bethel Road Dust Study, as this project does not involve the sampling or analysis of physical samples.

14. Quality Control

All E-BAMs will be calibrated in the field prior to the start of the study. One-point flow checks/verifications will be conducted both before the study begins and at its conclusion. If the study extends beyond 30 days, an additional one-point flow check/verification will be conducted around the 30-day mark. The performance criteria are detailed in Table 4 below. The one-point flow check form is located in Appendix E.

Table 4: Calibrations and QC Checks

Check	Interval	Tolerance	Reference
Temperature calibration	At start up, 1/year	< ± 2.1°C	40 CFR Part 50 App L
1-Point Temperature Check	1/month	< ± 2.1°C	
Pressure calibration	At start up, 1/year	< ±10.1 mmHg	
1- Point Pressure Check	1/month	< ±10.1 mmHg	
Flow calibration	At start up, 1/year	< ± 2.1% of indicated flow < ± 2.1% of design flow (16.7 L/min)	
1-Point Flow Check/Verification	1/month	< ± 4.1% of indicated flow < ± 5.1 % of design flow	
External Leak Check	1/month	≤ 1.5 L/min	
Clock verification	1/month	+/- 1 minute of NIST-Alaska Standard Time (AST) if not controlled by central data acquisition system	
Data logger verification (compare direct download from instrument to data logger results)	At start up, 1/month	Exact agreement (digital)	QA Handbook Vol II Appendix D

At least one audit will be performed during the study. The audit criteria are in Table 5 below. The E-BAM audit form is located in Appendix E.

Table 5: Audit Criteria

Check	Interval	Tolerance	Reference
Leak Check Audit	1/6 months	≤ 1.5 L/min	40 CFR Part 50 App L
Temperature Audit	1/6 months	< ± 2.1°C	
Pressure Audit	1/6 months	< ±10.1 mmHg	
Flow Audit	1/6 months	< ± 4.1% of audit standard < ± 5.1% of design flow (16.7 L/min)	
Clock verification	1/month	+/- 1 minute of NIST-Alaska Standard Time (AST) if not	

		controlled by central data acquisition system	

15. Instrument/Equipment Testing, Inspection, and Maintenance

AMQA staff are responsible for performing routine preventive and corrective maintenance. One logbook will be used to keep a record of the need for maintenance, the actions performed and the condition of the instrument after maintenance procedures were performed. Additionally, the date, time, initials, and any pertinent site observations will be recorded.

Acceptance Testing:

Acceptance testing of the sampling process and field and laboratory measurement systems will be conducted according to the procedures outlined in DEC's Environmental Beta Attenuation Monitor Standard Operating Procedures document, located in Appendix A. This includes initial calibration and performance verification of E-BAM units.

Preventative and Corrective Maintenance:

Equipment will be maintained according to frequencies outlined in EPA's Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II[4], or by the maintenance frequency recommended in the respective instrument manufacturer's manual. A summary of the maintenance items and frequency is provided below in Table 6. Maintenance activities will be performed in accordance with Section 5 of the Met One E-BAM manual[5].

Availability and Location of Spare Parts:

Spare parts for the E-BAM units, including filter tapes, nozzles, and other critical components, will be stored at the DEC's Fairbanks and Anchorage offices. An inventory of spare parts will be maintained and regularly updated.

Table 6: Maintenance Schedule

Maintenance Item	Frequency
Leak check	Monthly
Nozzle and tape vane cleaning	Monthly
Flow audit, including ambient temperature and pressure	Monthly
Clean PM_{10} inlet particle trap	Monthly
Clean $PM_{2.5}$ cyclone particle trap	Monthly
Data download	Monthly
E-BAM clock check	Monthly
Replace filter tape	As needed

[4] https://www.epa.gov/sites/default/files/2020-10/documents/final_handbook_document_1_17.pdf
[5] Met One, *E-BAM Particulate Monitor Operation Manual*, 2021.

16. Instrument/Equipment Calibration and Frequency

Multi-point calibrations will be used by AMQA to establish or verify the linearity of particulate monitor flow rate responses to known flow rates upon initial installation, following physical relocation, after major repairs, after failure of a one-point QC flow check or performance audit, and at specified frequencies.

Each E-BAM will undergo flow checks and calibration prior to and at the end of the study, and if the study is conducted for more than 30 days mid-way through the study. The calibration and verification frequencies are summarized in Table 4.

Calibration Standards and Traceability:

Calibration standards used for the E-BAM units will be certified and traceable to national or international standards. The certification date, expiration date, range, and accuracy of each calibration standard will be documented and included in the calibration records.

Calibration Standards and Equipment:

The required calibration standards and equipment for the E-BAM units include certified flow rate standards, temperature and pressure sensors, and other relevant calibration tools.

Calibration Records:

Calibration records will be maintained for each E-BAM unit, documenting the calibration date, results, and any adjustments made. These records will be traceable to the specific equipment and stored in the project logbook.

17. Inspection/Acceptance for Supplies and Consumables

The DEC Program Manager is responsible for identifying air monitoring equipment needs and approving equipment purchases. The following protocol will be used in the procurement of air monitoring equipment:

- **Equipment Evaluation and Selection:**
  - Prior to purchase, the equipment's performance will be evaluated, and other users will be queried regarding the performance, dependability and ease of operation.
- **Acceptance Testing:**
  - Prior to payment, the equipment will be tested to ensure that it meets the requirements listed in the purchase specifications.
- **Record Keeping:**

  - Records of the inspection and acceptance process will be maintained in the project logbook. This includes documentation of the equipment evaluation, selection, and acceptance testing results.

- **Responsible Individual**
  - The DEC Program Manager is responsible for overseeing the inspection and acceptance process and ensuring that all records are properly maintained.

18. Non-Direct Measurements

This study does not include non-direct measurements.

19. Data Management

Hourly PM data is recorded by the on-board Met One data acquisition system. Data will be manually downloaded from the instruments by means of an RS-232 serial port connected to a laptop using Met One's Comet data retrieval software; all data logs, errors logs, and settings files can be downloaded via Comet. Three E-BAMs will be outfitted with AirSis satellite units that will relay data to an online platform. Once data is downloaded, it will be stored in a project-specific folder on DEC's internal server. All AMQA staff have access to the project folder. DEC's data retention policy requires storage of project data for a minimum of 10 years.

Data Management Process

The data management process involves recording hourly PM data, manually downloading it using Comet software, and storing it on DEC's internal server. The $PM_{2.5}$ E-BAMs will be equipped with AirSis satellite communication units that relay real-time data to an online platform. DEC will download the data and it will be stored on DEC's internal server. PM_{10} data will be downloaded manually via the Comet data retrieval software.

Standard Record-Keeping

Standard record-keeping procedures include storing data in a project-specific folder on DEC's internal server and retaining project data for a minimum of 10 years. All project related documents will be stored in the project folder on DEC's internal server.

Data Handling Equipment and Procedures

Data handling equipment includes Met One's Comet data retrieval software and AirSis satellite units. The procedures for processing, compiling, and analyzing data involves averaging hourly data into 24-hour averages and generating a final project report with graphical summaries and validated data embedded in Excel spreadsheets.

20. Assessments and Response Actions

Assessments are evaluation processes used to measure the performance or effectiveness of a system and its elements. It is an all-inclusive term used to denote any of the following: audit, performance evaluation, management system review, peer review, inspection and surveillance. For this project, the assessments are:

- Network Review
- Bias — Performance Evaluations (DEC)
- Data Quality Assessments
- QAPP Revisions

Network Reviews

Using requirements of 40 CFR Part 58 Appendix D, and Section 10 Sampling Process & Design, the network is evaluated to ensure:

- The monitors are properly located based upon the monitoring objectives and spatial scale of representativeness.

Siting criteria are specified in 40 CFR Part 58 Appendix E and Section 11, Sampling Methods[6]. Using these criteria, on-site physical measurements and observations are made to determine compliance with sample probe/monitor criteria such as probe height and distance from potential obstructions, paved or vegetative ground cover, potential sources of point-source pollution, etc.

An on-site checklist is used to evaluate the DEC monitoring network; For this project, the checklist will be followed as closely as possible. In addition to items on this checklist, the reviewer should also:

- Inspect monitoring shelters for weather leaks, safety, and security.
- Check to ensure all sample lines are connected and free of kinks.
- Check equipment for missing parts, frayed cords, etc.
- Record findings/observations in a field notebook and/or checklist.
- Take photographs in each cardinal direction (both looking at and looking away from sample probe as well as the shelter's interior layout).
- Record monitoring site's GPS location (latitude/longitude/elevation).
- Document site conditions (include any additional photographs/videotape).

[6] https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-58/appendix-Appendix%20E%20to%20Part%2058

Bias – Performance Evaluations (DEC)

Performance evaluations are a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst, air monitoring station, and/or laboratory. To estimate bias, an external instrument/standard must be compared against the field instruments collecting monitoring data. This external (independent) standard cannot be the same standard(s) used to calibrate and/or perform the routine QC checks of the monitoring instruments. In addition, the individual conducting the "independent evaluation" must also be independent from routine operations and calibration(s) of the monitoring instruments. Bias is expressed as a positive or negative percentage of the "true" value.

Bias performance evaluations implemented in this project include periodic flow rate performance audits of the PM monitors.

The equations to be used to calculate results of performance audits are found in the respective monitoring methods, EPA *QA Handbook for Air Pollution Measurement Systems Volume II*[7], and references listed in Table 7, *Bias (Accuracy) Assessments*. The required frequency of performance audits and the equations used to assess gathered bias/accuracy data are listed and/or referenced in Table 5. In general, the corresponding equations in the referenced software (EPA Data Assessment Statistical Calculator, DASC)[8] are suggested rather than the hand-calculated versions.

Data Quality Assessments

Data quality assessments are statistical and scientific evaluations of the data set to determine the validity and performance of the data collection design and statistical test, and to determine the adequacy of the data set for its intended use. This information will be included in the final project report at the conclusion of the project. Each parameter reported will be used to assess the reported data:

- Completeness
- Bias
- Precision

Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount expected to be obtained under correct, normal conditions. Data completeness (DC) requirements are included in the reference methods (40 CFR 50). Data completeness objectives are listed in the Measurement Quality Objectives Table 3. The data completeness goal for this study using Special Purpose Monitors is ≥ 75% valid data/monitoring quarter. The completeness of the data will be determined for each monitoring instrument and expressed as a percentage (equations below):

PM_{10}/$PM_{2.5}$ % DC = valid 24-hour data/all scheduled sample run days within monitoring quarter

[7] https://www.epa.gov/sites/default/files/2020-10/documents/final_handbook_document_1_17.pdf
[8]https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.epa.gov/sites/default/files/2020-10/dasc_11_3_17.xls&ved=2ahUKEwjOlYn-4bmMAxUzOTQIHcaiHoUQFnoECBgQAQ&usg=AOvVaw0L0B5X9djCrpP9Os1YbfiB

Bias

The term *accuracy* is frequently used to represent closeness to truth and includes a combination of precision and bias components. This term has been used throughout the CFR. In general, DEC follows the conventions of the NIST and, more recently, of EPA (ref. NIST Report 1297 and EPA G-9) and will not use the term "accuracy", but will describe measurement uncertainties as precision, bias, and total uncertainty (total uncertainty is the combination of both precision and bias). For this study, bias is estimated using the results of the QC checks with a known concentration performed at least monthly using known flow for particulate pollutants and will be the major estimate of bias on an ongoing basis. The performance evaluations (performance audits) will provide another estimate of bias (see Table 7**,** *Bias Assessments* and web link to *EPA Data Assessment Statistical Calculator, DASC*). In general, the corresponding equations in the referenced DASC software are suggested rather than the hand-calculated version shown.

Table 7 Bias Assessment

Bias Assessment for continuous PM	
Single/Multi-Point Analyzer Audits	**References**
Audit flow rate percent difference, d_i, is calculated by: $$d_i = \frac{Y_i - X_i}{X_i} \times 100$$ where X_i is the flow rate of the audit standard and Y_i is the sampler's measured flow rate **Note 1**: for SLAMS, SPM and NCore sites each sampler audited 1/6 months.	*40 CFR Part 58 Appendix A section 4, Calculations for Data Quality Assessment,* https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-58/appendix-Appendix%20A%20to%20Part%2058 *Guideline on the Meaning and The Use of Precision and Bias Data Required by 40 CFR Part 58 App A* https://www.epa.gov/system/files/documents/2022-05/Guideline%20on%20the%20Meaning%20and%20the%20Use%20of%20Precision%20and%20Bias%20Data%20Required%20by%2040%20CFR%20part%2058%20Appendix%20A.pdf *Data Assessment Statistical Calculator (DASC) – The software to assist those in calculating the new precision and bias statistics – MS Excel File Type* https://www3.epa.gov/ttn/amtic/qareport.html

Precision

Precision is a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. For this project, precision will be assessed based on the data collected during two collocation periods: one performed indoors between the five E-BAMs that spanned two weeks, and one performed outdoors between the five E-BAMs that spanned five days. The following steps will be taken:

1. **Data Collection**
   a. The E-BAMs will be run together in a controlled warehouse environment for a period of two weeks. The E-BAMs will also be run together outdoors for a period of five days. Hourly PM data will be recorded for each instrument.

2. **Data Analysis**
   a. The recorded data will be analyzed to calculate the precision of the measurements. This will involve calculating the standard deviation and percent difference between the measurements from each E-BAM.

3. **Documentation**
   a. The results of the precision assessment will be stored on DEC's internal server and included in the final project report.

4. **Future Considerations**
   a. If feasible, a future collocation study at a regulatory site with a regulatory instrument will be conducted to provide a more comprehensive assessment of precision under field conditions.

QAPP Revisions

The process to revise the QAPP includes:

- Identifying the need for revisions due to changes in monitoring methods, criteria, siting, or other elements.
- Submitting proposed revisions to the QA Manager for review and approval.
- Documenting approved revisions in the QAPP and distributing updated versions to all relevant parties.

21. Reports to Management

At the conclusion of the project, a final project report will be issued and will provide graphical summaries and validated data. The final project report will include QA activities conducted during the study, including QC checks and audit results, and any corrective actions taken. The final project report will be distributed to the relevant stakeholders.

22. Data Review, Verification, and Validation

Method specific data validation criteria have been developed for the various ambient air quality and meteorological measurement methods. These criteria are ranked under three classes of "data acceptance criteria" for a measurement method and define how the criteria should/must be used to evaluate overall data quality. These method-specific Data Validation Tables are located in Appendix C. These data quality criteria categories are:

1. ***CRITICAL CRITERIA TABLE*** **-** Criteria deemed critical to maintaining the integrity of a sample or group of samples reside in the Critical Criteria Table. Observations that do not meet each and every criterion on the Critical Table should be invalidated unless there are compelling reasons and justification for not doing so. Basically, the samples for which one or more of these criteria are not met are invalid unless proven otherwise. The cause for not operating in the acceptable range for each violated criterion must be investigated and minimized to reduce the likelihood that additional samples will be invalidated.

2. ***OPERATIONAL EVALUATIONS TABLE*** **-** Criteria that are important for maintaining and evaluating the quality of the data collection system reside in the Operational Evaluations Table. Violation of a criterion or a number of criteria may be cause for invalidation. The decision should consider other quality control information that may or may not indicate the data are acceptable for the parameter being controlled. Therefore, the sample or group of samples for which one or more of these criteria are not met is suspect unless other quality control information demonstrates otherwise. The reason for not meeting the criteria MUST be investigated, mitigated and/or justified.

3. ***SYSTEMATIC ISSUES TABLE*** **-** Criteria important for the correct interpretation of the data but do not usually impact the validity of a sample or group of samples reside in the Systematic Issues Table. For example, data quality objectives are included in this table. If data quality objectives are not met, this does not invalidate any of the samples but it may impact the error rate associated with the attainment/non-attainment decision.

Data Review Process

The data review process involves a thorough examination of the collected data to ensure it meets the established criteria. This includes checking for completeness, accuracy, and consistency. Any discrepancies or anomalies identified during the review process must be documented and addressed.

Data Verification

Data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements. This step ensures that the data collected is accurate and reliable.

Documentation and Reporting

All data review, verification, and validation activities must be thoroughly documented. This includes maintaining records of any issues identified, corrective actions taken, and the final status of the data. The results of these activities will be included in the final project report.

Project-Specific Calculations and Algorithms

For this study, we will follow the data validation template for the BAM 1020, see Appendix C.

23. Verification and Validation Methods

Data verification is a two-step process:

1. Identify project needs for records, documentation, and technical specifications for data generation, and determine the location and source for these records.

2. Verify records that are produced or reported against the method, procedural, or contractual requirements, as per the field and analytical operations (i.e., sample collection, sample receipt, sample preparation, sample analysis and data verification records review).

Step 1 -- Identify project needs for records, etc**:** For ambient air and/or meteorological monitoring, project needs can be broken down into whether the monitoring project supports NCore, SLAMS, SPM, or PSD quality monitoring. The data verifier uses this and other support documents to determine the purpose of data collection and specified needs for sample collection, data generation and documentation of the analysis.

Project specifications may also include specifications for monitoring data (sample collection and field and/or lab analyses) and for the resulting data reports. These specifications are important in verifying that the actual methods employed (field/lab equipment as well as measurement procedures, etc. used) match what was requested. This ensures, *"verifies,"* that the specified method was used and that it met technical criteria established in the approved QAPP.

Know/determine where the records are maintained. Records may be produced by multiple personnel and maintained in multiple rooms or locations. Keeping backups of electronic records is strongly recommended. All personnel need to comply with the record-keeping procedures of the monitoring project (field, laboratory, etc). At any point in the data generation chain, the information needed for data verification needs to be available to the people responsible, and the respective project requirements need to be clearly identified in the planning documents.

Step 2 – Verify records that are produced or reported, etc**:** Step 2 compares the records produced against the project needs/requirements. The project planning document that specifies the records to be reported should be used to determine what records to verify. *Note*: In the rare absence of such an organizational specification, the determination of data to be verified may be left to the discretion of the project manager/principal investigator and the respective agency's quality assurance person. Such a determination must be justified/documented and appended to the data package for subsequent data validation.

Outputs of Data Verification

1. The first output is "***verified data***." Examples of verified data that have been checked for a variety of factors during the data verification process include:

- Transcription errors,
- Correct configuration of datalogger and/or the data acquisition system (DAS),
- Correct reporting units of measure, and
- Appropriate field and/or laboratory data qualifiers.

Any changes to the results as originally reported by the field/lab monitoring group must be accompanied by a note of explanation from the data verifier or reflected in a revised sample data report.

2. The second output of data verification is the ***"data verification record."*** This record includes a *"certification statement"* certifying the data have been verified. The statement is signed by responsible personnel either within the organization or as part of external data verification. Data verification records must also include technical non-compliance issues or shortcomings of the data produced during the field and/or laboratory activities. If the data verification identified any non-compliance issues, then the narrative must identify the records involved and indicate the appropriate corrective actions taken in response. The records routinely produced during field activities and at the analytical laboratory (commonly referred to as a data package) and other documentation such as checklists, handwritten notes, or tables should also be included as part of the data verification records. Definitions and supporting documentation for any field/laboratory qualifiers assigned also should be included.

a. Data Validation Methods

Data validation is an analyte- and sample-specific process that extends the evaluation of data beyond *"data verification"* to determine the analytical quality of a specific data set. Data validation criteria are based upon the MQOs. Data validation includes a determination, where possible, of the reasons for any failure to meet method, procedural, or contractual requirements, and an evaluation of the impact of such failure on the overall data set. Data validation applies to activities in the field as well as in the analytical laboratory.

Method specific data validation tables for continuous PM_{10} and $PM_{2.5}$ can be found in Appendix C. These validation tables list criteria for determining whether data under evaluation is acceptable.

Prior to DEC providing data to the project stakeholders data will be verified and certified by the AMQA project manager in consultation with the Air Quality Assurance Officer.

For the data to be considered valid, the following conditions must be satisfied:

- The air monitoring instrumentation must be calibrated and operated according to standard methods that have been approved for use in the ambient air and meteorological monitoring program.
- The data must be accompanied by back up documentation which meet the specifications outlined in **Section 14** of this Plan, and be identified with respect to station name, station number, date, time, operator, instrument identification, parameter, scale and units.
- The data must be bracketed by documented quality control which substantiate that they meet the criteria in **Section 14** of this plan.

Data which are reviewed and found to satisfy these criteria will be considered valid. Data that does not will be invalidated or appropriately qualified ("flagged") back to the last valid quality control check, and future data will be invalidated or qualified until it can be shown to meet the project's tolerances.

The primary focus of data validation is determining data quality in terms of accomplishment of the monitoring project's stated MQOs.

Data validation is typically performed by person(s) independent of the activity which is being validated. In large organizations this is standard practice. However, in smaller organizations/agencies it is acceptable for the air monitoring technicians (who conduct the monitoring) to conduct the first tier of data validation, with the focused data validation performed by the air monitoring project's supervisor/project manager.

As in the data verification process, planning documents, methods, procedures, data validation tables, verified data, etc. need to be readily available to the data validators. The data validator must be knowledgeable of the specific types of information to be validated. The data validator needs to be aware of signs that indicate improper field and laboratory practices that can/will affect data integrity. EPA QA/G-8*, "Guidance on Environmental Data Verification and Validation," EPA/240/R-02/004*, devotes chapter 4 to Data Integrity. This document can be found at: https://www.epa.gov/quality/guidance-environmental-data-verification-and-data-validation.

Issue Resolution Procedure and Responsible Individual(s)

The issue resolution procedure involves identifying any non-compliance issues or shortcomings during the data verification and validation processes. The responsible individual(s) for resolving these issues include the data verifier, the AMQA project manager, and the Air Quality Assurance Officer. The corrective actions taken in response to identified issues must be documented and included in the data verification records.

Method for Conveying Results to Data Users

The results of the data verification and validation processes will be conveyed to data users through the final project report. This report will include a summary of the data review, verification, and validation activities, as well as any issues identified and the corrective actions taken. The report will be distributed to all relevant stakeholders, including the project manager, QA Manager, and other key personnel.

24. Reconciliation with User Requirements

As part of the final project report, DEC AMQA staff will include information that describes data quality in terms of precision, accuracy, and data completeness.

Data Comparison & Validation

Data will be compared with the established MQOs and DQOs in Section 7 to ensure requirements and guidance set forth in CFR, QA Handbook Vol. II, *Data Quality Assessment: A Reviewers Guide* (EPA QA/G-9), and this QAPP have been met. Only data that has been validated, verified, and qualified, as necessary, shall be accepted and published in the report. If the data reviews reveal that data sets are inconsistent with the MQOs, or the underlying assumptions of the statistical tests are not supported by the data and fail to meet the criteria or objectives of the monitoring projects, then steps will be immediately taken to identify shortcomings, rectify discrepancies, and reconsider sampling design or adjustment to QC procedures as described in this QAPP.

Issue Resolution Procedure

If data reviews reveal inconsistencies with the MQOs or other criteria, the following steps will be taken:

- **Identify shortcomings**
  - The specific issues or discrepancies in the data will be identified and documented.

- **Rectify Discrepancies**
  - Corrective actions will be implemented to address the identified issues. This may include re-sampling, re-analysis, or adjustments to the data processing methods.

- **Reconsider Sampling Design**
  - The sampling design will be reviewed and adjusted if necessary to ensure it meets the project objectives and quality criteria.

- **Adjust QC Procedures**
  - Quality control procedures will be reviewed and modified as needed to prevent future discrepancies and ensure data integrity.

<u>Reporting Limitations on Use of Data</u>

Any limitations on the use of data will be clearly documented in the final project report. This includes any issues identified during the data review process, the impact of these issues on data quality, and any corrective actions taken. The report will also include recommendations for future monitoring efforts or adjustments to the current project based on the review findings.

<u>Conveying Results to Data Users</u>

The results of the data validation and reconciliation process will be conveyed to data users through the final project report. This report will include:

- **Summary of Data Quality**
  - A detailed description of data quality in terms of precision, accuracy, and completeness.

- **Validation & Verification Results**
  - Documentation of the validation and verification processes, including any issues identified and corrective actions taken.

- **Compliance with MQOs and DQOs**
  - An assessment of how the data meets the established MQOs and DQOs.

- **Recommendations**
  - Any recommendations for future monitoring efforts or adjustments to the current project based on the data review findings.

The final project report will be distributed to all relevant stakeholders, including the project manager, QA Manager, and other key personnel. This ensures that all parties are informed of the data quality and any actions taken to address issues.

Appendix A - Met One E-BAM Particulate Monitor Standard Operating Procedures, DEC

Environmental Beta Attention Monitor

Standard Operating Procedures

Alaska Department of Environmental Conservation

Air Quality Division

Air Monitoring and Quality Assurance

555 Cordova Street

Anchorage, AK 99501

Phone: (907) 269-7577

Fax: (907) 269-7508

dec.alaska.gov/air

Revision 0 – April 2025

This page intentionally left blank

Table of Contents

1. Abbreviations & Acronyms

E-BAM	Environmental Beta Attenuation Monitor
l/min	liter per minute
PM	particulate matter
PM2.5	Particulate matter less than or equal to 2.5 microns.
PM10	Particulate matter less than or equal to 10 microns.
QC	quality control

2. Pre-Deployment

Set up and test the Met One Instruments Environmental Beta Attenuation Monitor (E-BAM) following Met One's manual for a quality control (QC) check. Before deployment, a QC check needs to be performed, and the pump should be tested. Power connections should be checked, and firmware should be updated. The span membrane test needs to be done at the beginning QC and does not need to be completed after the E-BAM has collected data. Refer to Section 4 for QC procedures.

3. Assembly and Setup

An E-BAM is meant for rapid deployment in remote areas, thus can be set up quickly following these steps. An equipment list is provided in Appendix A. Siting criteria is provided in Appendix B.

3.1. Tripod Setup

Lift the tripod and remove the lock pins one at a time, placing them back in the lock pin hole once the leg is straightened out. Repeat this for all three legs. It is recommended to stabilize the instrument by either bolting it to the ground or using boards to help level the feet of the tripod.

Note: remove the ¼ inch nut and bolt on the mast, this is the bolt that attaches the cabinet to the tripod.

3.2. E-BAM Cabinet

With the aerosol inlet tube oriented upward, slide the E-BAM cabinet into the slot on the top of the tripod. Use the ¼ inch nut and bolt to secure the bottom of the cabinet to the tripod.

3.3. Sampling Inlet

Loosen the large black collar on the top of the cabinet (by hand), push the sample inlet tube through the locking nut and into the cabinet. It goes through two O-rings, push firmly and twist until it stops. Place the black locking collar on top and tighten. Slide the PM_{10} inlet onto the sample inlet; this must also go through two O-rings so push firmly. If you are sampling for $PM_{2.5}$ place the $PM_{2.5}$ inlet on the sample inlet tube first and then the PM_{10} inlet.

Note: O-rings are factory lubricated, but with frequent removal and replacement they need to be relubricated with silicone grease. This can be done using your fingers or a cotton swab.

3.4. Temperature and Relativity Humidity

To install the temperature and relative humidity sensors, attach a mounting clamp to the top of the tripod with the cross-piece facing towards the E-BAM cabinet. Next, install the long cross arm through the mounting clamp, ensuring it extends equally on both sides, and tighten the two Allen screws. Slide the temperature sensor down the left arm of the tripod and then slide the relative humidity sensor onto the same side of the cross arm, leaving several inches between the two sensors. Tighten the plastic clips using fingers or slip-joint pliers, securing them to the first ridge. Plug the cables from both sensors into the EX-593 adaptor and connect the adapter to the corresponding port on bottom of the E-BAM cabinet, tightening all locking collars. Use caution when connecting cords to the E-BAM cabinet ports. Carefully line up pins before pushing the cord into the port. Do not use excessive force, as the pin holes are fragile and prone to bending if misaligned.

Note for all sensors: practice good cable management and protect power connection points from weather (utilize drip loops, extension cord covers etc.).

3.5. Wind Sensor

Attach a mounting clamp to the opposite end of the long cross arm and level it is using a hand level. Next, attach the adapter tube to the shaft of the wind sensor by removing the bolt, sliding on the adapter tube, and securing it in place with the bolt. Slide the wind sensor into the mounting clamp but do not tighten it yet. Using a compass to find true north, rotate the entire wind sensor until the counterweight (shaped like a bullet) is pointing due south, then tighten the mounting clamp Allen bolts to secure the sensor. Slide the vane tail into the hub until it is fully seated, ensuring the vane tail is vertical before tightening the Allen screw. Loosen the shoulder screw by hand and remove it completely to allow the wind vane to rotate, then store the shoulder screw in a bag or tool kit. Plug the cable into the underside of the E-BAM cabinet and tighten the weatherproof collar.

3.6. Cellular Modem

Use the included U-bolts to fasten the cellular modem to one leg of the tripod. The sequence of hardware along the shafts of the U-bolt is: washer, spring washer, and bolt. Tighten the top and bottom until it is snug on the tripod. It’s easier to do this with one person holding the modem in place while the other tightens the nuts. Before the modem is attached to power make sure that the cell antenna is attached, this is better for the instrument. Next, plug the communication cable from the modem into the "Comm" outlet on the bottom of the E-BAM cabinet and tighten the locking collar. Finally, plug the modem into an AC power supply using the power splitter.

3.7. Power Supply

The standard E-BAM is supplied without a power source, but Met One Instruments provides various power sources as accessories. Any 12V DC power source can be used to power the E-BAM, if it provides at least four amps of continuous power. Connect one end of the E-BAM power cable to the 12V power source and connect the other end at the bottom of the E-BAM cabinet. Next, use the U-bolts provided with the AC power supply from Met One Instruments to fasten the power supply to one leg of the tripod, tightening the top and bottom until secure. Plug the power supply into the power splitter, then attach the power supply cord to the "Power" outlet on the bottom of the E-BAM. Finally, plug in the main power cord.

4. Leak Check, Calibration, and Flow Check

A self-test should be run every time the instrument is set up. A leak check is necessary to ensure that the E-BAM is properly sealed and must be performed before any flow calibrations are performed. A flow check is required to measure the volume of air flowing through the E-BAM. Temperature and pressure measurements must be taken before performing a flow check. The leak check and flow check should be performed after setting up in the field but prior to data collection as well as after data collection has concluded.

4.1. Self-Test

The self-test should be run every time the instrument is set up.

1. From the "**MAIN MENU**" select "**SELF-TEST**".
2. The self-test will automatically assess various components, including tape condition, nozzle motor, beta counts, flow system, and pressure sensor.
3. If any issues are detected, there will be guidance on what is wrong and how to proceed. The system will indicate if it is functioning properly by displaying a "**PASS"** on the screen.

4.2. Leak Check

The E-BAM flow system must be checked for leaks before any flow calibrations are performed.

1. Press "**MENU/SELECT**" to get to main menu.
2. Scroll to "**FIELD CALIBRATION**" and press "**MENU/SELECT**" button to select.
3. Select "**STOP**" to stop E-BAM operation.
4. Remove the PM_{10} inlet head as well as the $PM_{2.5}$ inlet head.
5. Put the zero-filter test valve (this is an external device that creates a vacuum to test for leaks and flow rate) on the inlet tube. Make sure the valve is open.
6. Scroll through the choices and select "**PUMP TEST**". Press "**MENU/SELECT**" to select this option.
7. Next, select "**LEAK TEST**" The E-BAM will automatically start its pump. The pump will need time to warm up.
8. Ensure the l/min numbers are going up. Allow the flow to increase to about 10 l/min and then slowly close the valve.
9. The flow rate should drop to less than 1.5 l/min. Record this in the instrument's logbook.
    a. If the flow rate is greater than 1.5 l/min, thoroughly clean the nozzle/vane interface and then perform this test again.
10. Press the "**EXIT**" button (top left button) to stop the E-BAM's pumping.
11. SLOWLY open the zero-filter test valve by rotating the valve on side of the zero filter.

12. Remove the zero-filter test valve and replace the PM_{10} inlet head as well as the $PM_{2.5}$ inlet head.

4.3. Membrane Test

The membrane test is used to audit the E-BAM's beta particle measurement system by simulating a particulate load with a polyester foil. The test consists of four 4-minute beta count steps for a total of about 16 minutes. This test only needs to be completed at the beginning of a deployment to ensure operational standards are met.

1. Scroll to "**MEMBRANE TEST**" and press "**MENU/SELECT**" button to select. Press the **START** key to begin the test.
2. The unit will advance the filter tape and begin a 4-minute blank zero count.
3. After 4 minutes, the unit will raise the nozzle and prompt you to enter the zero membrane. This is the shim attached to the chain inside the E-BAM that is used during shipping. The unit will then automatically lower the nozzle and begin a 4-minute count with the zero membrane in place.
4. After the zero count, the unit will prompt you to remove the zero membrane and will then start a 4-minute blank span count without any membrane in place.
5. The unit will then prompt you to insert the span membrane. This is in the plastic sleeve inside the front panel of the E-BAM cabinet. Each E-BAM has its own specific plate-ensure that the serial number on the plate matches the E-BAM unit. *Do not drop the plate or touch the plastic film as it is very fragile*. Insert the span membrane into the E-BAM above the filter tape. The unit will perform the final 4-minute span count and display the results. If performing properly, the unit will say "**SPAN MEMBRANE: PASS**".
6. Press "**OK**" to exit.
7. If the test fails, consult the Met One manual.

Table 1. Span Membrane Test Steps

Step	Count Type	Description
1	BLANK ZERO COUNT	4-min count through filter tape only.
2	CAL ZERO COUNT	4-min count through tape and zero (empty) membrane.
3	BLANK SPAN COUNT	4-min count through filter tape only.
4	CAL SPAN COUNT	4-min count through tape and span membrane foil.

4.4. Temperature and Air Pressure Checks

1. Turn on the Alicat flow device. Allow it to equilibrate (to outside temperature and pressure) for 15 minutes, keeping it away from wind and rain.
2. Turn on the E-BAM if not on already.
3. Press "**MENU/SELECT**" to get to the E-BAM's main menu.
4. From the "**FIELD/CALIBRATION** menu, scroll to the "**TEMPERATURE**" option and press "**MENU/SELECT**".

5. The "**HIGH**" calibration point is for ambient temperature. Scroll until "**HIGH**" is selected if it is not already.
6. Use arrow keys to select "**CHANGE REF TEMP**".
7. Read the current temperature from the Alicat and input that reading for the REF parameter.
8. Press "**CALIBRATE**" and the E-BAM 's temperature will now match the REF temperature.
9. Go back one menu and choose the "**PRESSURE**" option.
10. Read the current pressure from the Alicat and change the REF parameter to match.
11. Press "**CALIBRATE**" and the E-BAM's pressure will now match the REF pressure.

4.5. Flow Check and Flow Calibration

1. Remove the PM_{10} and $PM_{2.5}$ inlets.
2. Turn on the Alicat flow device. Allow it to equilibrate (to outside temperature and pressure) for 15 minutes, keeping it away from wind and rain.
3. From the "**FIELD CALIBRATION**" menu, select "**FLOW**".
4. Use the arrow keys to scroll through the specified flow types. For a one-point flow check, stop at **16.7 l/min**. The pump will automatically turn on and flow will begin to regulate.
    a. Wait five minutes for the flow to equilibrate.
5. Compare and record the flow rate on the Alicat. If they are within 2% of 16.7 (16.37-17.03 l/min) no calibration is necessary.
    a. If calibration is needed, proceed with the following steps.
    b. With the Alicat device installed on the inlet tube, scroll to the "**FLOW**" line and press "**MENU/SELECT**" to enter the flow sensor calibration menu.
    c. The SETPOINT parameter selects which flow is to be calibrated. The E-BAM uses a two-point flow calibration at 17.5 and 14.0 l/min. The 16.7 l/min point can only be audited, not calibrated.
    d. Use the arrow keys to select the 17.5 l/min setpoint first. The E-BAM will automatically turn the pump on and regulate the flow until the internal flow sensor output matches the 17.5 l/min setpoint.
    e. The REF parameter field is where you enter the correct flow as shown on the Alicat device. After you have entered the correct flow using the arrow keys, press the "**CALIBRATE**" key to correct the E-BAM sensor reading. The E-BAM should then re-regulate the flow to the setpoint, and the E-BAM and REF parameters should match.
    f. Set the SETPOINT to 14.0 l/min and repeat the calibration process.
    g. After the 17.5 and 14.0 l/min points are calibrated, select the 16.7 l/min setpoint and verify that the E-BAM flow and the flow from the Alicat device match within 0.1 l/min. Press the ESC key to exit the flow calibration menu when finished.
6. Remove the Alicat device and replace the $PM_{2.5}$ and PM_{10} inlets.
7. Record the date and time calibrated in the logbook or associated form.

5. Operation

The E-BAM turns on and off when plugged in or unplugged, as there is no power switch. If left powered on for more than 30 minutes without input, it will automatically begin sampling using the default settings from its last programming. When powering up, the unit will ask if you're ready to start and will then prompt you to verify several setup menus, run a short self-test, and begin automatic operation.

When setting up or turning on the unit, it's important to pay attention to the tape advance rate and real-time average measurement cycles. The **TAPE ADVANCE** rate determines how often the E-BAM will automatically advance the filter tape. If the concentration is too high and the filter tape becomes clogged, the unit will override this setting and advance the tape automatically, recording this as an alarm in the data log. The **REAL-TIME AVG** refers to the time the E-BAM uses to record particulate concentration.

1. Power-on the E-BAM by plugging it into a standard AC power outlet (3-prong).
2. Press "**YES"** on the display when you are ready to use the E-BAM.
3. Check for correct date and time; follow "**yes/no**" prompts and arrows to update as needed. Use local Alaska time from your cellular phone for setting the time.
4. Verify the tape advance rate as **1 hour.**
5. Verify the real-time average measurement setting as **1 minute.**
6. Verify the **MACHINE TYPE** as **PM-10** or **PM-2.5.**
7. Remove the nozzle packing material when prompted by removing the packing shim attached to the chain tether after it is mechanically released.
8. Load filter tape if it is not already loaded (see instructions for performing this function in the Common Tasks section, below), the E-BAM will not operate without tape.
9. The E-BAM will automatically perform a self-test which takes several minutes. Let it run through; a prompt will indicate when the self-test is complete.
10. Check the temperature and pressure. It is recommended to calibrate both in the lab as well as in the field.
11. Start sampling by selecting "**OPERATE**". The first hour of data should be discarded as the machine warms up.

6. Common Tasks

6.1. Changing Filter Tape

Filter tape should be checked regularly and replaced once the tape is almost used up to prevent data gaps.

1. Open the E-BAM cabinet. The screen inside should be in the default sampling menu, displaying date, time, and other information. If it is not, press the "**MENU/SELECT**" button to access the main menu.
2. From the main menu, use the up/down arrow keys to highlight the "**LOAD TAPE**" option. Press the **"MENU/SELECT"** button to select this option.

3. Use the right-hand white button to select the onscreen "**STOP**" command to stop the E-BAM operation.
4. The screen will display a "**PLEASE LOAD TAPE**" message and the sample nozzle will automatically raise.
5. Unscrew both spool covers (the black plastic knobs) and remove them, putting them somewhere clean and dry.
6. Remove the used roll from the left reel hub and put in a plastic bag. Mark the location, date, and time on the bag.
7. Note - if the filter tape roll is not totally used up, you will have to unroll the last bit off the original core tube.
8. Place the old core tube on the left reel hub. This will be the core that the next roll of filter tape will roll on to.
9. Inspect the underside of the sample nozzle and the area that the filter tape slides over. Look for the presence of any burs or built-up debris. If so, gently clean using a cotton swab and isopropyl alcohol.
10. Inspect the last several samples on the filter tape for pin holes or scuffs that would indicate buildup.
11. Now place a full new roll of filter tape on the right reel hub.
12. Feed the end of the filter tape underneath the sample nozzle and tape it to the core tube on the right-hand side so that it can be rolled up in a counterclockwise direction.
13. Tape the free end of the filter tape to the core tube. *Never tape the filter tape directly to the aluminum hub!*
14. Reinstall the spool covers- hand tighten firmly.
15. Rotate the filter tape spool counterclockwise to remove any slack. Ensure the tape is seated properly along the rollers (i.e. not crooked and with even spacing on both sides)
16. Press the right-hand white button to select the onscreen "**CONTINUE**" command and the screen will display the main menu again.
17. Use the up/down arrow keys to highlight the "**OPERATE**" option
18. Press the **"MENU/SELECT**" button. The screen will now display a message reading "**WARNING: START OPERATION?**"
19. Press the right-hand white button to select the onscreen "**YES**" command. The E-BAM nozzle may move up and down and the tape may cycle in one spot. After about a minute, the pump should turn on and the E-BAM will begin sampling.

6.2. Changing Sample Interval

1. Open the E-BAM cabinet. The screen inside should be in the default sampling menu, displaying date, time, and other information. If it is not, press the "**MENU/SELECT**" button to bring it up.
2. Press the "**MENU/SELECT**" button to access the main menu.
3. From the main menu, use the up/down arrow keys to highlight the "**SETUP**" option.
4. Press the "**MENU/SELECT**" button to select this option.
5. The first screen displays date and time. If this is correct, press the right-hand white button which correlates with the on-screen "**CONTINUE**" command.

6. The second screen displays **LOCATION, TAPE ADVANCE**, and **REALTIME AVG**. To edit the **REALTIME AVG** option (which is also the sample interval), use the left/right arrow keys to highlight the "**REALTIME AVG**" option.
7. Use the up/down arrow keys to change the interval to whichever option is desired (1-, 5-, 10-, 15-, 30-, and 60-minute sampling intervals).
8. Once the interval has been changed (ex. to 10- or 15-minute averages in the event of ash resuspension) use the left-hand white button to select the on-screen "**SAVE**" command.
9. Press the "**ESC**" button once to return to the main menu and the "**ESC**" button again to return to the sampling menu.

6.3. Data Communication

You will need to download the Comet2 software on to your device for manual data retrieval. Appendix C also contains information on downloading data from the E-BAM or follow the instructions below:

1. Open 'Device Manager' in your computer settings – plug in the METOne cord into the device. You will need a RS232 cord that transfers the connection from standard to null, you will be able to tell this connection in your 'Device Manager'. Note what (COM) is labeled USB Serial Port.
2. Open the Comet2 software and select add new station.
3. Select BAM then press next.
4. Select EBAM and press next.
5. Select Serial Port and press next.
6. Select the correct COM channel.
7. Name the station.
8. Select 'Retrieve Data'.
9. Select the following parameters: 'parameter setting' 'alarm/error log' 'diagnostic' 'data log' and press 'OK'.
10. Data should begin downloading to your computer.

7. Disassembly and Packing

Before disconnecting the power, you must prepare the E-BAM for shipping. From the menu, select **SHUTDOWN/SHIPPING**. The nozzle will rise. Insert the "packing material" (the metal shim chained inside the E-BAM cabinet) so that the metal tab slides into the slot. The E-BAM will then lower the nozzle onto the shim and display "**OK TO TURN OFF EBAM**" At this point, you can unplug the instrument.

To pack the instrument, disassemble by following assembly instructions in reverse order. Use caution when unclipping the plastic clips on the temperature and relative humidity sensors as they can be cracked with excessive force. A flathead screwdriver is recommended to gently pry the tab of each clip up until it unlocks.

7.1. Troubleshooting

Refer to MetOne's E-BAM manual[1] for further maintenance and troubleshooting information. Below is the contact information for Met One Instruments.

Met One Technical Support

Phone: 541-471-7111

Email: service.moi@acoem.com

Web: www.metone.com

7.2. Maintenance Schedule

Regular maintenance is essential to ensure accurate particulate matter measurements and extend the instrument's lifespan. Key maintenance tasks include:

Pump Maintenance: The internal pump draws air through the filter tape. Over time, the pump may experience wear, especially under high particulate loading conditions. Monitoring pump performance and replacing it when flow rates deviate from specified ranges can prevent sampling inaccuracies.

Beta Detector Calibration: The beta detector measures the attenuation caused by particulate matter on the filter tape. Periodic calibration ensures consistent and precise measurements.

Pressure Sensor Verification: Accurate pressure readings are vital for flow rate calculations. Regular verification of the internal pressure sensors helps in identifying potential issues before they affect data quality.

Nozzle and Vane Assembly Inspection: The nozzle directs air onto the filter tape, and the vane assembly aids in flow regulation. Ensure these components are free from obstructions and damage to maintain proper airflow and sampling efficiency.

O-ring lubricants: It is important to check and re-lubricate the O-rings as necessary.

[1] https://metone.com/wp-content/uploads/2019/06/E-BAM-9805-Manual-Rev-B.pdf

Table 2. E-BAM Maintenance Items

Maintenance Item:	Interval:
Set E-BAM clock	Monthly
Leak Check	Monthly
Nozzle and vane cleaning	Monthly
Flow Check (w/ temperature and pressure calibrations)	Monthly
Clean $PM_{2.5}$ and PM_{10} inlets	Monthly
Check error log	Monthly
Span membrane test	Monthly

7.3. Fixing a Leak

The following checklist is to be used when a leak check indicates that the flow rate of the E-BAM is less than 1.5 l/min, signifying a problem with the integrity of the flow system. Most often, the source is material buildup on the nozzle or vane.

1. Press "**MENU**/SELECT" to get to the main menu.
2. Scroll up through the list of choices using the arrows. When the cursor is on "**LOAD TAPE**", press the "**MENU/SELECT**" button.
3. The nozzle will automatically rise.
4. Loosen and remove the spool covers from the screws holding the filter tape.
5. Carefully pull/lift the filter paper out of the nozzle area.
6. Using a cotton applicator with a small amount of isopropyl alcohol, gently clean the lip of the nozzle (the piece that moves up and down). The area that needs to be cleaned is the small lip that contacts the filter paper. Clean the entire diameter.
7. Next, clean the vane (the crosshatch piece directly underneath the nozzle were the
8. filter normally rests). Using a cotton applicator, gently rub the four crosspiece sections of the vane as well as around the edge.
9. Replace the filter paper between the nozzle and the vane.
10. Replace and tighten the spool covers on the screws holding the filter tape. Manually roll one of the spools to gently tighten the tape so that it is not drooping or loose. Ensure the tape is seated properly along the rollers (i.e. not crooked and with even spacing on both sides).
11. Once the tape is seated and the spools tightened, select "**CONTINUE**".
12. Select "**LOAD TAPE**" again. This will automatically move the nozzle down.
13. Sometimes, the nozzle will not stay down against the tape. If this happens, select "**SELF TEST**" from the main menu. This will forward the filter tape. After the Self-Test, the nozzle should be down. If not, select "**LOAD TAPE**" yet again. This will bring the nozzle back into place on the filter tape.
14. After cleaning, retest using the Leak Check procedures. If the flow value still does not drop below 1.5 l/min, there is still a problem.
15. If problems persist, contact the service team at Met One and see E-BAM manual.

7.4. Pump Replacement

The pump is rated for at least 4000 hours of normal operation. If used for continuous operation, the pump may need to be replaced approximately every 6 to 9 months when it can no longer regulate at the normal 16.7 l/min flowrate. The flow check and leak check performed during initial calibration will help assess pump health.

1. **Disconnect the instrument from power.** Completely review these instructions prior to beginning.
2. Remove the two screws that hold the pump cover plate. *Never remove plate when the pump is running.* Unplug the switch harness (mounted in the cover plate) and set the plate aside.
3. Remove the two small screws securing the clear plastic inlet heater cover. Set parts aside.
4. Remove the vertical sample tube and inlet assembly by sliding the two sealing collars upward. Unplug the inlet assembly and set the sample tube and inlet assembly aside.
5. Unplug the pump from the J17 connector on the 3610 PCB. The connector is on the left in the back attached to the circuit board. Try to pull straight out, minimizing any up and down movement. Use caution when reaching around pump fan blades.
6. Remove the three screws holding the pump assembly to the transport plate.
7. Unplug the four ⅜” ID tube connections from the front of the pump. Mark them to make sure they are replaced in the same positions. Removal can be difficult to do- the tubes are attached tightly and hard to access. A large flathead screwdriver is useful to apply gentle leverage to pry each tube from its port.
8. Completely remove the hose clamp holding the pump to the mounting bracket.
9. Turn the pump assembly upside down and find the two screws visible through the holes in the sheet metal bracket. Loosen, but do not remove them. The pump should now slide away from the bracket assembly. Set the old pump aside. You may have to cut a zip tie.
10. Orient the new pump onto the bracket and slide it in place so that the slots on the pump fully engage the two square nuts you just loosened. Now tighten those two screws/nuts.
11. Make sure the pump harness is on top.
12. Reattach the hose clamp to secure the pump to the bracket.
13. Reinstall the pump assembly into the E-BAM. Make sure the tube connections are fully seated and are in the correct positions. Fasten the three mounting screws.
14. Reinstall the sample tube and inlet assembly. Plug the heater back into its harness and reposition the two sealing collars.
15. Plug the new pump harness into J17 of the 3610 PCB. Make sure the harness does not interfere with the fan blades. Ensure that all wires are routed with adequate clearance of fan blades. Replace the inlet heater cover plate. Plug the switch harness back in.
16. Record date of pump replacement in the E-BAM logbook.

8. Appendix A – Packing list

E-BAM Parts List:

- Tripod
- E-BAM cabinet
- PM_{10} and $PM_{2.5}$ inlet
- Inlet adaptor tube
- Mounting cross arm
- Temperature sensor
- Relative humidity sensor
- Wind sensor with hardware
- Wind mount clamp
- Wind sensor vane
- Wind sensor cable
- Signal splitter
- Cell modem with power cords and signal cables
- Cell antenna with small O-ring and mount
- Power supply
- Three prong power splitters
- Power weatherproof casing
- Power cord
- SOP document
- Met One operation manual

Other Items and Tools

- Leak check valve (Met One Instruments part no. BX-305 or BX-302)
- Allen wrench set
- Isopropyl alcohol
- Q-Tip's
- Vaseline
- Flat head screwdriver
- Philips screwdriver
- Shovel
- Sandbags and plywood
- Hand level
- Threading tape
- Ziplock's and towels for drying
- Packing tape
- Logbook
- GPS / compass
- Zip ties
- Filter tape
- Alicat flow calibrator

9. Appendix B – Siting Criteria

9.1. Inlet Height

- **Inlet Location**: Between 2 and 15 meters above ground level.
- **Specifics**:
    - Inlet with PM_{10} on a tripod is just over 2 meters tall.
    - Maximum height includes any additional height from rooftop installation.

9.2. Inlet Radius Clearance

- **Clearance**: Minimum 1 meter radius free of any objects that could obstruct airflow.
- **Obstruction Guidelines**:
    - Keep at least 2 meters from short walls, fences, or other obstructions.
    - If near a major obstruction (e.g., a building), the distance between the E-BAM and obstruction must be **twice** the obstruction's height.
        - Example: If the building is 10 meters tall, the E-BAM must be 20 meters away.
- **Tree Clearance**: The inlet must be **20 meters** from the drip line of any overhanging trees.
- **Airflow**: A **270-degree arc** of unrestricted airflow around the inlet is required.

9.3. Artificial Particulate Sources

- **Avoid Locations Nearby**:
    - Blowers, vents, air conditioning units, etc.
    - Roads (especially unpaved ones) as much as possible.
    - At least **5 meters** away from roads with daily traffic of less than 3,000 vehicles.
    - **25 meters** from elevated roadways greater than 5 meters high.
- **Site Location**:
    - Avoid installing in unpaved areas unless vegetative cover is present.

9.4. Wind Considerations

- **Wind Direction**: Consider the direction of predominant winds when siting to avoid fugitive dust (e.g., do not site downwind of a gravel pit).
- **Ash Resuspension**: Consider the wind direction for resuspending ash.

Appendix B - E-BAM Particulate Monitor Operation Manual, Met One Instruments

E-BAM
PARTICULATE MONITOR
OPERATION MANUAL

E-BAM-9800 REV N

Met One Instruments, Inc.
1600 NW Washington Blvd.
Grants Pass, OR 97526
Telephone: (541) 471-7111
Facsimile: (541) 471-7116
www.metone.com

Table of Contents

1 INTRODUCTION

1.1 About This Manual

This document is organized with the most important information toward the front of the manual, such as site selection, installation, setups, and field calibrations, which all E-BAM owners and operators should read and understand. Toward the back are sections that provide in-depth information on subjects such as theory, diagnostics, accessories, and alternate settings. These sections provide valuable information which should be consulted as needed. Electronic versions of this manual are also available.

1.2 Technical Service

Should support still be required after consulting the printed documentation, contact one of the expert Met One Instruments, Inc. Technical Service representatives during normal business hours of 7:00 a.m. to 4:00 p.m. Pacific Standard Time, Monday through Friday. In addition, technical information and service bulletins are often posted on our website. Please contact us and obtain a Return Authorization (RA) number before sending any equipment back to the factory. This allows us to track and schedule service work and to expedite customer service.

Contact Information:	Tel:	+ 541 471 7111	Address:	Met One Instruments, Inc.
	Fax:	+ 541 471 7115		1600 Washington Blvd
	Web:	http:/www.metone.com		Grants Pass, Oregon 97526 U.S.A.
	Email:	service@metone.com		

Please have the instrument serial number available when contacting the manufacturer. On most models manufactured by Met One Instruments, it will be located on a silver product label on the unit, and also printed on the calibration certificate. The serial number will begin with a letter and be followed by a unique five-digit number such as U15915.

1.3 E-BAM: Environmental Beta Attenuation Monitor

The Met One Instruments, Inc model E-BAM automatically measures and records airborne PM_{10} or $PM_{2.5}$ particulate concentration levels using the principle of beta ray attenuation. This method provides a simple determination of concentration in units of milligrams of particulate per cubic meter of air. A small ^{14}C (Carbon 14) element emits a constant source of high-energy electrons known as beta particles. These beta particles are detected and counted by a sensitive scintillation detector. A vacuum pump pulls a measured amount of dust-laden air through the filter tape, which is positioned between the source and the detector thereby causing an attenuation of the beta particle signal. The degree of attenuation of the beta particle signal is used to determine the mass concentration of particulate matter on the filter tape, and the volumetric concentration of particulate matter in ambient air. An in-depth scientific explanation of the theory of operation and the related equations is included toward the back of the manual. Complete descriptions of the measurement cycles are found in Section 6.

The E-BAM is designed as a simple, compact, and self-contained beta gauge, for portable applications where rapid deployment and short interval real-time measurements are required.

1.4 Beta Radiation Safety Statement

The Met One Instruments E-BAM contains a small ^{14}C (Carbon 14) beta radiation-emitting source. The nominal activity of the source is **60 µCi** ±15µCi (microcurries), which is below the “Exempt Concentration Limit” as defined in 10 CFR Section 30.71 – Schedule B. The owner of an E-BAM is not required to obtain any license in the United States to own or operate the unit. The owner of an E-BAM may elect to return the entire unit to Met One Instruments for recycling of the ^{14}C source when the unit has reached the end of its service life, although the owner is under no obligation to do so. Under no circumstances should anyone but factory technicians attempt to remove or access the beta source. The beta source has a half-life of about 5730 years, and should never need to be replaced unless it becomes damaged or corroded. Neither the ^{14}C source nor the beta particle detector are serviceable in the field. Should these components require repair or replacement, the E-BAM must be returned to the factory for service and recalibration. The E-BAM is manufactured in compliance with the U.S. NRC safety criteria in 10 CFR 32.27.

1.5 The E-BAM and U.S. EPA Equivalent Methods

The Met One Instruments, Inc. Model E-BAM is not currently designated as a U.S. EPA Federal Equivalent Method (FEM) for continuous PM_{10} or $PM_{2.5}$ monitoring. However, the unit is designed to accurately predict FRM or FEM concentration measurements when operated in accordance with this manual. The E-BAM is intended as a rapid-deployment particulate monitor which can be used for emergency response situations, micro to neighborhood scale particulate studies, perimeter monitoring, remote monitoring, and other applications where a small, self-contained, portable unit is required. To that end, the E-BAM is unparalleled in its flexibility and ease of use.

The internal DC pump E-BAM configuration is not usually intended for permanent, long-term installations at a fixed monitoring site, due to the 4000 hour pump rating. This is often an application for the Met One Instruments Model BAM-1020, which is an EPA designated FEM for both PM_{10} and $PM_{2.5}$ monitoring, and is intended for continuous operation at a fixed site. Many agencies have networks which contain both types of Met One BAM units in order to meet their diverse sampling needs. The following table shows some of the features of the E-BAM compared to the BAM-1020:

	E-BAM	**BAM-1020**
Configurable for $PM_{2.5}$, PM_{10}, or TSP monitoring:	yes	yes
Compatible with EPA PM_{10} inlets, cyclones, and WINS impactors:	yes	yes
U.S. EPA $PM_{2.5}$ and PM_{10} Federal Equivalent Method:	no	yes
Portable unit designed for rapid deployment:	yes	no
Designed for continuous long-term operation at a fixed site:	no	yes
Hourly concentration measurements:	yes	yes
Hourly concentration accuracy:	good	best
Quasi real-time concentration output available:	yes	no
Analog and digital data outputs available:	yes	yes
16.7 lpm actual or standard flow rate:	yes	yes
Separate weatherproof shelter or enclosure required:	no	yes
Automatic hourly span checks:	no	yes
12 volt DC operation for remote sampling:	yes	no
Meteorological sensor inputs:	yes	yes
Sample RH control:	yes	yes
Filter tape advances:	variable	hourly
Operation time per standard filter tape roll:	variable	60 days

1.6 E-BAM Specifications

PARAMETER	SPECIFICATION*
Measurement Principle:	Particulate Concentration by Beta Attenuation.
U.S. EPA Designations:	Designed to meet Class III monitoring criteria. Not an EPA-designated FEM.
Measurement Range:	-0.005 to 65.530 mg/m3 (-5 to 65,530 µg/m3) 16 bit digital range.
Accuracy:	± 10% of indicated value for hourly measurements.
Data Resolution:	1 µg/m3
Lower Detection Limit:† (2σ, 1 hour measurement)	Less than 6.0 µg/m3
Lower Detection Limit:† (2σ, 24 hour average)	Less than 1.2 µg/m3
Sample Time:	Continuous air sampling with variable filter change periods.
Measurement Cycles:	Automatic hourly concentration measurements, with user selectable 1, 5, 10, 15, 30, or 60 minute quasi-real-time average output.
Flow Rate:	16.7 liters/minute. Adjustable up to 17.5 lpm. Actual or Standardized flow modes.
Flow Accuracy:	±2% of setpoint typical.
Pump Type:	Internal DC dual-diaphragm pump standard. 4000 hour rated.
Filter Tape:	Continuous glass fiber filter, 30mm x 25M roll. Up to 1 year operation per roll.
Span Check:	Manual 800µg (typical) span foil included.
Beta Source:	14C (carbon-14), 60 µCi ±15 µCi (< 2.22 X 106 Beq), Half-Life 5730 years.
Beta Detector Type:	Photomultiplier tube with patented scintillator assembly.
Operating Temp. Range:	-25 to +50°C intermittent. -25 to +40°C continuous.
Ambient Humidity Range:	0 to 90% RH, non-condensing.
Humidity Control:	Automatic 15 Watt inlet heater module.
Approvals:	CE, NRC, ISO-9001
User Interface:	Menu-driven interface with 4x20 character VFD display and dynamic keypad.
Analog Voltage Output:	0-1, 0-2.5, or 0-5 volt DC output equals 0-1000 µg/m3. Selectable to represent the hourly or real-time concentration.
Serial Interface:	RS-232 2-way serial port for PC, datalogger, or modem communications.
Alarm Contact Closures:	Normally closed contact closure relay output. 0.5A @ 100V DC max.
Compatible Software:	Comet™, Air Plus™, terminal programs such as HyperTerminal®
Error Reporting:	Available through serial port, display, and relay output.
Memory:	4369 records (182 days @ 1 record/hr. 3 days @ 1 record/min).
Power Supply:	12 to 16 Volt DC input. 4.1 amps @12 VDC (50 Watts) max continuous draw.
Weight:	13.2 kg (29 lbs) E-BAM only. 23 kg (50 lbs) with tripod, PM10, 9250, power supply.
Unit Dimensions:	41cm high x 36cm wide x 20cm deep. (16” x 14” x 8”).

* Specifications may be subject to change without notice.

† The hourly detection limit is defined as twice the standard deviation of the hourly zero noise of the instrument. The 24 hour detection limit is defined as the hourly detection limit divided by the square root of 24 (approx 4.9).

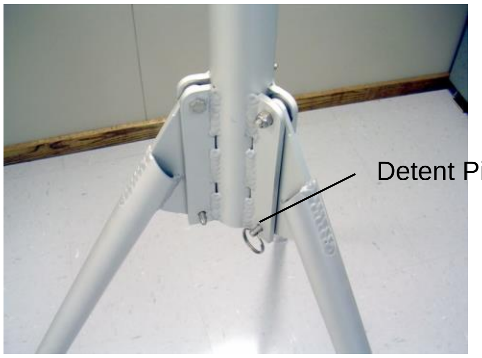
2 E-BAM UNIT ASSEMBLY AND START-UP

This section describes assembly, start-up, and filter tape installation for the E-BAM unit.

2.1 Assembling the E-BAM

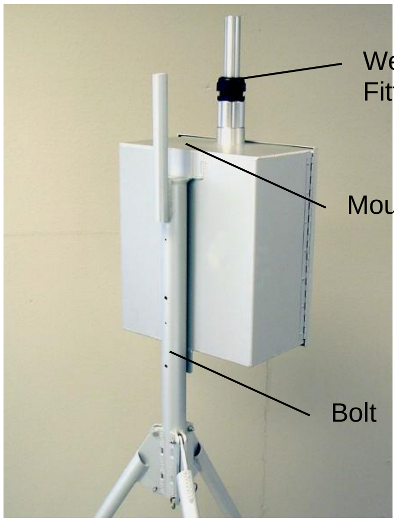
The standard DC version of the E-BAM is designed to be field deployable by an average person in less than 15 minutes under normal conditions. Refer to the photos and diagrams below while performing the following steps to assemble the unit:

1. **Deploy the tripod:** Remove the three stainless steel detent pins from the tripod base by pulling the rings. Unfold the three tripod legs and reinsert the three pins so that each pin secures a leg in the open position. Make sure the erected tripod is rigid and stable.



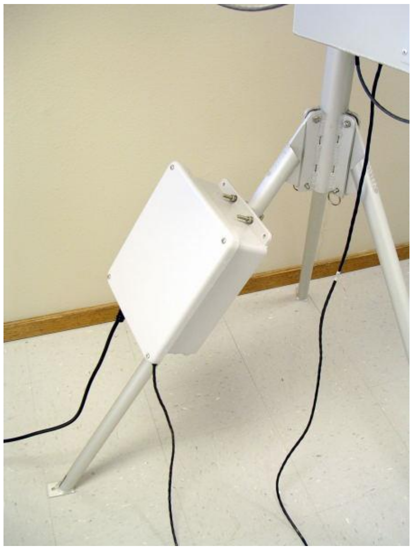
2. **Install the E-BAM onto the tripod:** Lift the E-BAM assembly and slide the slot on the back of the E-BAM over the tab on the top of the tripod. Insert the supplied ¼-20 bolt through the tab on the bottom of the E-BAM and through the hole in the body of the tripod. Secure it with the supplied washers and nut. This prevents the E-BAM from shifting on the tripod.

3. **Install the inlet tube and the PM_{10} and $PM_{2.5}$ inlets:** Loosen the black weatherproof fitting on top of the E-BAM and insert the short inlet tube into the top of the unit. The tube must go through the black fitting and through two o-rings in the top of the E-BAM. *Make sure the tube is fully seated* by rotating it back and forth. Tighten the black weatherproof fitting to secure the inlet tube. For PM_{10} monitoring, install the BX-802 PM_{10} inlet directly onto the top of the short inlet tube. *If a BX-807 cyclone is to be used for $PM_{2.5}$ monitoring, it must be installed under the PM_{10} head* as shown in the picture below. Lubricate the o-rings as necessary.



4. **Install the cross-arm and temperature sensor:** Connect the 18" cross-arm to the post on the back of the tripod with the supplied ¾" x ¾" fitting and set screws. The 9250 ambient temperature sensor snaps onto the cross-arm and plugs into the bottom of the E-BAM.

5. **Optional wind sensor:** If an optional EX-034 wind speed/direction sensor is supplied, then it will come with a longer cross-arm tube to use instead of the short one that came with the temp sensor. Install the wind sensor on one end of the cross-arm, and the temperature sensor on the other. The wind sensor should be as far from the E-BAM unit as possible, and the wind vane must be able to rotate fully without hitting anything. Plug the wind sensor into the corresponding connector on the bottom of the E-BAM. The sensor will need to be oriented to the north. Consult the separate manual that comes with the 034 wind sensor.
6. **Power Supply:** Many E-BAMs are supplied with an EX-121 AC-to-12 $_{VDC}$ power supply as shown in the photo below. Bolt it to one of the legs of the tripod with the included U-bolts. Plug the power supply output cable into the DC power input on the bottom of the E-BAM. When the power supply is plugged into AC power, the E-BAM will turn itself on automatically. **Note:** If the E-BAM is to be powered by a battery array or solar system, or if the unit is supplied with an external AC pump box with a built-in power supply, then these items will plug into the E-BAM power input instead of the normal power supply.

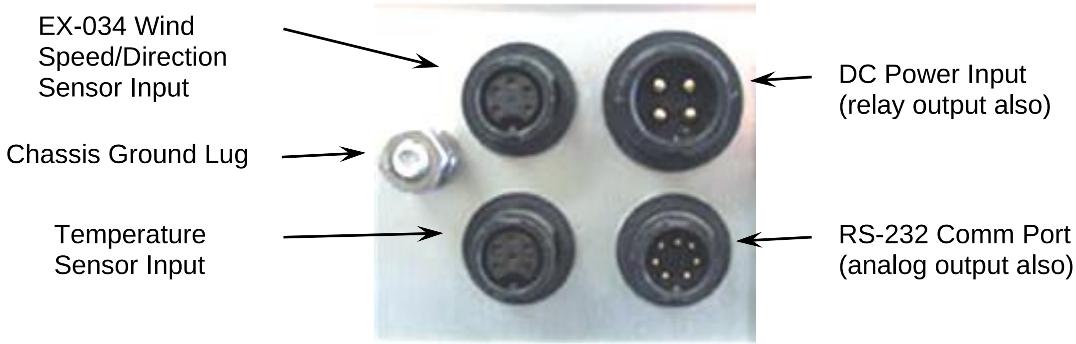



7. **Optional met sensors:** If the E-BAM is supplied with other optional met sensors such as ambient RH or barometric sensors, then these attach to the cross-arm and plug into the same connector as the temperature sensor, using a supplied splitter junction box.

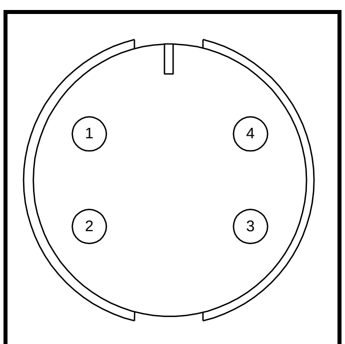
2.2 Electrical Connections

The standard E-BAM has a set of weatherproof connectors on the bottom of the unit. These connectors provide the connections for the power supply, external sensors and communications options. Each connector has a different pin configuration to prevent plugging cables into the wrong connector. The E-BAM will turn on when a power source is connected to the power input. **Note:** There is a 3-color LED located on the bottom of the E-BAM near the electrical connectors. This LED may flash or hold various colors, but is used for factory test software applications only, and does not indicate any specific status information to the user.

The E-BAM chassis ground lug should be connected to an earth ground whenever possible, to reduce electrical noise in the unit.

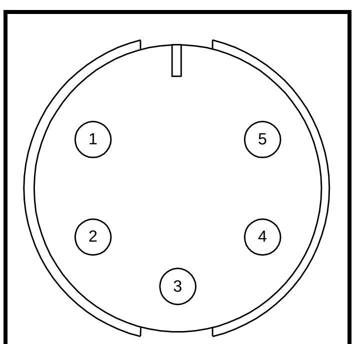


E-BAM connector layout



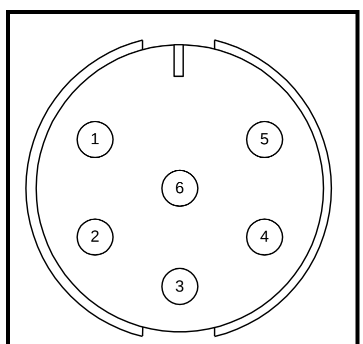
DC Power Input

Pin	Function
1	+12 VDC Pwr Input
2	Ground/Common
3	Alarm Relay IN
4	Alarm Relay OUT



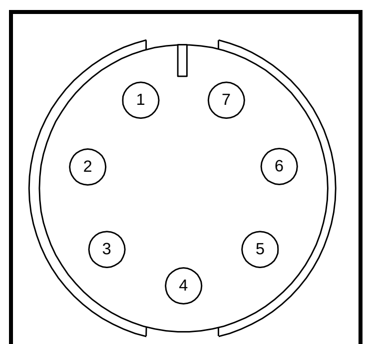
WS/WD Sensor In

Pin	Function
1	Wind Direction Ref.
2	Ground/Common
3	Wind Direction Input
4	Wind Speed Input
5	Shield



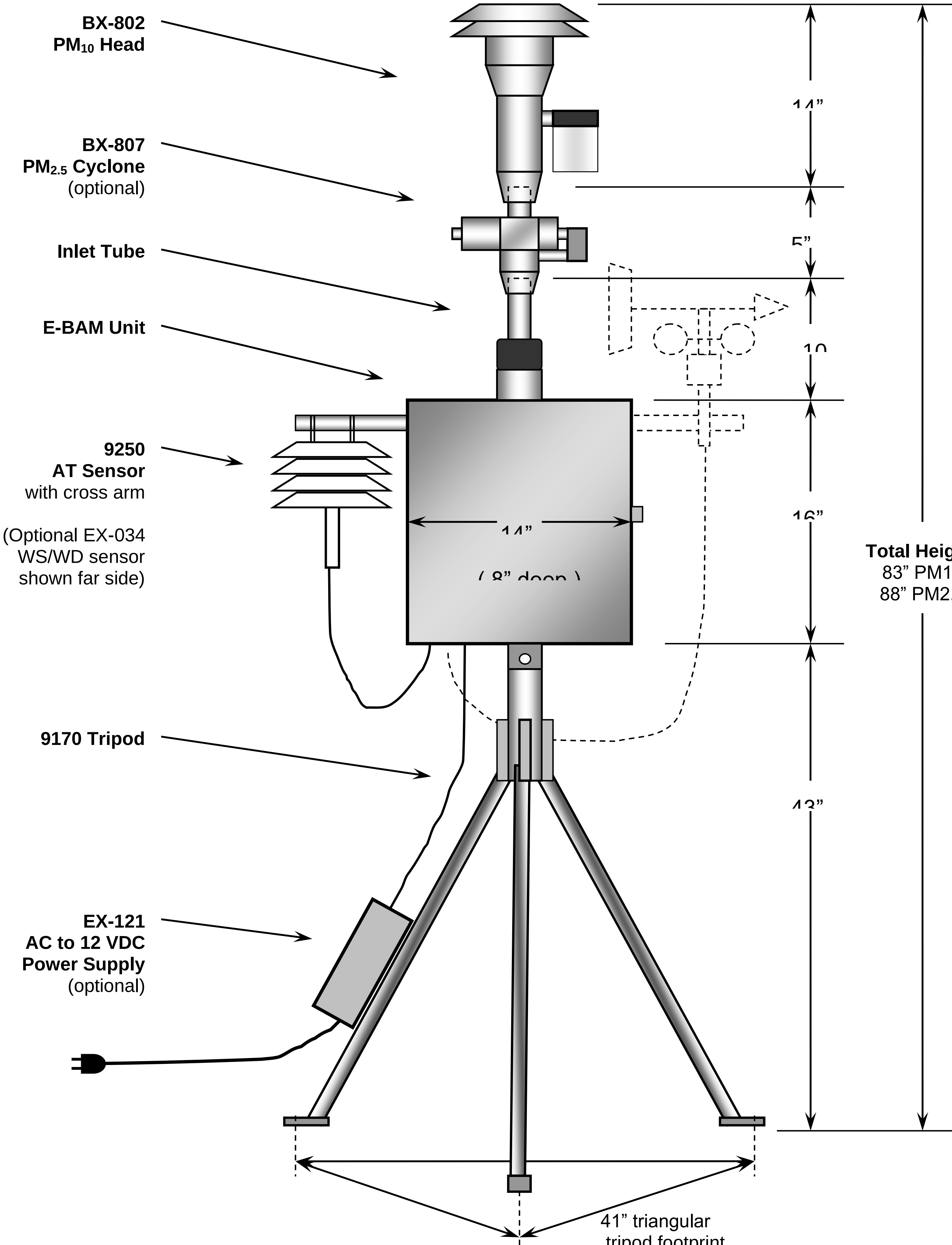
Temp Sensor Input

Pin	Function
1	RH Signal Input
2	Ground/Common
3	+12 VDC Output
4	Temp Signal Input
5	Baro Signal Input
6	Shield



RS-232 Serial Port

Pin	Function
1	RST
2	RX
3	TX
4	Ground/Common
5	STX
6	Analog Volt Output
7	TCK



Standard E-BAM Configuration
Not to scale. Some items simplified for clarity.

2.3 Power-up and Automatic Operation

The E-BAM is designed to turn on automatically when power is applied. The unit will ask if you are ready to start, then prompt you to verify several setup menus which are described below. Then the unit will perform an automatic self-test routine which takes several minutes. After the self-test, the unit will begin sampling automatically.

Note: If no keypad activity is detected for several minutes after power-up, the E-BAM will automatically begin sampling based on the existing SETUP options and settings, as long as filter tape is installed and no hardware or voltage failures are detected. This makes it possible to fully configure and calibrate the unit in the lab, then simply deploy it to the field and power it up with no further actions required.

2.4 Power-up Settings Verification and Automatic Self-Test

The E-BAM will prompt you to verify several setup parameters whenever it is powered on. These setup screens can also be viewed or edited in the SETUP menu under the main E-BAM menu system. See Section 7 for detailed descriptions of the SETUP parameters.

When power is applied to the E-BAM, the unit will show the firmware revision and unit serial number for a moment, then display the welcome screen:

```
WELCOME TO E-BAM
ARE YOU READY TO
START?
                     YES
```

Press the YES soft key, and the clock screen is displayed as shown below. If the time and date are correct, press the YES key. If you need to change the time or date, press NO and the display will show the time/date set screen. Use the arrow keys to change the values, then press SET. Or press CONTINUE to go on without making changes.

```
DATE:   19-NOV-2008
TIME:   16:36:37
IS THIS CORRECT?
 NO               YES
```

```
19-NOV-2008  16:36:42

SET          CONTINUE
```

After the time is verified, the unit will display the AVERAGE PERIOD screen shown below. This menu is important to understand. See Sections 6.2 and 7.2 for detailed descriptions of these parameters. Press OK if the settings are correct. If the settings need to be changed, press the EDIT key to enter the edit mode. Select the parameter to be changed with the ◄► keys, and modify the settings with the ▲▼ keys and press SAVE. Press CONTINUE to exit the edit mode without making changes.

```
   LOCATION:  01
TAPE ADVANCE:  24 HRS
REALTIME AVG:  10 MIN
 EDIT             OK
```

```
   LOCATION:   01
TAPE ADVANCE: ▼24 HRS
REALTIME AVG: ▼10 MIN
 SAVE        CONTINUE
```

LOCATION is an ID number which will appear in the data array to indicate which unit collected the data, and to enable tracking of measurement information. This is used instead of a UNIT ID because the E-BAM is portable. This may be any number from 01 to 99.

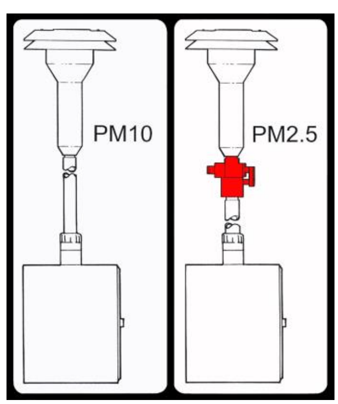
TAPE ADVANCE is how often the E-BAM will automatically advance to a new spot of filter tape. This value can be set to 1, 2, 3, 4, 6, 8, 12, or 24 hours. The default setting is 24 hours for maximum tape life. The unit will override this setting and automatically advance the filter tape if the concentration is too high and the filter tape becomes clogged. If the filter tape is advanced due to high concentrations, an alarm will be recorded in the alarm log. **Note:** the tape advance setting does not change how often the concentration is calculated or stored.

REALTIME AVG is the averaging period for the real-time concentration value. The real-time concentration measurement is updated every minute, and the REALTIME AVG is the mean of these real-time values over the selected time period. The REALTIME AVG may be set to the following time periods: 1, 5, 10, 15, 30, or 60 minutes. This also sets the averaging period for the datalogger. See Sections 6.2 and 7.2 for important considerations regarding this setting.

After the real-time settings are verified, the E-BAM will go on to display the MACHINE TYPE screen. Press EDIT to change the setting with the arrow keys, or press OK to go on without changes:

```
MACHINE TYPE:  PM10
< SEE PICTURE

 EDIT             OK
```

MACHINE TYPE tells the E-BAM which type of inlet it is equipped with, $PM_{2.5}$ or PM_{10}. *The only difference between the two is whether a $PM_{2.5}$ cyclone is installed or not*. The E-BAM will put the machine type setting onto the data array, so that you can tell if the collected data was $PM_{2.5}$ or PM_{10}. The screen refers the user to a picture located inside the door of the E-BAM for easy identification of the two possible inlet types:



E-BAM Door Label for Inlet Identification

After the MACHINE TYPE is set or verified, the E-BAM will raise the nozzle and check to see if the stainless steel shipping shim is installed under the nozzle. **Note:** The shim is attached to the unit with a tether chain, and is also used for the zero portion of the span membrane test. The shim should be installed any time the E-BAM is shipped or transported in order to prevent nozzle damage. The unit can sense the shim with a photo sensor. If the shim is still in place the unit will display the message "PLEASE REMOVE NOZZLE PACKING MATERIAL".

After the nozzle shim has been removed, the E-BAM will check if a roll of filter tape installed. If tape is already installed, the unit will go on to the power status screen. If no tape is detected, the unit will prompt you to install a new roll:

```
      CHECKING FOR
      LOADED TAPE.

      PLEASE WAIT...
```

```
PLEASE LOAD TAPE!
E-BAM WILL NOT
OPERATE WITHOUT
TAPE!        CONTINUE
```

Install a roll of filter tape as described in Section 2.5. When the filter tape is installed, press CONTINUE. The unit will again try to detect the tape. If tape is detected, the unit will go on to display the power status screen. This is mostly useful if the unit is powered with batteries:

```
BATTERY: 14.3 VOLTS
ESTIMATED OPERATION
TIME FOR 100 AMP-HRS
IS 33 HRS.   CONTINUE
```

Press CONTINUE to proceed. The unit will begin the self-test process and will show "SELF TEST RUNNING…" on the display. The self-test takes several minutes and can only be bypassed by pressing the ESC key. The unit will test the nozzle, tape motor, beta detector, pump, flow sensor, and pressure sensors. If a fault is detected during the self-test, the hardware failure screen will be shown. Press CONTINUE to view the cause of the failure. See Section 8.1 for error descriptions. In the example below, the operator has forgotten to connect the 9250 ambient temperature sensor to the E-BAM. The unit has indicated that the sensor is not operational. If a hardware failure is detected, the problem must be corrected before proceeding. Press the MENU key to enter the menu system if needed. Other hardware failures that will hinder E-BAM operation include:

- Ambient or filter temperature sensor missing or failed.
- Ambient or filter pressure sensor failure.
- Broken or missing filter tape.
- Low battery voltage or DC input voltage below 10 volts DC.

```
WARNING
HARDWARE FAILURE

            CONTINUE
```

```
25-NOV-2008 10:08:00
SENSOR FAILURE
Ambient Temp
-29.6
```

If the self-test finishes without errors, the screen will display that the unit is functioning properly. Press CONTINUE to go on to the start operation screen as shown below. Press YES to immediately start the E-BAM sampling on a normal operating cycle. Press MENU to forgo operation and enter the main E-BAM menu system instead.

```
SELF TEST COMPLETE:
E-BAM FUNCTIONING
PROPERLY.
   CONTINUE
```

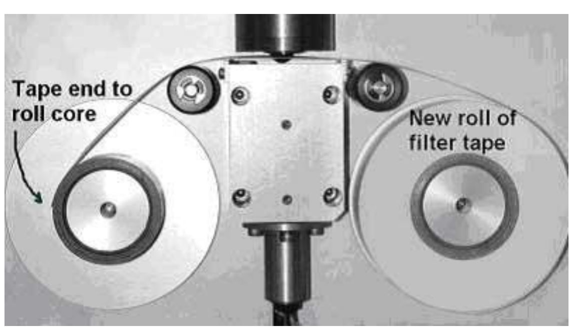
```
WARNING
START OPERATION?

MENU                YES
```

This is the end of the automatic E-BAM start-up sequence. It is recommended that you perform a leak check and flow check/calibration as described in Section 5. *Become comfortable with these checks, as they will be performed often.*

2.5 Filter Tape Loading

Filter tape must be loaded into the E-BAM for sampling. One roll of tape will last anywhere from a few weeks to more than a year, depending on the TAPE ADVANCE setting and ambient particulate levels. It is important to have several spare rolls of tape available to avoid data interruptions. Some agencies save used rolls of tape for post-sampling analysis, although there is no guarantee that the sampled spots have not been contaminated. Used filter tape should never be “flipped over” or re-used! This will result in measurement problems. Loading a roll of filter tape is a simple matter using the following steps:

1. If the sample nozzle is in the down position, it will need to be raised. Enter the LOAD TAPE screen in the main E-BAM menu. The unit will raise the nozzle and prompt you to load the tape.
2. If you are replacing a used roll of tape. Remove the old roll, then thoroughly clean the nozzle and vane as described in Section 5.1.
3. An empty core tube must be installed on the left (take-up) reel hub. This provides a surface for the used tape to spool-up on. Met One supplies a plastic core tube to use with the first roll of tape. After that, you can use the empty cardboard core tube left over from your last roll to spool-up the new roll. Never fasten the filter tape directly to the aluminum hub!
4. Load the new roll of filter tape onto the right (supply) reel, and route the tape through the nozzle area as shown below. Attach the loose end of the filter tape to the empty core tube with tape.
5. Rotate the tape roll to remove excess slack, then install the plastic spool covers **tightly**. The spool covers clamp the tape rolls to the hubs to prevent them from slipping.



2.6 Warm-up Period

The E-BAM must warm up for at least one hour before optimum accuracy of the concentration data can be obtained. This is because the beta detector contains a vacuum tube which must stabilize. This applies any time the unit is powered up after being off for more than a moment. Setups, tests, and flow calibrations can be performed during this warm up time. The first hour of data should often be discarded or ignored. Some agencies choose to discard the first few hours of concentration data after the E-BAM unit is powered up.

3 E-BAM USER INTERFACE and MENU SYSTEM

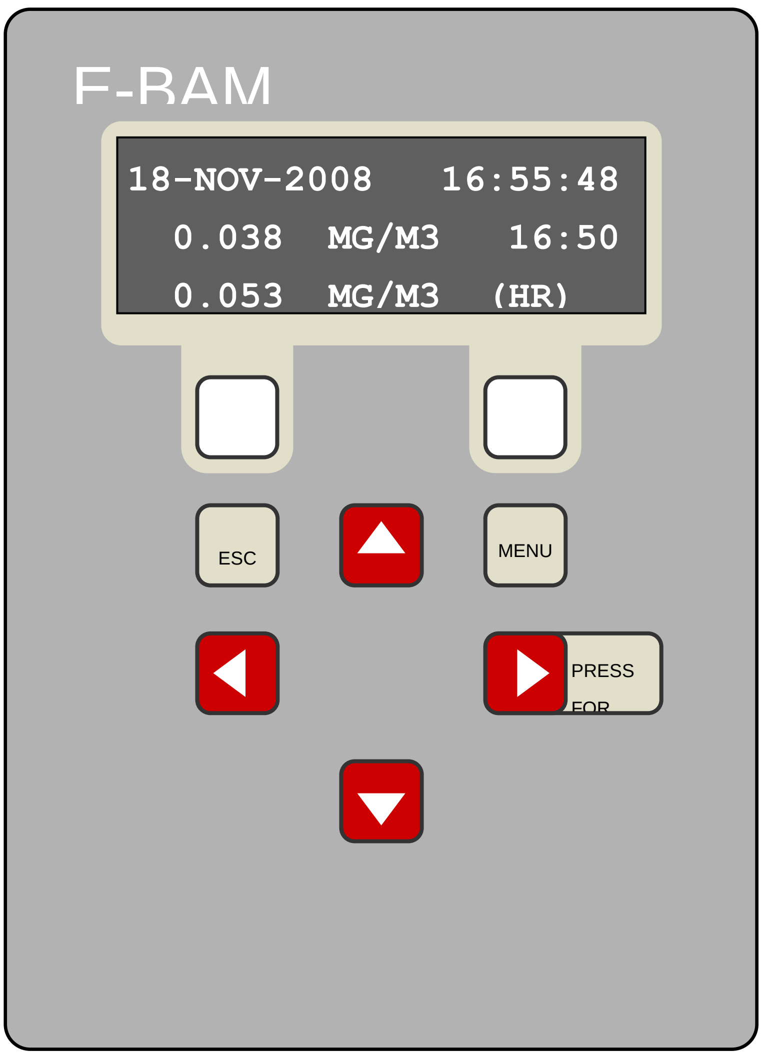
This section describes the E-BAM user interface system, and describes the functions of the main menu options, including how to view data and errors.

3.1 The User Interface - Keypad and Display Functions

The E-BAM user interface consists of a 4x20 character vacuum fluorescent display (VFD) and a dynamic keypad. The two white keys under the display are called “soft keys”. These are dynamic keys which change in response to a menu option displayed directly above the key on the bottom row of the display. The function of these keys depends on which menu is shown on the display, and are often used for functions such as “save”, “edit”, and “set”.

The four red arrow (cursor) keys are used to scroll up, down, left, and right, to navigate in the menu system, and to select items or change fields on the screen. The arrow keys are also often used to change parameters or increment/decrement values in the menu system. The right arrow key can be used to wake up the display if it has turned off to save power.

The MENU/SELECT key is used to enter the main menu or to select an item in a list. The ESC key is used to escape or exit out of a menu.

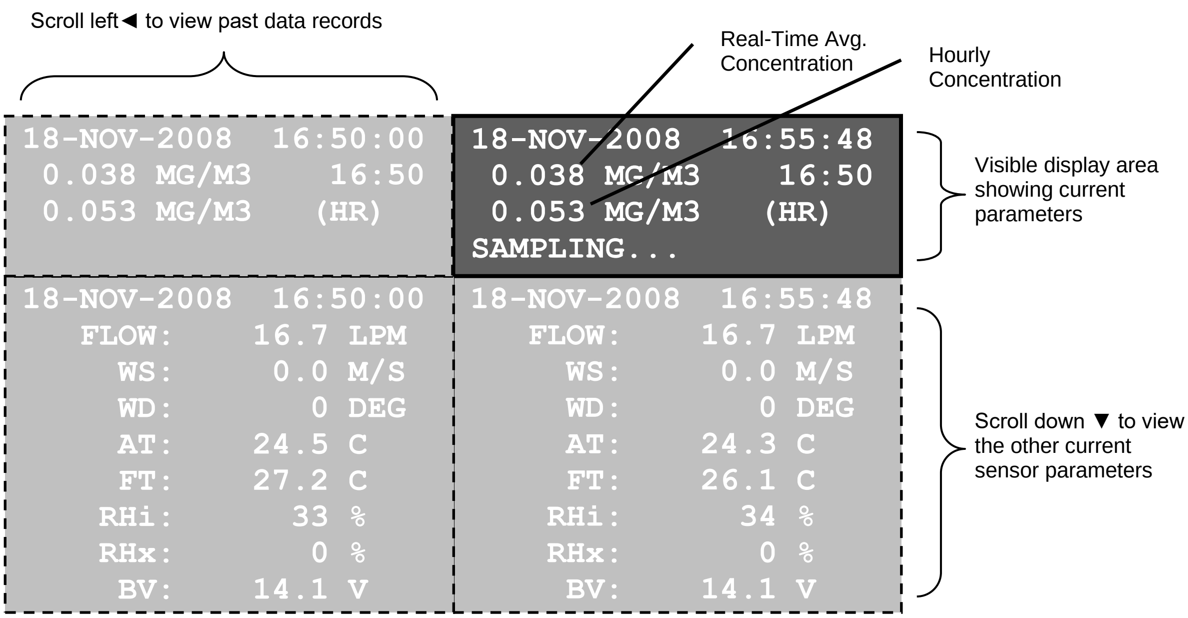


E-BAM User Interface

3.2 Using the Main Sampling Screen

The E-BAM display shows the Sampling screen when the unit is in normal operation. The active display area shows the current date and time, the latest real-time average concentration, and the last hourly concentration. Also shown is a status message, such as "SAMPLING…". To view the rest of the instantaneous sensor parameters which do not all fit on the display at once, press the down ▼ arrow. The date and time will remain at the top of the display at all times.

To view past data, use the left ◄ arrow key to scroll back to previous data records. There will be one complete data record for every real-time average interval, indicated by the time/data stamp at the top of the screen. For example, if the real-time average is set to 10 minutes, then there will be a complete data record stored every 10 minutes as shown below. Again, you can use the ▼ key to view the rest of the sensor parameters for that record. Press the ESC key at any time to return to the current concentration sampling screen.



Main Sampling Screen Format

Below is a table which describes the other parameters visible in the main sampling display as shown above. In addition to the hourly and real-time average concentrations, these are all of the logged parameters in the E-BAM:

Parameter	Description
FLOW	Primary air flow rate in actual LPM or standard SLPM.
WS	Wind speed in meters per second (if equipped).
WD	Wind direction in degrees (if equipped).
AT	Ambient temperature in degrees C.
FT	Filter temperature in degrees C.
RHi	Internal filter RH.
RHx	External ambient RH (if equipped).
BV	Battery voltage (or DC input voltage).
FLOW	Secondary flow in LPM. Only appears if primary flow is set to SLPM.

3.3 Using Main E-BAM Menu System

The main E-BAM menu system can be entered at almost any time by pressing the MENU/SELECT key. Use the ▲▼ arrow keys to select the desired menu option, then press the MENU/SELECT key to enter the selected sub-menu. The functions in the FIELD CALIBRATION menu are described in Section 5. The functions in the SETUP menu are described in Section 7. All of the other main menu functions are described below.

Visible display area

```
 OPERATE
 LOAD TAPE
 SETUP
▼MEMORY
```

Scroll down ▼ to view these options

```
 SELF TEST
■FIELD CALIBRATION
 SHUTDOWN/SHIPPING
 VIEW ALARM LOG
 ABOUT
```

The Main E-BAM menu

OPERATE: This menu option starts the E-BAM into normal operation mode and starts a new sample cycle. You will see a message which says" WARNING: START OPERATION?" Press the YES key to start a new sample. If the unit is already sampling, this option will simply exit the main menu and display the main sampling screen.

LOAD TAPE: This menu option is used for filter tape installation. If this option is selected, the E-BAM will simply raise the sample nozzle for easy tape loading, then display "PLEASE LOAD TAPE." Load the tape and press the CONTINUE key to go back to the main menu.

SETUP: This is the setup menu for the E-BAM. All of the setup parameters in this menu are described in Section 7.

MEMORY: This menu option displays the amount of memory left in the E-BAM digital data system as shown below. To erase the memory, press the CLEAR key. Use the arrow keys to select either the DATA LOGGER or ALARM LOG to be cleared, then press the CLEAR key again. The unit will show a CAUTION screen. If you are sure you want to erase the selected log, press the YES key. **CAUTION! Once the data log or the error log is cleared, the erased data can never be recovered.**

```
MEMORY
 99 % REMAINING
 30.3 DAYS REMAINING
```

```
CLEAR MEMORY
CLEAR:▼DATA LOGGER
```

```
 >>>>> CAUTION <<<<<
 CLEAR DATA LOGGER
      MEMORY?
```

The unit contains memory for **4369** data records. The memory will fill up faster the shorter the real-time average interval is set to, as shown in the table below. This is another reason why the 1 and 5 minute RT averages are rarely used.

Note: When the memory is full, the unit over-writes the oldest data.

Real-Time Average Setting	Records Stored Per Hour	Memory Capacity (Days)
1 min	60	3.03
5 min	12	15.1
10 min	6	30.3
15 min	4	45.5
30 min	2	91
60 min	1	182

SELF TEST: This menu option starts the E-BAM on an automatic self-test cycle, just like the self-test it performs when powered on. Press the ESC key to escape from the self-test and return to the main menu.

FIELD CALIBRATION: This is the field calibration menu for the E-BAM. All of the calibrations and tests in this menu are described in Section 5.

SHUTDOWN / SHIPPING: This menu option is used to prepare the E-BAM for transport. When you enter this screen, the nozzle will raise, and the display will show "PLEASE INSERT NOZZLE PACKING MATERIAL". This is the empty zero membrane shim which is connected to the unit with a tether chain. This shim prevents damage of the nozzle during transport or shipment. Insert the shim under the nozzle with the tab extending through the slot. The E-BAM will automatically lower the nozzle onto the shim, then display: "OK TO TURN OFF E-BAM". The power cord can now be unplugged to power off the E-BAM. **Note:** It is OK to power off the E-BAM at almost any time during normal operation. This menu simply allows the opportunity to insert the nozzle shim.

VIEW ALARM LOG: This menu option allows you to quickly view the error log entries in the E-BAM without having to download the digital data. The screen will display the type or error, as well as the time and date when the error occurred. Scroll through the error records using the ◄► arrow keys. Press the MENU/SELECT key to return to the main menu.

ABOUT: This menu option displays the E-BAM firmware version and revision, as well as the E-BAM serial number as shown in the example below. The up/down arrow keys may be pressed to change which firmware version is shown. The E-BAM has two separate firmware files. One is for the master CPU and the other is for the 3610 I/O control board. Press the MENU/SELECT key to return to the main menu.

```
   3613-01 R1.50.5
      SN: F1768
 Met One Instruments
    www.metone.com
```

Note: If the ESC key is pressed while the E-BAM is displaying the ABOUT screen, the unit will prompt the user for a password. This is for entry into an advanced factory test menu. Do not enter this system unless instructed to do so by a Met One technician.

```

Password (000■)

```

4 SAMPLE SITE SELECTION

Use the following criteria when deciding on a sampling location for the E-BAM. Always consider the safety and security of the unit as well as the suitability of the sampling environment.

4.1 Site Selection Requirements

Selection of a proper site for the E-BAM is critical for accurate measurements. In many cases, these items must be correctly addressed in order for the collected data to be acceptable for regulatory requirements, such as FEM, ARM or SPM methods. U.S. EPA Specifications for the site selection can be found in the EPA documents listed below:

- 40 CFR, Part 58 Appendix E.
- Quality Assurance Guidance Document 2.12 "Monitoring $PM_{2.5}$ in Ambient Air Using Designated Reference or Class I Equivalent Methods" Section 5.1.2.

The following is a summary of the primary site requirements. In any case, the Code of Federal Regulations takes precedence where applicable. Refer to the EPA website at www.epa.gov .

Inlet Height:

- The inlet should be located in the "breathing zone", between 2 and 15 meters above ground level. When installed on the standard tripod, the E-BAM PM_{10} inlet is positioned just over two meters above the ground or other mounting surface. A $PM_{2.5}$ cyclone will add about five inches.
- If the inlet is located on (or through) a rooftop, the total height should be no more than 15 meters from the ground level.
- If the BAM-1020 is to be co-located with other particulate instruments, such as FRM filter-type samplers or other BAM units, then the air inlet must be the same height as the inlet of the other samplers, within one meter vertically. Within one foot is preferred.
- If the E-BAM inlet is the highest point on a building, then lightning rods must be installed to prevent destruction of the unit during electrical storms.

Inlet Radius Clearance:

- The E-BAM inlet must have a one meter radius free of any objects that may influence airflow characteristics, including the inlet of another instrument.
- If a E-BAM is to be co-located at a station with other BAM or FRM sampler, the inlets of each sampler must be no less than one meter apart from each other, and no more than four meters apart. Two meter spacing is recommended where possible.
- If installed near a PM_{10} Hi-Volume sampler, then the distance between the inlet of the E-BAM and the Hi-Vol must be no less than two meters.
- The E-BAM inlet must be located away from obstructions such as short walls, fences, and penthouses, so that the inlet is unobstructed for two meters in all directions.
- If located beside a major obstruction (such as a building) then the distance between the E-BAM and the building must be equal to twice the height of the building.

- The inlet must be at least 20 meters from the drip line of any overhanging trees.
- There must be at least a 270 degree arc of unrestricted airflow around the inlet. The predominant direction of concentration movement during the highest concentration season must be included in the 270 degree arc.

Artificial Particulate Sources:

To avoid possible errors in the concentration measurements, the inlet must be located as far as possible from any artificial sources of particulate, such as blowers, vents, or air conditioners on a rooftop. Especially if any of these types of devices blow air across the inlet of the E-BAM. Even sources of filtered air must not blow across the inlet.

Spacing from Roadways:

The E-BAM should usually not be located directly next to a major highway or arterial roadway, as vehicle exhaust will dominate the concentration measurement. This effect can be difficult to predict accurately as shifting winds may direct the plume toward or away from the E-BAM inlet.

- Roads with a daily traffic volume of less than 3,000 vehicles are generally not considered major sources of pollutants, and in this case the E-BAM must be located at least five meters from the nearest traffic lane.
- The E-BAM must be located at least 25 meters from any elevated roadway greater than five meters high.
- The unit should be located as far as possible from unpaved roadways, as these also cause artificial measurements from fugitive dust.
- The unit should not be installed in unpaved areas unless year-round vegetative ground cover is present, to avoid the effects of re-entrained fugitive dust.

4.2 Fall Hazard and Security Cautions

If the E-BAM is to be installed more than three meters above ground level, then the tripod legs must be bolted down to prevent the unit from falling to the ground. An accidental fall of more than three meters may compromise the containment of the radioactive source and the unit will need to be returned to the factory for testing. In addition, dropping the E-BAM from any height will cause a potential safety hazard for those below, and may damage the unit beyond repair.

The E-BAM tripod should be secured to the mounting surface in windy conditions to prevent the unit from falling over, even at ground level. This is especially important in winds over 30 mph. If bolt-down is not possible, then the tripod legs may be weighted down with sand bags to secure the unit. Wind or fall damage is not covered under warranty.

The E-BAM should be secured from theft or vandalism to the extent possible. A limited-access rooftop or a fenced lot are often good places to deploy the unit. Solar panels and batteries are also highly susceptible to theft and should be secured.

4.3 Confined Sampling Locations

Because of the portable nature of the unit, the E-BAM is sometimes deployed in confined or non-ambient locations to monitor highly localized particulate sources, such as tunnels, mines, quarries, shopping malls, train stations, etc. Each of these applications are unique and present various challenges. We recommend that you contact a Met One Service representative to determine the suitability of the unit if you plan a custom deployment like this.

4.4 Smoke and Ash Monitoring

A primary design use for the standard E-BAM is for tracking smoke and ash plumes from wildfires, prescribed burns, agricultural burns, and even volcanic activity. In these cases, the unit is often sited at the outskirts of a populated area in the expected path of the smoke plume. The unit is usually equipped with the optional EX-034 wind speed and direction sensor for these applications, in order to correlate changing wind patterns with particulate events. The wind sensor is plug-and-play, and only requires an extended cross-arm for the tripod mount. The EX-034 will need to be oriented to the north for accurate wind direction measurements.

In smoke tracking applications, the filter tape may be consumed at a much faster rate than normal. This is because the E-BAM may automatically advance the filter to a new spot if the particulate loading becomes excessive, **regardless of the user-defined tape advance setting**. This is based on the measured pressure drop across the filter tape. This feature protects the pump, preserves accurate flow control, and prevents damage to the filter tape.

4.5 Remote Monitoring With Solar or Battery Power

The standard version of the E-BAM is designed to be deployable in remote areas where AC power is not available. These applications require deep-cycle batteries, and sometimes a solar panel array as well. The E-BAM is rated for a worst-case continuous power draw of 50 Watts (approximately 4.1 amps at 12 volts DC).

Battery Operation:

The simplest method for remote deployment is to use batteries. The most common type for this application are 12 volt, 110 amp-hour, gel-cell or AGM, deep cycle batteries. The E-BAM is supplied with a battery cable which plugs into the power connector on the bottom of the unit. The other end connects to the battery terminals. The batteries are typically enclosed in a plastic box on the ground near the E-BAM.

Assuming a continuous E-BAM current draw of 4.1 amps, a single fully-charged 110Ah battery would have the theoretical capacity to run the unit for 26.8 hours. However, the general rule is that a lead-acid battery should not be discharged by more than 2/3 of its capacity, especially in temperatures below 40 degrees F, so:

((110Ah / 4.1A) * .67) = **18.0** hours of run time per battery.

Additional run time is achieved by connecting more batteries **in parallel** to the first battery. Additional batteries **must** be of the same type! A set of three fully charged 110Ah batteries in parallel should run an E-BAM for at least 54 hours under worst-case conditions. When the battery voltage discharges below 10.0 volts, the unit will shut itself down until fresh batteries are supplied and the restart voltage threshold is exceeded. See Section 7.10.

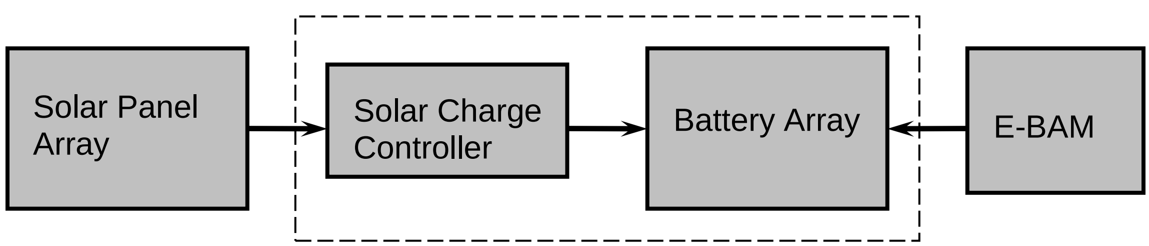
Solar Operation:

Some remote applications require operating the E-BAM with a solar array. Care must be taken to ensure that the solar array is designed correctly, and is specified to meet the power requirements or the unit. Many people greatly underestimate the amount of solar wattage required to run a particular load continuously year-round. If the solar array is not large enough, the batteries will eventually become depleted and the E-BAM will shut down. The size of the solar array will vary depending on the Peak Sun-Hour (PSH) rating of the sample location. PSH ratings are usually based on worst case winter conditions at a particular location. Summer sun ratings at the same location will be considerably higher. Sun rating maps can be found on the National Renewable Energy Laboratory website at www.nrel.gov. The table below shows some estimated solar array wattages required to run a 50 Watt DC E-BAM continuously in various sun ratings:

Local PSH Sun Rating kWh/m^2/day	Minimum Solar Array Wattage	Battery Array for 5 Days Backup
2.0	1010	7 x 110Ah
2.5	810	7 x 110Ah
3.0	675	7 x 110Ah
3.5	580	7 x 110Ah
4.0	500	7 x 110Ah
4.5	450	7 x 110Ah
5.0	400	7 x 110Ah
5.5	370	7 x 110Ah
6.0	340	7 x 110Ah
6.5	310	7 x 110Ah
7.0	290	7 x 110Ah

A bank of parallel batteries is required to run the E-BAM when using a solar array, to ensure function during the night and cloudy weather. The solar panels must be wired to charge the batteries through an appropriate charge controller. The E-BAM runs off of the battery pack only. **Never connect a solar panel directly to the E-BAM power input!** The E-BAM will be immediately damaged because solar panels output a high DC voltage during sunlight hours. The E-BAM will only run on 12 to 16 VDC. Ensure that the charge controller output does not exceed 16 volts when connected to the battery pack, or damage to the E-BAM can result.

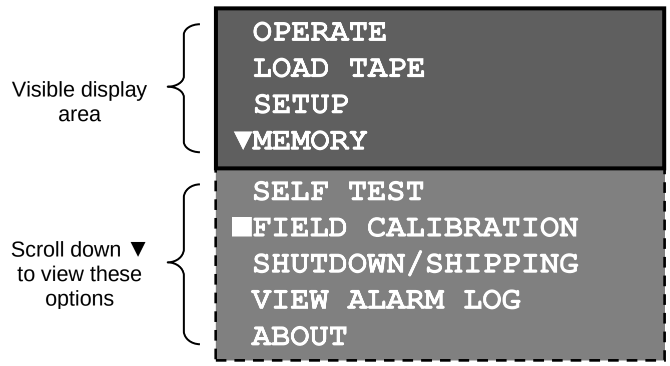
A solar array for the E-BAM tends to end up being fairly large, heavy, and expensive. It is usually easiest and cheapest to contact your local solar shop for help in building the array. You may also contact a service representative at Met One for assistance. Met One Instruments can also supply complete E-BAM solar systems on a custom order basis.



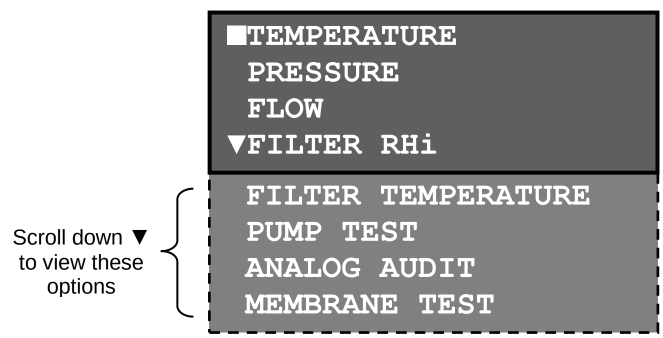
Simplified E-BAM Solar System Block Diagram

5 FIELD CALIBRATIONS AND FLOW CHECKS

This section describes the audit and calibration process for the E-BAM flow system, ambient temperature sensor, barometric pressure sensors, filter sensors, analog output, and span membrane. **The most important maintenance parameters are the leak checks, nozzle/vane cleaning, and flow checks!** The audit screens for the parameters described here are all found in the FIELD CALIBRATION menu under the main E-BAM menu as shown below:



The main E-BAM menu



The FIELD CALIBRATION menu

5.1 Leak Checks and Nozzle/Vane Cleaning

The E-BAM flow system *must be checked for leaks before any flow calibrations are performed*.

5.1.1 Basic Leak Check

Use the following steps to perform the basic leak check:

1. Stop the current sample, if one is in progress.
2. Raise the nozzle by entering the LOAD TAPE menu. The nozzle should raise automatically when entering the menu.
3. With the nozzle raised, manually pull the filter tape toward the take up spool. The leak check requires a clean unused portion of filter tape to be positioned beneath the nozzle. This must be done by hand as there is no automated means for doing it using the keypad.

4. Inspect the last sample spot on the tape roll. Examine it closely for any abnormal deformation or holes. The presence of abnormalities indicates debris build up at the nozzle / vane interface. This will need to be cleaned to restore proper operation.
5. Remove the PM_{10} size selective inlet from the sample tube and install the BX-305 leak check valve (or BX-302 zero filter). If a $PM_{2.5}$ cyclone is being used, it should be left in place and included in the leak check. Verify that the leak valve is in the closed position as shown in Figure 5-1.

Figure 5-1 BX-305 Leak Check Valve Installed on Inlet Tube

6. Navigate to the FIELD CALIBRATION>PUMP TEST menu. The MODE field selects either the LEAK TEST or PUMP TEST mode. For this check, set the MODE field to LEAK TEST. The E-BAM should automatically lower the nozzle and start the pump.
7. The pump flow rate should drop below 1.5 LPM.
    a. If the flow rate is 1.5 LPM or less, the leak check is satisfactory. Proceed to step 8.
    b. If the flow rate is greater than 1.5 LPM, then cleaning is required. Thoroughly clean the nozzle / vane interface and then perform this test again. If it passes, proceed to step 8. If it fails a second time, go to section 5.1.2.
8. Exit to the main menu.
9. Open the BX-305 valve to release the vacuum inside the E-BAM.
10. Remove the BX-305 and replace the PM_{10} size selective inlet.
11. Resume normal sampling operations.

5.1.2 Advanced Leak Checks

If the basic leak check detailed in section 5.1.1 fails, the following procedures will isolate the problem.

Required Tools: Leak Check Valve (Met One Instruments Part No. BX-305 or BX-302)

Nozzle Seal Tool (Part No. 7440)

5.1.2.1 Total System Leak Test

This procedure will create a positive seal at the nozzle / vane interface. With this seal in place, the rest of the flow system can be tested for leaks.

The following procedure assumes steps 1 through 7 in section 5.1.1 have just been completed and a flow rate of greater than 1.5 LPM was found.

1. Exit the LEAK TEST menu and navigate to the LOAD TAPE menu. The nozzle should raise automatically.
2. Remove the filter tape from beneath the nozzle and insert the Nozzle Seal Tool with the hole positioned beneath the nozzle. See Figure 5-2.

Figure 5-2 Nozzle Seal Tool with Hole Under the Nozzle

3. Verify the BX-305 valve is still mounted on the inlet and is in the closed position.
4. Return to the FIELD CALIBRATION>PUMP TEST menu and set the MODE field to LEAK TEST. The E-BAM should automatically lower the nozzle and start the pump.
5. The pump flow rate should drop below 0.3 LPM.
   a. If the flow rate is 0.3 LPM or less, the leak check is satisfactory. The high flow rate observed during the basic leak test is located at the nozzle / tape interface. Proceed to section 5.1.2.3

b. If the flow rate is greater than 0.3 LPM, then there is a leak somewhere in the system. Go to section 5.1.2.2 to locate the leak.

5.1.2.2 Lower Leak Test

This procedure will split the flow system at the nozzle / vane interface. With this seal in place, only the portion of the flow system downstream of this location will be placed under vacuum and tested for leaks.

The following procedure assumes the steps listed in section 5.1.2.1 were performed and a leak of greater than 0.3 LPM was found.

1. Exit the LEAK TEST menu and navigate to the LOAD TAPE men. The nozzle should raise automatically.

2. Rotate the Nozzle Seal Tool so that the solid portion of the tool is positioned beneath the nozzle. See Figure 5-3.

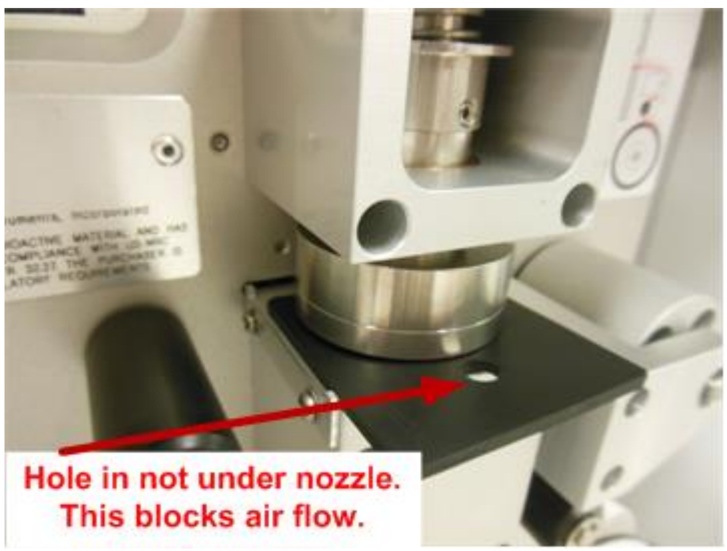


Figure 5-3 Nozzle Seal Tool with Solid Side Under the Nozzle

3. Return to the FIELD CALIBRATION>PUMP TEST menu and set the MODE field to LEAK TEST. The E-BAM should automatically lower the nozzle and start the pump.

4. The pump flow rate should drop below 0.3 LPM.

    a. If the flow rate is 0.3 LPM or less, the leak check is satisfactory. This confirms that the leak is above the nozzle. Investigate all mating connections and O-rings in the flow path before the nozzle / vane interface to locate and correct the leak.

    b. If the flow rate is greater than 0.3 LPM, then there is a leak downstream of the nozzle. Investigate all mating connections and O-rings in the flow path after the nozzle / vane interface to locate and correct the leak.

c. Once resolved, repeat the steps listed in section 5.1.1 to verify the flow system integrity.

5.1.2.3 Filter Tape Leak Test

Use this procedure to assess a high flow rate at the nozzle / tape interface. It is assumed that the Basic Leak Check and the Total System Leak Test have both already been performed and a high flow rate at the nozzle / tape interface was found.

Required Tools: Certified Calibration Transfer Standard (CTS) such as the BX-307

Nozzle Seal Tool (Part No. 7440)

Filter Tape (Part No. 460180)

1. Remove the BX-305 from the sample tube and install the calibration transfer standard (CTS).
2. If the Nozzle Seal tool may already be installed with the hole positioned beneath the nozzle (see Figure 5-2). If this is not the case, go to the LOAD TAPE menu to raise the nozzle and install it in this configuration now.
3. Return to the FIELD CALIBRATION>PUMP TEST menu and set the MODE field to PUMP TEST. The E-BAM should automatically lower the nozzle and start the pump.
4. Allow at least 10-12 minutes for the flow to fully stabilize. When the flow rate stabilizes, write down the CTS flow rate value. This is the “Without Tape” value.

   NOTE: *If after 15 minutes, the flow still has minor fluctuations, estimate the average flow rate and use that for the “Without Tape” value.*
5. Exit the PUMP TEST menu and enter the LOAD TAPE menu. The nozzle should raise automatically.
6. Remove the Nozzle Seal Tool.
7. Place a three-inch-long piece of filter tape directly below the nozzle.
8. Return to the FIELD CALIBRATION>PUMP TEST menu and set the MODE field to PUMP TEST. The E-BAM should automatically lower the nozzle and start the pump.
9. When the flow rate stabilizes, write down the CTS flow rate value. This is the “With Tape” value.
10. Exit the PUMP TEST menu and return to the LOAD TAPE menu. The nozzle should raise automatically.
11. Remove the strip of filter tape.
12. Subtract the “With Tape” value from the “Without Tape” value using the following equation:

    WithoutTape – WithTape = LeakRate

    The result should be a positive value of 0.3 LPM or less. A typical example might look like this: 16.71 LPM – 16.58 LPM = 0.13 LPM

    If the difference is greater than 0.3 LPM, an out of tolerance leak exists at the nozzle / tape interface. Thoroughly clean the nozzle and vane area and then perform this test again. Repeat this test. If after a couple of attempts this test still fails, contact the Met One Instruments, Inc. service department (see section 1.2) for assistance.

⚠ **Important Notes About Leak Checks:**

Leak checks should be performed at least monthly and whenever the filter tape is changed. Almost all air leaks in the E-BAM system occur where the nozzle contacts the filter tape. **The E-BAM has no way of automatically detecting a leak at this interface!** This is because the airflow sensor is located downstream of the filter tape. There will normally be a small amount of leakage at the tape, but an excessive leak lets an unknown amount of air enter the system through the leak instead of the inlet. This will cause the air volume calculation and the concentration measurement to be incorrect. **Allowing a leak to persist may cause data to be invalidated back to the last known good leak check.**

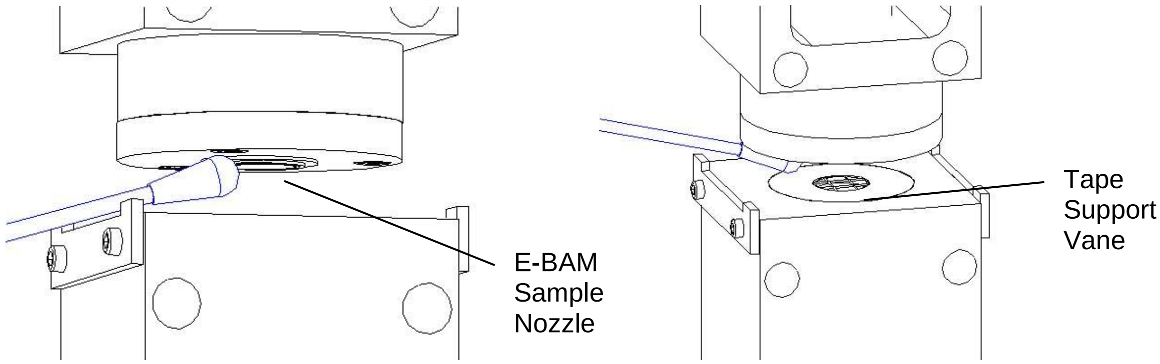
The 1.5 lpm leak check allowance is due to the test conditions. With the inlet shut off, the vacuum in the flow system is several times greater than during normal sampling, which exaggerates any leaks. If the leak reading during this test is less than 1.5 lpm, there should not be a significant leak during normal operation.

Some agencies choose to adopt tighter tolerances for the leak test. Most agencies perform as-found leak checks (before cleaning the nozzle and vane) for data validation purposes. The typical recommended threshold for invalidating data is an as-found leak value (before cleaning nozzle and vane) of 2.0 lpm or higher. Again, some agencies adopt tighter standards.

5.1.3 Nozzle and Vane Cleaning:

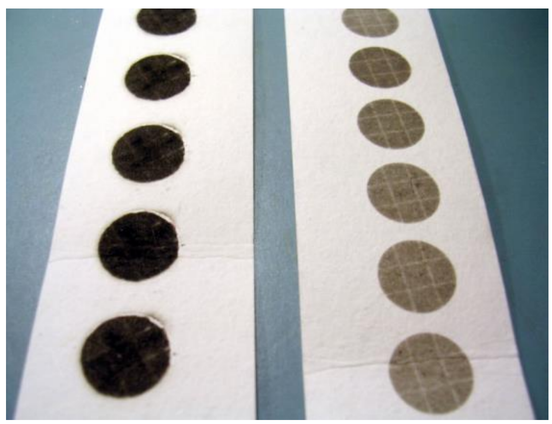
The nozzle and vane (located under the tape) must be cleaned regularly to prevent leaks and measurement errors. The cleaning must be done at least each time the filter tape is changed, though monthly cleaning is highly recommended. Some sites will require more frequent cleaning as determined by the site administrator. The worst environment for nozzle contamination seems to be hot, humid environments. This is because damp filter tape fibers more easily stick to the nozzle and vane. The fibers can quickly build up, creating air leaks or punching small holes in the filter tape which will cause measurement errors. Use the following steps to clean the parts:

1. It is advisable to perform an as-found leak check before cleaning the nozzle, in order to validate past data as being leak-free.
2. If the nozzle is down, raise it by entering the LOAD TAPE screen in the main E-BAM menu. The nozzle will automatically raise.
3. Remove the filter tape (if installed) from the nozzle area so that you have access to the vane.
4. Thoroughly clean the nozzle sealing surface and the vane crosshairs with a cotton-tipped applicator and isopropyl alcohol. Any hardened deposits may have to be carefully scraped off with the wooden end of the applicator.
5. Inspect the nozzle lip and vane for any burrs which may cause leaks or tape damage.
6. After the cleaning process, it is recommended to use canned dusting air to blow down through the vane crosshairs. This removes any filter debris from the face of the beta detector, which is located directly under the vane. Be careful not to damage the beta detector window!
7. Reinstall the filter tape and perform a final leak check.



Cleaning the E-BAM nozzle and Vane with a cotton-tipped applicator

The figure below shows the difference between good and bad filter tape spots. The tape on the right is from an E-BAM with a clean nozzle and vane. The particulate spots have crisp edges, are perfectly round, and are evenly distributed. The tape on the left is from a unit with a dirty vane. A spot of debris has built up, and is punching a pin-hole at the edge of each spot. The spots also show a "halo" effect from an air leak because the debris has built up to the extent that the nozzle no longer seals correctly. These faults are easily prevented by keeping the nozzle and vane clean.



E-BAM Filter Tape Examples

5.2 Ambient Temperature Sensor Audit

The ambient temperature must be audited or calibrated before any flow calibrations are performed. Scroll to the TEMPERATURE line and press the MENU/SELECT key to enter the ambient temperature sensor calibration menu:

```
 POINT:▼HIGH
 E-BAM: 23.6 C
   REF: 23.9 C
CALIBRATE     DEFAULT
```

```
POINT:▼LOW
 E-BAM: -10.2 C
   REF: -10.8 C
CALIBRATE     DEFAULT
```

The POINT parameter selects either the HIGH or LOW calibration point. The HIGH point is the normal ambient calibration point which is used for all field calibrations. The LOW point is only used for laboratory ice-bath calibrations of the ambient temperature sensor. Select HIGH to perform an ambient temperature sensor calibration.

The E-BAM parameter is the instantaneous output from the unit's ambient temperature sensor. This is the parameter that you are auditing.

The REF parameter is the field where you enter the correct temperature as shown on your traceable reference standard temperature audit device. After you have entered the correct temperature using the arrow keys, press the CALIBRATE key to correct the E-BAM sensor reading. The E-BAM and REF parameters should now match. Press the ESC key when finished.

If difficulty is encountered during the process, the DEFAULT key can be pressed to erase all field calibration factors from the temperature sensor and to start over with factory default calibration factors. Then try the calibration again.

5.3 Ambient Barometric Pressure Sensor Audit

The ambient barometric pressure sensor must be audited or calibrated before any flow calibrations are performed. Scroll to the PRESSURE line and press the MENU/SELECT key to enter the ambient pressure sensor calibration menu:

```
PRESSURE
 E-BAM: 732.8 mmHg
   REF: 737.9 mmHg
CALIBRATE     DEFAULT
```

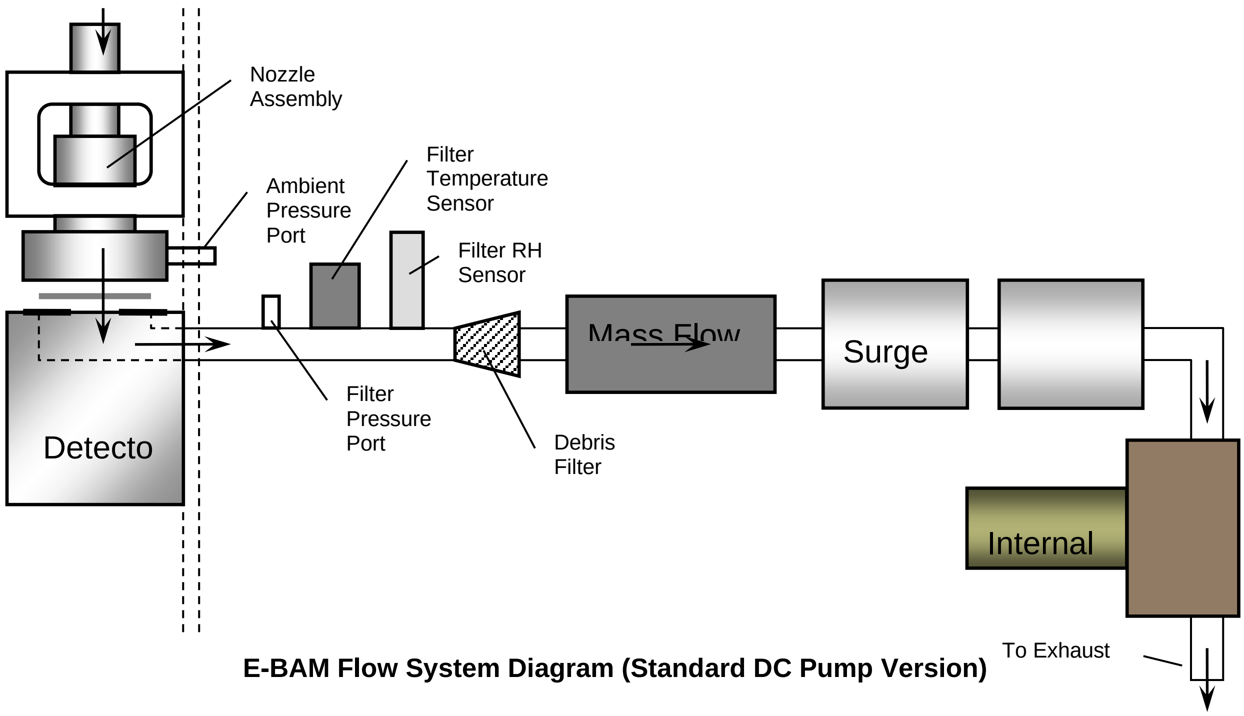
The E-BAM parameter is the instantaneous output from the unit's ambient barometric pressure sensor. This is the parameter that you are auditing.

The REF parameter is the field where you enter the correct pressure as shown on your traceable reference standard barometric pressure audit device. After you have entered the correct pressure using the arrow keys, press the CALIBRATE key to correct the E-BAM sensor reading. The E-BAM and REF parameters should now match. Press the ESC key when finished.

If difficulty is encountered during the process, the DEFAULT key can be pressed to erase all field calibration factors from the pressure sensor and to start over with factory default calibration factors. Then try the calibration again.

5.4 Flow Audits and Calibrations

The flow calibration is performed after the temperature and pressure sensors are audited, because the E-BAM uses these parameters to calculate flow. In addition, *the nozzle and vane must be clean, and a leak check must be performed before the flow calibration*. You will need to remove the PM_{10} inlet head and install your traceable reference standard flow audit device (BGI DeltaCal® or equivalent) onto the top of the E-BAM inlet tube to measure the flow.



E-BAM Flow System Diagram (Standard DC Pump Version)

Scroll to the FLOW line and press the MENU/SELECT key to enter the flow sensor calibration menu as shown:

```
SETPOINT:▼17.5 LPM
   E-BAM: 17.5 LPM
     REF: 17.4 LPM
CALIBRATE     DEFAULT
```

```
SETPOINT:▼14.0 LPM
   E-BAM: 14.0 LPM
     REF: 14.1 LPM
CALIBRATE     DEFAULT
```

```
SETPOINT:▼16.7 LPM
   E-BAM: 16.7 LPM
     REF: 16.6 LPM
  EXIT
```

The SETPOINT parameter selects which flow point is to be calibrated. The E-BAM uses a two-point flow calibration at 17.5 and 14.0 lpm. The 16.7 lpm point can only be audited, not calibrated. Notice that there is no CALIBRATE option when the SETPOINT is set to 16.7. Use the arrow keys to select the 17.5 lpm setpoint first. The E-BAM will automatically turn the pump on and regulate the flow until the internal flow sensor output matches the 17.5 lpm setpoint. It may take a moment for the flow to regulate to the setpoint. Note: The high flow point also verifies the pump's ability to maintain adequate head room above the 16.7 lpm sample flow rate, so make sure that the unit can regulate to this point.

The E-BAM parameter is the instantaneous output from the unit's internal flow sensor. This is the parameter that you are auditing.

The REF parameter is the field where you enter the correct flow as shown on your traceable reference standard flow audit device. After you have entered the correct flow using the arrow keys, press the CALIBRATE key to correct the E-BAM sensor reading. The E-BAM should then re-regulate the flow to the setpoint, and the E-BAM and REF parameters should match.

Set the SETPOINT to 14.0 lpm and repeat the calibration process. After the 17.5 and 14.0 lpm points are calibrated, select the 16.7 lpm setpoint and verify that the E-BAM flow and the flow from your traceable standard match within 0.1 lpm. Press the ESC key to exit the flow calibration menu when finished.

If difficulty is encountered during the process, the DEFAULT key can be pressed to erase all field calibration factors from the flow sensor and to start over with factory default calibration factors. Then try the calibration again.

To audit the flow system without performing any calibrations, simply select the 16.7 lpm setpoint without calibrating the other setpoints first. Allow the E-BAM flow to regulate to the setpoint, then compare the E-BAM flow reading to your traceable standard and record the results. If the audit device flow and the E-BAM flow differ by 4% (about 0.67 lpm) or more, then a full flow calibration must be performed. Most agencies adopt tighter standards. Met One recommends that the flow be maintained within ±0.2 lpm, which is well within the units capabilities.

Flow Calibrations on E-BAMs Operated in STANDARD Flow Type: If your E-BAM is set to report in EPA Standard flow conditions instead of actual (volumetric) flow conditions, then the flow reading in the FLOW calibration screens shown above will indicate SLPM instead of LPM. **It is critical that the flow type of your traceable flow audit device matches the flow type of the E-BAM.** Flow calibration on E-BAM units operated in STANDARD flow mode can be done a couple of different ways:

- The easiest method is to simply use a traceable flow audit device which reports STANDARD flow values, such as the BGI deltaCal which reports both STANDARD ($\mathbf{Q_s}$) and ACTUAL ($\mathbf{Q_a}$) flow.
- The second option is to change the FLOW TYPE from STANDARD to ACTUAL in the E-BAM SETUP menu, then perform a regular flow calibration as described above. If this method is used, be sure to set the unit back to STANDARD flow when finished.
- The third option is to convert the ACTUAL flow output from your traceable reference flow meter to STANDARD conditions ($\mathbf{Q_s}$) using a formula:

$$\mathbf{Q_s = Q_a * (P_a / T_a) * (298 / 760)}$$

T_a = Ambient Temperature Kelvin (Kelvin = Celsius + 273)

P_a = Ambient Barometric Pressure (mmHg)

Q_a = Actual Volumetric Flow from Reference Meter

5.5 Filter RH Sensor Audit

The filter relative humidity sensor is used to measure the humidity of the sample air and to control the inlet heater to prevent moisture from being sampled as particulate mass. Scroll to the FILTER RHi (RH internal) line and press the MENU/SELECT key to enter the filter RH sensor calibration menu:

```
FILTER RHi
 E-BAM: 32 %
   REF: 35 %
CALIBRATE     DEFAULT
```

The E-BAM parameter is the instantaneous output from the unit's filter RH sensor. This is the parameter that you are auditing.

The REF parameter is the field where you enter the correct RH as shown on your traceable reference standard relative humidity audit device. After you have entered the correct RH using the arrow keys, press the CALIBRATE key to correct the E-BAM sensor reading. The E-BAM and REF parameters should now match. Press the ESC key when finished.

If difficulty is encountered during the process, the DEFAULT key can be pressed to erase all field calibration factors from the RH sensor and to start over with factory default calibration factors. Then try the calibration again.

Important Note: It is often difficult to calibrate the sensor if the E-BAM is warm, as the heating of the unit will reduce the sample RH (as it should) making it difficult to compare the E-BAM filter RH reading to an ambient RH traceable standard reading. If the sensor is to be calibrated, it is best to do it when the E-BAM is cold (equilibrated to ambient) and the nozzle is lifted up. It is recommended to leave the sensor at the factory default calibration. The E-BAM filter RH sensor is only a ±4% device when functioning properly, and will typically read a completely unreasonable value if it fails, such as 135% or -25%.

5.6 Filter Temperature Sensor Audit

The filter temperature sensor is used to measure the temperature of the sample air and to monitor the function of the inlet heater. Scroll to the FILTER TEMPERATURE line and press the MENU/SELECT key to enter the filter temperature sensor calibration menu:

```
FILTER TEMPERATURE
 E-BAM: 23.8 C
   REF: 24.6 C
CALIBRATE     DEFAULT
```

The E-BAM parameter is the instantaneous output from the unit's filter temperature sensor. This is the parameter that you are auditing.

The REF parameter is the field where you enter the correct temperature as shown on your traceable reference standard temperature audit device. After you have entered the correct temperature using the arrow keys, press the CALIBRATE key to correct the E-BAM sensor reading. The E-BAM and REF parameters should now match. Press the ESC key when finished.

If difficulty is encountered during the process, the DEFAULT key can be pressed to erase all field calibration factors from the temperature sensor and to start over with factory default calibration factors. Then try the calibration again.

Important Note: It is often difficult to calibrate the sensor if the E-BAM is warm, as the heating of the unit will increase the sample temperature (as it should) making it difficult to compare the E-BAM filter temperature reading to an ambient temperature traceable standard reading. If the sensor is to be calibrated, it is best to do it when the E-BAM is cold (equilibrated to ambient) and the nozzle is lifted up. It is recommended to leave the sensor at the factory default calibration. The E-BAM filter temperature sensor very rarely fails.

5.7 Pump Tests

The E-BAM pump should be periodically tested to ensure it has sufficient vacuum capacity for normal operation. Scroll to the PUMP TEST line and press the MENU/SELECT key to enter the leak test and pump test menu. The pump will turn on automatically when this screen is entered:

```
 MODE:▼PUMP TEST
 FLOW:     14.3 LPM
 PRES:   398.3 mmHg
EXIT
```

The MODE parameter selects either the LEAK TEST or the PUMP TEST mode. The PUMP TEST mode is used to test the capacity of the pump to determine when it needs to be replaced.

The FLOW parameter is the instantaneous output from the unit's internal flow sensor.

The PRES parameter is the filter pressure reading which indicates the vacuum beneath the filter tape. This is used to measure the vacuum capacity of the pump during the pump test.

Perform the pump test as follows:

1. Remove the PM_{10} head and install the BX-305 leak test valve onto the inlet tube. Turn the valve to the OFF position to prevent any air from entering the inlet tube.
2. Enter the PUMP TEST screen as described above, and set the MODE to LEAK TEST. The pump should turn on automatically and ramp up to full speed.
3. **Very slowly** open the leak check valve on the inlet just a small amount, so that the FLOW reading on the E-BAM display increases to between 14 and 15 lpm, with the pump still at full speed. Allow the flow reading to stabilize.
4. Compare the PRES (vacuum) value from the E-BAM display to the chart below for the particular flow rate. The PRES value should be less than or equal to the values in the chart. If the PRES value on the E-BAM display is higher than the "poor" value in the chart at that particular flow rate, then the E-BAM pump may need to be replaced.

Flow Rate	Vacuum Measurement Value		
	Good	Marginal	Poor
14.0	390.5	406.1	429.5
14.1	391.6	407.3	430.8
14.2	393.8	409.6	433.2
14.3	395.0	410.8	434.5
14.4	396.5	412.3	436.1
14.5	398.5	414.5	438.4
14.6	399.5	415.5	439.5
14.7	401.1	417.2	441.3
14.8	403.2	419.3	443.5
14.9	404.5	420.7	445.0
15.0	406.0	422.2	446.6

Notes on Pump Testing: The test above is simply a way to quantify the pump capacity. The true indicator of pump function is its ability to maintain 16.7 lpm during normal operation, despite filter loading and altitude. The simplest and most effective way to verify the pump capacity is to just verify that the E-BAM flow can regulate at the 17.5 lpm flow rate during the normal flow calibrations. The internal DC diaphragm pump in the standard version of the E-BAM has an estimated lifetime of six to nine months in continuous operation, or at least 4000 hours in intermittent operation. Actual lifetime varies depending on concentration levels and ambient temperature. The pump is not rebuildable, and must be replaced. Contact the Met One Service Department to obtain a replacement.

5.8 Analog Output Audits

If the E-BAM is used with an external analog datalogger, then the analog voltage output of the E-BAM must be periodically checked to ensure data integrity. Scroll to the ANALOG AUDIT line and press the MENU/SELECT key to enter the analog output test menu:

```
  MODE:▼AUDIT

 SETPT: 0.500 V
EXIT
```

```
  MODE:▼HIGH
OUTPUT: 0.990 V
ADJUST: 0.000
SAVE           DEFAULT
```

```
  MODE:▼LOW
OUTPUT: 0.010 V
ADJUST: 0.000
SAVE           DEFAULT
```

The MODE parameter selects either the AUDIT mode, or the HIGH or LOW adjustment modes as shown above. In the AUDIT mode, the user can use the arrow keys to change the SETPT voltage to any value between 0.000 and 1.000 volts DC. The actual voltage measured on the E-BAM analog output wires must match this setting within ±0.001 volts. If not, the analog output on the E-BAM will need to be adjusted.

In the HIGH mode, the analog output is forced to 0.990 volts. Measure the actual voltage output of the E-BAM, and if it does not match, the ADJUST field can be set (using the arrow keys) to adjust the voltage up or down by as much as 0.100 volts. In the LOW mode, the analog output is forced to 0.010 volts. Measure the actual voltage output again and make any adjustments. The LOW mode can only be adjusted from -0.016 to 0.100 volts. After the HIGH and LOW modes are adjusted, go back to the AUDIT mode and make sure that all voltage points from 0.000 to 1.000 volts now match your voltmeter within ±0.001 volts.

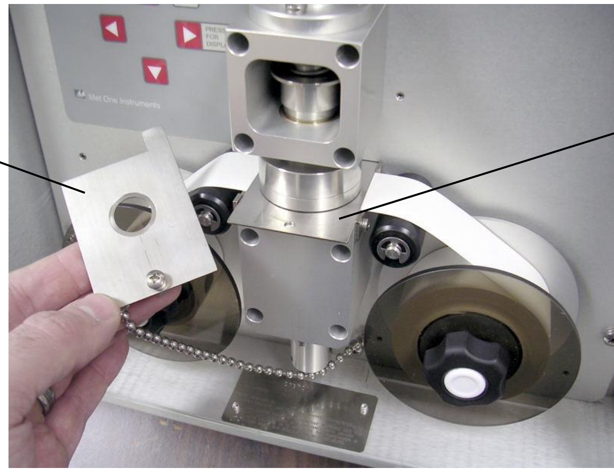
Notes About the Analog Output Tests: Only a high quality voltmeter should be used for this test. Cheap voltmeters usually do not give accurate measurements at millivolt levels. The E-BAM analog output should also be checked with the external datalogger connected, in order to make sure that the logger or cables are not affecting the voltage.

The E-BAM analog output is split out of the serial communications cable. If your serial cable does not have an analog output breakout, contact the Met One Service department.

5.9 Span Membrane Tests

The membrane test is used to audit the E-BAM beta particle measurement system by simulating a particulate load with a polyester foil. The test consists of four 4-minute beta count steps for a total of about 16 minutes.

Step	Count Type	Description
1	BLANK ZERO COUNT	4-min count through filter tape only.
2	CAL ZERO COUNT	4-min count through tape and zero (empty) membrane.
3	BLANK SPAN COUNT	4-min count through filter tape only.
4	CAL SPAN COUNT	4-min count through tape and span membrane foil.



Span Membrane and Zero Shim

Scroll to the MEMBRANE TEST line and press the MENU/SELECT key to enter the membrane test menu. The E-BAM will ask to start the test as shown below. Press the START key to begin the test. The unit will advance the filter tape and begin a 4-minute blank zero count. Then the unit will raise the nozzle and prompt you to enter the insert the zero membrane. This is the same shim that is used to protect the nozzle during shipment and is connected to the unit with a chain:

```
MEMBRANE TEST
START ZERO TEST.

                  START
```

```
BLANK ZERO COUNT

                    172
CANCEL
```

```
INSERT ZERO MEMBRANE


CANCEL
```

Insert the zero membrane (on top of the filter tape) so that the tab protrudes through the transport plate and triggers the photo sensor. The nozzle will lower and the unit will begin a 4-minute count with the zero membrane in place. After the zero count, the unit will prompt you to remove the zero membrane. The unit will then start a 4-minute blank span count without any membrane in place:

```
CAL ZERO COUNT

                    180
CANCEL
```

```
REMOVE ZERO MEMBRANE!


CANCEL
```

```
BLANK SPAN COUNT

                    171
CANCEL
```

The unit will then prompt you to insert the span membrane. This is located in a pouch inside the E-BAM door. Handle the span membrane very carefully to avoid damaging the fragile film. Insert the span membrane into the E-BAM above the filter tape. The unit will perform the final 4-minute span count and display the results:

INSERT SPAN MEMBRANE	CAL SPAN COUNT	MEMBRANE TEST RESULT
	184	SPAN MEMBRANE: PASS
CANCEL	CANCEL	OK

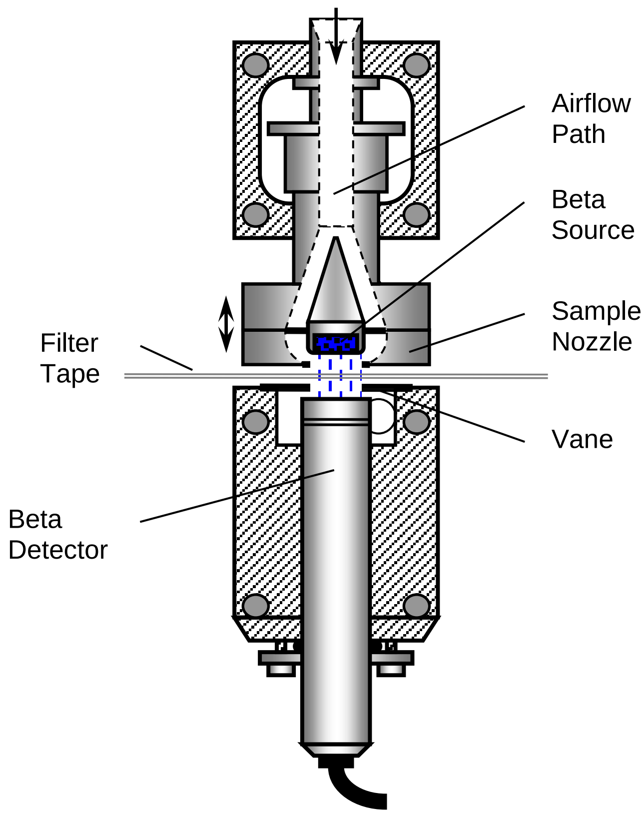
This is a pass/fail test in which the E-BAM will compare the measured mass of the span membrane to the expected mass (ABS) for that exact foil which has been programmed into the E-BAM memory. See Section 7.12. If the measured and expected values are within 5%, the test will pass. If the values are outside of 5%, a failure will be generated. If the test fails, the most common causes are a failing or dirty beta detector, or a dirty or damaged span membrane.

The measured span value from the test can be viewed. Press the ▼ (down arrow) button on the E-BAM while it is displaying the pass or failure message at the end of the test. The display should show the ZERO and SPAN values the unit just measured. Compare the SPAN value from the display to the expected mass of the membrane (ABS value).

The ZERO and SPAN values from a failed membrane test may also be downloaded through the serial port of the E-BAM with a computer. Download the Error Log, and find the appropriate Membrane Test Failure record and look for the “Z” and “S” values.

6 THE E-BAM MEASUREMENT CYCLE

This section describes the measurement and timing cycles of the E-BAM instrument. A clear understanding of the measurement is helpful for the effective operation of the unit and for data analysis. For advanced information on the underlying theory and mathematics of the measurement see Theory of Operation, Section 11.



E-BAM Beta Measurement System (not to scale)

6.1 The Hourly Measurement Cycle

The E-BAM will always make an hourly concentration measurement *regardless of how the real-time average is set*. This hourly measurement is stored to the data array each hour, and is a fixed data parameter which cannot be modified or removed from the array. *The hourly value is the most accurate concentration measurement made by the E-BAM*. Daily averages are computed by taking the 24-hour mean of these hourly data points.

The hourly concentration is based on two four minute long beta counts, one at the beginning and one at the end of each sample hour. At the beginning of the sample hour (minutes 2 to 5), the E-BAM counts the beta particles through the filter tape for four minutes to establish a zero reading. Particulate then accumulates on the tape spot throughout the hour. At the end of the sample hour (minutes 57 to 60) the unit makes another four minute long beta count through the dirty filter tape to establish a span reading. The two beta counts are used to calculate the particulate mass on the tape, and the air flow data over the sample hour is used to determine the particulate concentration in milligrams per cubic meter of air. As soon as the new hour starts, the E-BAM stores the previous hourly concentration to the data array, and starts a new hourly measurement.

Note: The hourly E-BAM concentration measurement is not an hourly average of the real-time measurements! These are two completely separate measurements. For example, if the E-BAM is set for a real-time average of five minutes, then the unit will store 12 real-time values over the course of an hour. The average of these twelve real-time values may not exactly match the hourly value for that same hour, though they should be fairly close.

When the filter tape advances in the middle of a sample hour due to heavy particulate loading on the sample spot, the E-BAM is still able to make the hourly concentration measurement for that hour. This is known as a “split cycle” measurement, and is based on a time-weighted average of the concentration before and after the tape advance. This is because a tape advance could occur at any time during the sample hour. The hourly concentration data point will still appear in the data array, along with a pressure drop alarm flag. The hourly data points that occur during these tape advance hours are somewhat less reliable than normal hourly measurements because the original four minute beta count cannot be used as a baseline for the final four minute count at the end of the hour. For this reason, some agencies omit these points from their 24 hour averages. If the E-BAM records pressure-drop tape advances every day, it is advisable to simply shorten the automatic tape advance setting.

6.2 The Real-Time Average Measurement Cycle

The beta source and beta detector are located inside the air path of the E-BAM. This allows the E-BAM to simultaneously measure the beta attenuation of the particulate *as it is being deposited on the filter tape*, resulting in a quasi real-time output. The vacuum pump is always running except when the tape is moved, and the E-BAM is constantly measuring the beta particle signal throughout the entire sample period. The unit generates raw real-time concentration measurements which are updated every 60 seconds. The Real Time Average stored by the E-BAM is a user-selected average of these 60-second measurements over a 1, 5, 10, 15, 30, or 60 minute period. See Section 7.2 for details on how to decide which real-time average to use, and how to set the average. The real-time average is intended for particulate trending throughout the sample hour, especially for smoke plume tracking.

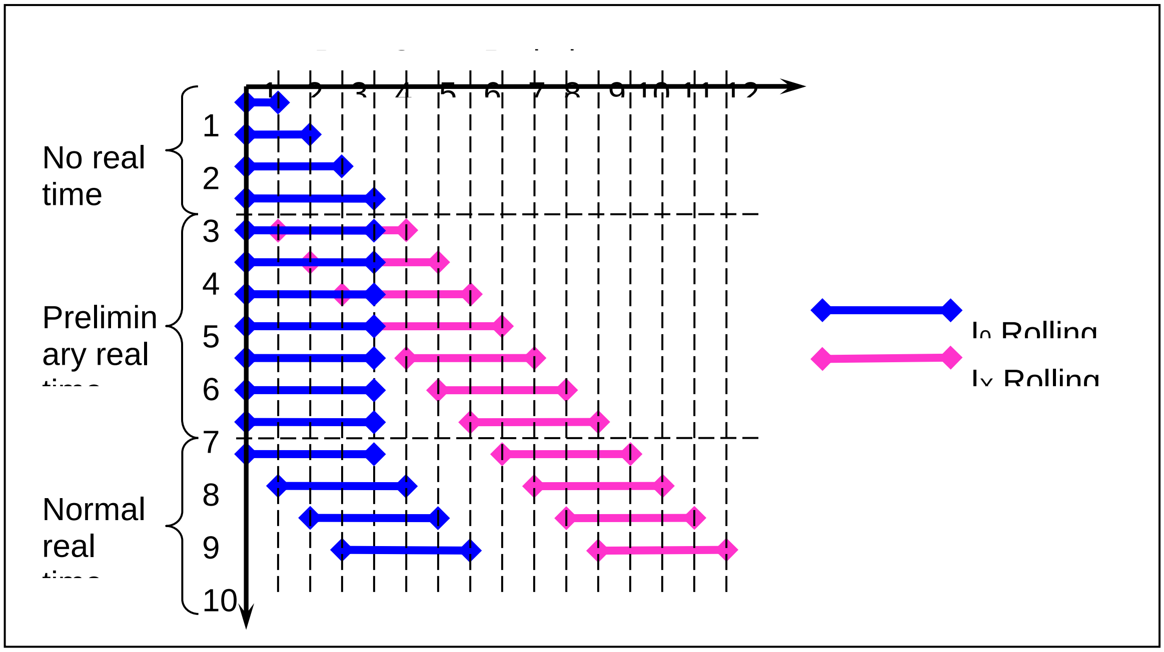
Several factors conspire to make real-time beta measurement difficult. First, very little particulate is deposited on the filter tape is such a short time, resulting in a poor signal-to-noise ratio except in high concentrations. Second, very little air is sampled in such a short time, increasing the detection limit of the real-time output. Third, the sample air is flowing around the beta source and beta detector, so correction factors for air density and temperature are used by the E-BAM to compensate for the effect on the beta signal. *All of these factors become less significant the longer the real-time average period is set to*. For these reasons, any single real-time average measurement from the E-BAM (especially a 1 or 5 minute average) may not be an accurate representation of the true particulate level at that exact moment, but it will be useful for trending and detecting sudden spikes in concentration. However, the main advantage of the E-BAM style real-time output over other methods (such as laser based nephelometers) is that the beta method does not require any K factors or slope corrections for changes in variables such as particle size, color, or chemical composition.

E-BAM real-time measurements are based on a constant series of one minute long beta particle count totals. These one minute counts are averaged into a four minute rolling average, so each minute a new one minute count value is added to the average, and the oldest value is dropped out. To make a concentration measurement, the E-BAM needs two of these rolling averages, an initial or “zero” count average (**I_0**) and a final count average (**I_X**) separated by some time period for particulate to accumulate. Each minute, both of the four minute rolling averages are advanced by one minute, and a new concentration value is calculated and stored. These are the raw 60-second real-time values which are averaged together over 5, 10, 15, or 30 minutes to form the user-selected real-time average concentration values.

- At the beginning of a new sample period, such as when the unit is started up, or whenever the filter tape is advanced to a fresh spot, The unit must start all counts and rolling averages over.
- For the first four minutes after any tape advance, there will be no 60-second real-time concentration values generated, because the four minute rolling average for the zero beta count has not finished loading up.
- At the end of minute five, the E-BAM will have the two required four minute rolling averages, but they will be overlapping. The I_0 count will be a rolling average of the count totals from minutes 1 to 4, and the I_X count will be a rolling average of the count totals from minutes 2 to 5. A 60-second raw real-time concentration value will be calculated from these.
- At the end of minutes 6 and 7 additional 60-second raw real-time concentrations will be calculated, again based on overlapping four minute rolling averages of the beta counts. Each minute the final I_X rolling average gets farther away from the I_0 rolling average, reducing the noise of the resulting concentration values.
- At the end of minutes 8, 9, 10 , and 11, the concentration values are still generated based on the I_0 rolling average from minutes 1 to 4, but the I_X rolling average continues to get farther away each minute and is no longer overlapping the I_0 rolling average.
- At the end of minute 12, the first “normal” 60-second raw real-time concentration is calculated when there are a full eight minutes between the end of the I0 rolling average (minute 4) and the end of the IX rolling average (minute 12).
- Each minute after minute 12, both the I_0 and the I_X rolling averages advance by one minute, so that the end of each of the two average are always separated by exactly eight minutes. The 60-second raw real-time concentration values generated during and after this time are all normal and useful values.
- At the first user-selected real-time average period (such as 10 or 15 minutes), The unit averages all of the 60-second raw real-time concentration values over that selected time period into the REALTIME AVERAGE, and stores it to the data array.
- The process continues until the next time the filter tape is advanced to a fresh spot.

The 60-second raw real-time concentration values generated during the first 11 minutes after a filter change tend to be noisy due to the shortened time between the count averages. For this reason, the first real-time average of these raw values is often disregarded after an E-BAM tape advance.

The following chart shows the four minute rolling average count sequences that the E-BAM uses to generate the real-time output as described above. In this example the tape has advanced at minute zero, and the real-time average period is set to fifteen minutes.

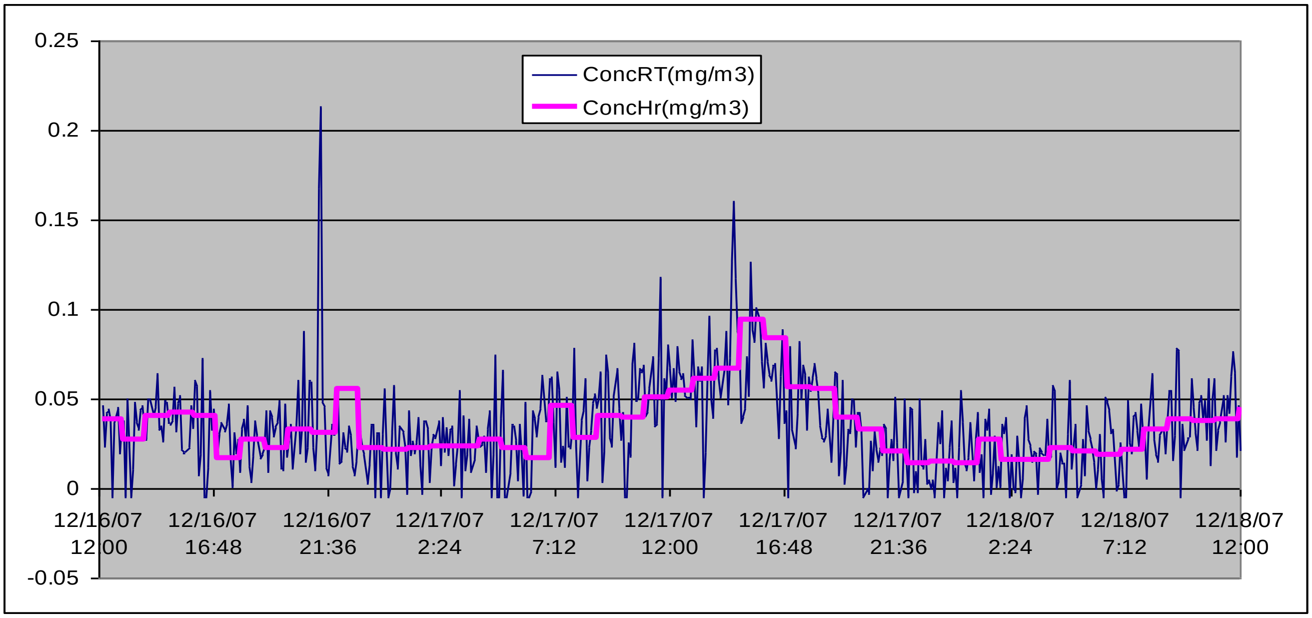


The table below shows the relationship between the I_0 and I_X four minute rolling average counts, the 60-second raw real-time concentration values, and the resulting real-time averages. Notice how the real-time values load up after the tape advance as described above. In this example, after fifteen minutes a real-time average is generated and is held constant until minute 30 when it is updated again. The first real time average will not include the first four minutes after a filter change.

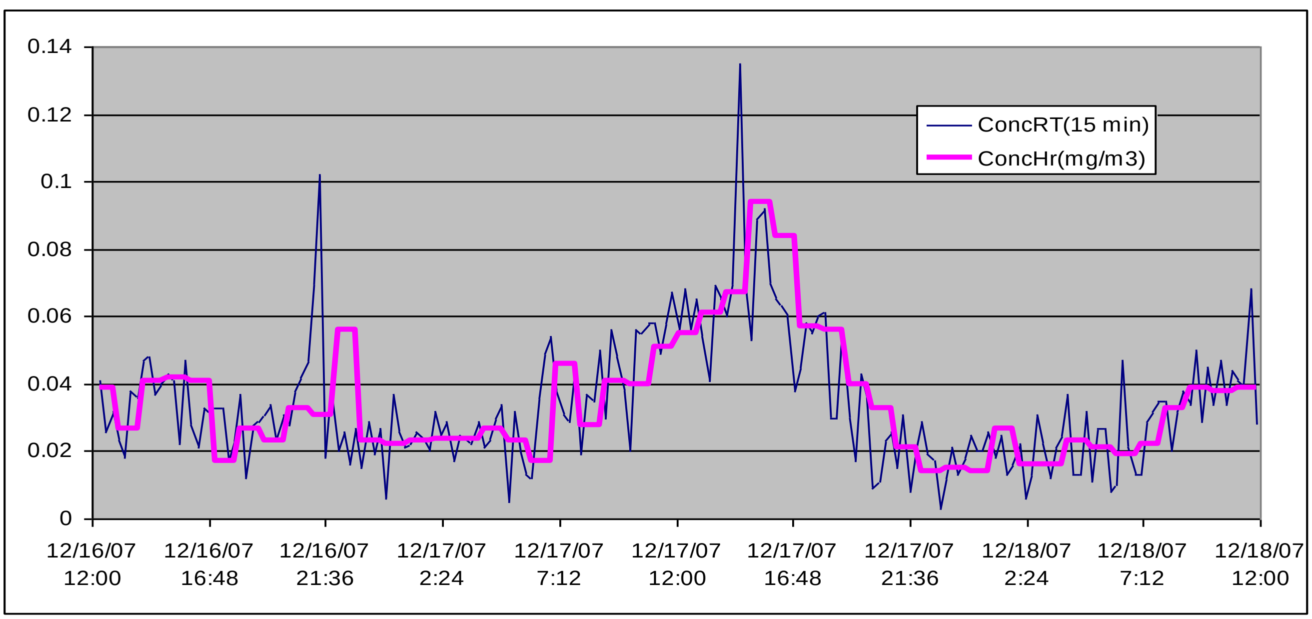
	Real-Time I0	Real-Time IX	Real-Time 60-sec Conc	15-Min RT Average
Minute	Minutes	Minutes	mg/m3	mg/m3
1	---	---	None	---
2	---	---	None	---
3	---	---	None	---
4	1-4	---	None	---
5	1-4	2-5	preliminary	---
6	1-4	3-6	preliminary	---
7	1-4	4-7	preliminary	---
8	1-4	5-8	preliminary	---
9	1-4	6-9	preliminary	---
10	1-4	7-10	preliminary	---
11	1-4	8-11	preliminary	---
12	1-4	9-12	normal	---
13	2-5	10-13	normal	---
14	3-6	11-14	normal	---
15	4-7	12-15	normal	Avg min 5-14
16	5-8	13-16	normal	Avg min 5-14
17	6-9	14-17	normal	Avg min 5-14
18	7-10	15-18	normal	Avg min 5-14
19	8-12	16-19	normal	Avg min 5-14
20	9-13	17-20	normal	Avg min 5-14

6.3 *Comparing the Hourly and Real-Time Values*

The chart below shows data collected by an E-BAM over a two day period. The unit is set for a real-time average of 5 minutes. The 5 minute data predicts the hourly values, and is very responsive to sudden spikes in concentration, but the noise band (and thus the detection limit) of the 5 minute data is high enough to make it generally unsuitable in concentrations below about 40 micrograms. The average of the 5 minute data over these two days is 34.2 µg, and the average of the hourly data is 34.8 µg. Remember that the hourly data values represent air actually sampled during the *previous* hour.



The chart below shows the same data collected over the same two day period by the same E-BAM, only this time the real-time average period was set to 15 minutes. The real-time values still predict and trend the hourly values, but the noise band of the RT values is improved, making the 15 minute data useful at lower concentrations. The average of the 15 minute data over these two days is 34.4 µg, and the average of the hourly data is 34.8 µg.



7 SETUP MENU DESCRIPTIONS

The E-BAM has a system of setup menus which contain all of the settings and parameters needed to perform the measurement and operation of the unit. Many of these settings are set at factory default values which are correct for most applications, but may be altered by the operator to suit the specific needs of your monitoring program. This section describes the SETUP menu in detail, and should be reviewed to ensure desired operation. Once set, most of the values in the SETUP menus will not need to be changed by the site operator. The settings will not be lost if the unit is unplugged or powered down.

The SETUP menu is located in the main E-BAM menu. Use the arrow keys to select the SETUP option in the main menu, then press the MENU/SELECT key to enter the setup menu. **Note: Some of these setup screens are the same ones that the E-BAM automatically prompts you to verify each time you power the unit up.** When entered, the SETUP menu will guide you through each of the following screens in a sequential manner.

7.1 The Clock Setup Screen

When the SETUP menu is entered, the clock setup screen is displayed first as shown below. If you need to change the time or date, use the arrow keys to change the values, then press SET. Press CONTINUE when finished, or to go on without making changes.

```
19-NOV-2008  16:36:42

SET            CONTINUE
```

7.2 The Tape Advance and Real-Time Average Setup Screen

The unit will next display the average period setup screen shown below. This menu is important to understand. If the settings need to be changed, select the parameter to be changed with the ◄► keys, and modify the settings with the ▲▼ keys and press SAVE. Press CONTINUE when finished, or to go on without making changes.

```
    LOCATION:  01
TAPE ADVANCE: ▼24 HRS
REALTIME AVG: ▼10 MIN
 SAVE          CONTINUE
```

LOCATION is an ID number which will appear in the data array to indicate which unit collected the data, and to enable tracking of measurement information. This is used instead of a UNIT ID because the E-BAM is portable. This may be any number from 01 to 99.

TAPE ADVANCE is how often the E-BAM will automatically advance to a new spot of filter tape. This value can be set to 1, 2, 3, 4, 6, 8, 12, or 24 hours. The default setting is 24 hours for maximum tape life. The unit will override this setting and automatically advance the filter tape if the concentration is too high and the filter tape becomes clogged. If the filter tape is advanced due to high concentrations, an alarm will be recorded in the alarm log. **Note:** the tape advance setting does not change how often the concentration is calculated or stored.

REALTIME AVG is the averaging period for the real-time concentration value. The real-time concentration measurement is updated every minute (see Section 6.2). The REALTIME AVG is the mean of these real-time values over the selected time period. The REALTIME AVG may be set to the following time periods: 1, 5, 10, 15, 30, or 60 minutes. The following are some Important notes about the REALTIME AVG setting:

- The E-BAM always measures and stores a separate hourly concentration measurement *regardless of how the REALTIME AVG is set*. For this reason, it is usually not useful to set the REALTIME AVG to 60 minutes also.
- The hourly measurement is always the most accurate concentration data! The real-time data function is intended for trending purposes only.
- The shorter the average period is (such as 5 minutes), the noisier the real-time data will be. This is because very little particulate is typically sampled in such a short amount of time, resulting in a poor detection limit. The 1 and 5 minute real-time averages are intended only for smoke plume tracking in extremely high concentrations.
- Because the real-time averages are a completely separate measurement from the hourly measurement, taking an hourly average of the real-time averages might not result in an exact to the E-BAM hourly measurement taken over the same time period.
- The shorter the REALTIME AVG is set, the faster the E-BAM memory is filled up. If the real-time average is set to 60 minutes, the memory will last 182 days before the oldest data is overwritten. If a 1 minute real-time average is selected, the E-BAM memory will be filled up in just three days!
- The REALTIME AVG setting also sets the averaging period for the internal datalogger for the meteorological sensors, such as a wind sensor. Some wind sensor applications require the shorter average periods.
- For ambient monitoring in normal concentrations, a 10 or 15 minute REALTIME AVG is recommended. This is a good balance between time resolution, accurate measurements, and memory capacity.

7.3 The MACHINE TYPE PM_{10}/$PM_{2.5}$ Setup Screen

After the real-time settings are verified, the E-BAM will go on to display the MACHINE TYPE setup screen. If needed, change the setting with the arrow keys and press SAVE. Press CONTINUE when finished or to go on without changes:

```
MACHINE TYPE: ▼PM10
< SEE PICTURE

SAVE          CONTINUE
```

MACHINE TYPE simply tells the E-BAM which type of inlet it is equipped with, $PM_{2.5}$ or PM_{10}. *The only difference between the two is weather a $PM_{2.5}$ cyclone is installed or not*. The E-BAM will put the machine type setting onto the data array, so that you can tell if the collected data was $PM_{2.5}$ or PM_{10}. The screen refers the user to a picture located inside the door of the E-BAM for easy identification of the two possible inlet types.

7.4 The Analog Output Setup Screen

The next screen is the analog output setup menu. This screen contains the settings for the voltage output, when the E-BAM is used with an external analog datalogger. See Sections 5.8 and 9.1. Use the arrow keys to edit the values, then press SAVE. Press CONTINUE when finished, or to go on without changes.

```
 ANALOG FS:▼1.0 V
      MODE:▼HOURLY
REF DAC FS:▼ 8.0 V
SAVE         CONTINUE
```

ANALOG FS is the setting for the desired full-scale range of the E-BAM analog output voltage. This can be set to **1.0**, **2.5**, or **5.0** volts. The analog output will then have a range from zero up to the selected voltage. The default setting is 1.0 volts, so that 0.000 to 1.000 volts equals 0.000 to 1.000 mg/m^3 concentration on the output. **Note:** The analog output <u>concentration range</u> is always 0.000 to 1.000 mg/m^3 regardless of the full scale voltage setting. Concentration values higher than this range must be downloaded from the digital data file.

MODE sets weather the HOURLY or the REAL TIME concentration is represented on the analog output. If this is set to HOURLY, the voltage output will hold constant at the previous hourly concentration value. If this is set to REAL TIME, the analog output will update based on the REALTIME AVG setting; for example every 10 or 15 minutes.

REF DAC FS is the digital-to-analog system rail voltage. This is factory-set and will never be changed unless instructed by Met One technicians. Default is 8.0V for all new E-BAMs. Only older units were set to 10.0V.

7.5 The Serial Port Setup Screen

Next is the serial port setup screen. This is used to select the baud rate for the E-BAM digital RS-232 serial port. The E-BAM baud rate can be set to **300**, **600**, **1200**, **2400**, **4800**, **9600**, **19200**, or **38400** baud. Use the fastest baud possible, while still able to communicate reliably with the computer. The 9600 baud setting is the default and is adequate for most applications. Settings slower than this are almost never used. Use the arrow keys to edit the values, then press SAVE. Press CONTINUE when finished, or to go on without changes.

Note: When a computer is connected to the E-BAM for digital data retrieval, it will need to be set to the same baud rate as the E-BAM or communication will not occur.

```
SERIAL PORT
BAUD RATE:▼9600

SAVE         CONTINUE
```

7.6 The RH Control Setup Screen

Next is RH control setup menu. These settings determine how the inlet heater is used to control the RH of the sample air stream. Use the arrow keys to edit the values, then press SAVE. Press CONTINUE when finished, or to go on without changes.

```
  RH SETPOINT: 045 %
DELTA-T SETPT: 20  C
   RH CONTROL:▼ON
SAVE         CONTINUE
```

RH SETPOINT is the threshold at which the E-BAM turns on the inlet heater to limit the RH of the sample air. This can be set from 0 to 100%. When the sample RH exceeds this setpoint, the inlet heater turns on to drive down the humidity through mild 15 watt heating. When the RH drops 1% below the setpoint, the heater turns off. The default setting is 45%, which is adequate for many applications. If the sample RH levels exceed this level, moisture can be absorbed by the particulate on the filter tape and measured as mass. This causes errors in the particulate measurement. A lower set point such as 35% is often used to further reduce the potential for sample RH effects, although this results in some additional power consumption due to longer heater cycles.

DELTA-T SETPT The Delta Temperature Setpoint is a parameter which overrides the RH SETPOINT. The sample air stream is heated whenever the inlet heater is turned on, in order to reduce sample RH. If the sample air temperature exceeds the ambient air temperature by more than 1 degree above this setpoint, the inlet heater is turned off regardless of the sample RH level. This is used in areas with high volatile compound levels in order to prevent overheating of the sample, particularly when the TAPE ADVANCE is set to 24 hours. The value can be set from 0 to 20 degrees C. The default is 15 C which is adequate in most applications. If this value is set to 0 C, then the inlet heater will be virtually disabled.

RH CONTROL is the ON/OFF setting for the inlet heater. If this is set to OFF, the heater is disabled entirely to save power. When this is set to ON, the heater is governed by the above parameters for RH and Delta-T. **Note:** If the RH CONTROL is set to ON, but the filter RH sensor fails, then the E-BAM will stop operation and generate an alarm. Also, any time the pump turns off, the heater will also turn off to save power.

7.7 The Flow Rate and Flow Type Setup Screen

Next is the flow setup screen. This is where the airflow settings for the E-BAM are located. Use the arrow keys to edit the values, then press SAVE. Press CONTINUE when finished, or to go on without changes.

```
FLOW
SETPOINT: 16.7 LPM
    TYPE:▼ACTUAL
SAVE         CONTINUE
```

FLOW SETPOINT is the airflow rate at which the E-BAM will regulate for all sampling. The E-BAM is designed to operate at 16.7 liters per minute (l/min or lpm). This is important, because the PM_{10} inlets and $PM_{2.5}$ sharp-cut cyclones require this flow rate in order to separate the correct sizes of particles from the air stream. The flow setpoint value can be set to other flow rates from **10.0** to **17.5** lpm, primarily for testing the pump capacity or for special applications.

TYPE is the flow type setting which determines what flow conditions are reported by the E-BAM. This can be set to either ACTUAL or STANDARD flow. All E-BAM units have a mass airflow sensor, barometric pressure sensor, and ambient temperature sensor, so the unit can be set for either type of flow. The flow types are described below:

STANDARD Flow Control:

STANDARD flow type is often selected when required by specific EPA monitoring regulations, such as PM_{10} reporting. At low altitudes and moderate temperature, standard flow can be very close to the actual volumetric flow rate. At high altitudes or extreme temperatures the difference between standard and actual flow will be very significant.

- Because the E-BAM has ambient temperature and pressure sensors, the flow rate will be controlled to *actual conditions*, but reported in standard conditions, meaning that the volume of air is calculated with the assumption that the ambient temperature is 0, 20, or 25 degrees C (user-selectable), and the barometric pressure is 760mmHg, regardless of the actual temperature and pressure.
- The concentrations will be reported in standard conditions (based on the standardized air volume).
- The flow is designated on the display as “SLPM”.
- The flow rate in the Flow Test and Pump Test field calibration screens will also be controlled to standard conditions.

ACTUAL Flow Control:

ACTUAL (volumetric) flow type is the most accurate flow control mode, and is required for all $PM_{2.5}$ monitoring. The actual flow type is also the easiest and fastest to calibrate and audit. The unit uses actual ambient air temperature and barometric pressure to calculate the flow rate, and the flow rate is continuously and automatically adjusted to correct for changes in ambient conditions and filter loading.

- The flow values will be *controlled and reported* in actual conditions.
- The concentrations will be reported in actual conditions (based on the actual air volume).
- The flow is designated on the display as “LPM”.
- The flow rate in the Flow Test and Pump Test field calibration screens will also be controlled to actual conditions.

7.8 The Ambient RH Sensor Setup Screen

The next setup screen asks you if the E-BAM is equipped with an external (ambient) RH sensor, such as the EX-593. Most applications do not use the ambient RH sensor. If the RH sensor is to be connected to the E-BAM, use the arrow keys to set this field to YES, then SAVE and continue. This setting determines if the E-BAM will attempt to validate the sensor by monitoring its output voltage. **Note:** If an RH sensor is not connected to the input, but the setting is set to YES, then the E-BAM will measure the floating input voltage, assume the sensor has failed, and generate an alarm.

```
EXTERNAL
 RH CONNECTED: ▼NO

SAVE         CONTINUE
```

7.9 The Pump Protection Setup Screen

The next setup screen is the pump protection setting. If this field is set to ON, the E-BAM will automatically turn the pump off and shut down any time the ambient temperature exceeds 48 degrees C. The pump will then remain off until the temperature drops back below 45 degrees C. This can slightly extend the lifetime of the internal DC vacuum pump in certain environments. This feature should always be set to OFF unless recommended by a Met One technician, in order to avoid sample interruptions.

```
PUMP PROTECT: ▼OFF

SAVE         CONTINUE
```

7.10 The Restart Voltage Setup Screen

Next is the setup screen for the DC power input restart voltage. This is an important parameter to understand if the unit is to be run on batteries or solar power. The E-BAM will automatically shut down when the external battery voltage (input voltage) drops to 10.0 volts. Then the MINIMUM RESTART VOLTAGE is *the lowest input voltage at which the E-BAM will resume functioning after this shutdown*, such as after the battery has been recharged or replaced. This can be set anywhere from 10.0 to 15.0 volts. This allows the batteries enough time to adequately recharge before the E-BAM turns back on, particularly when used with a solar panel array, and prevents the unit from rapidly cycling on and off when the batteries are low. If unsure, set this parameter to 12.0 volts for most applications. Consult your battery documentation for the optimal recharge profile. Use the arrow keys to change the setting, then press SAVE and CONTINUE.

```
MINIMUM RESTART
VOLTAGE:  12.0V

SAVE         CONTINUE
```

7.11 The STANDARD Temperature Setup Screen

Next is the standard temperature setup screen. This setting is the temperature value that will be used to calculate the flow volume whenever the unit is set to STANDARD flow type. This can be set to **25**, **20**, or **0** degrees C. In the United States, 25C is almost always used for standard temperature. Some other countries use 20 or zero degrees instead. If the E-BAM is set to ACTUAL flow type, the unit will ignore this setting and use the actual ambient temperature for the flow calculations.

```
STANDARD CONDITIONS
TEMPERATURE: ▼25 C

SAVE         CONTINUE
```

7.12 The Span Membrane Setup Screen

Next is the BAM span calibration setup menu. These are the parameters that govern the reference membrane span test. These should already be set to the correct factory-determined values for your particular E-BAM. The values can be changed with the arrow keys, then saved. **Note:** The SAVE soft-key can be changed to DEFAULT using the arrow keys. Pressing the DEFAULT key will revert these settings back to the factory-set parameters in the event that they are accidentally changed. Press CONTINUE when finished.

```
BAM Calibrate
 ZERO: 0.350 mg/cm2
 SPAN: 0.832 mg/cm2
▼SAVE        CONTINUE
```

ZERO This value is set to a default of 0.350 mg/cm^2. This value is not used by the E-BAM.

SPAN is the expected value of the span membrane foil used for the span test. Each membrane foil has a unique mass, but typically the value is around 0.800 mg/cm^2. The mass of the membrane which was included with the E-BAM should already be entered here. This field is editable in case the user needs to replace the membrane assembly, or if a different membrane is used for a special application. This is sometimes called the “ABS” value.

This is the end of the SETUP menu system. The E-BAM will exit to the main menu when finished.

8 MAINTENANCE and TROUBLESHOOTING

This section provides information about routine maintenance of the E-BAM, and for performing more detailed diagnostic tests if a problem is encountered. The E-BAM often generates error messages on the display or in the data log if a failure or other problem is detected. Many times there is a simple solution, but persistent errors often signify a failure which will require investigation. The E-BAM error codes are described in this section.

8.1 E-BAM Error Displays, Error Logs, and Error Codes

The E-BAM contains a comprehensive system of error and alarm codes which are used to alert the operator of any problems with the unit. These error codes may be generated during normal operation, during a self-test routine, or when the E-BAM attempts to start a new sample cycle.

The errors appear on the E-BAM display, and are also stored in the digital error log as a detailed record of the time and type of the error. In addition, errors are stored in the digital data log as a code number in the data array, and are reported on the analog concentration output as a full-scale voltage. A single dry contact closure relay output is also provided to indicate an unspecified error to external devices such as alarms or dataloggers.

The following table describes each of the error and alarm types which can be generated by the E-BAM, along with the conditions which cause the alarms. Most of these alarms indicate critical parameters which must be working correctly for machine operation.

Alarm/Error Message	Alarm Description
POWER OUTAGE	This alarm message indicates that the E-BAM power has been cycled off and then back on. This can mean that there was a power failure or that someone simply unplugged the unit to turn it off. The E-BAM alarm display will show an OFF time indicating how long the power was off, and an ON time indicating how long the power was on before the power failure. A second type of power alarm can be shown on the display as a COP RESET. This means "Computer Operating Properly", and will only occur when the E-BAM firmware is flash updated by the user. This is normal and does not indicate a failure.
INTERNAL HARDWARE	This alarm indicates that there was an internal SPI bus failure, preventing the CPU from communicating with the I/O board for 10 seconds or more. The time and date of the error will be displayed. The E-BAM will stop operation until internal communication is restored. If these errors occur regularly you will need to contact the Met One Service Department.
NOZZLE FAILED UP or NOZZLE FAILED DOWN	This alarm indicates that the E-BAM attempted to move the nozzle gearmotor up or down for 20 seconds, but did not sense the nozzle motor reaching the up or down position. The motor has a single-slot encoder disk on its shaft which triggers a separate photo sensor when the motor is in the up or down position. This alarm could mean that the motor has failed, or that the photo sensors have failed or are out of alignment. The E-BAM will stop operation until the nozzle is functional. The time and date of the error will be displayed.
SHIPPING DEVICE INSERTED	This alarm indicates that the zero membrane shim (also called the nozzle shipping shim) is inserted under the nozzle. The alarm will be generated if the shim is left in place during the startup process, or if it is detected when the E-BAM attempts to start an operation cycle. The unit senses the shim with a photo sensor which is triggered by the tab on the shim which extends through the transport plate when it is inserted. The E-BAM cannot operate with the shim in place.
TAPE BROKE	This alarm indicates that the tape is broken or has run out. The E-BAM has a motor which drives the left (take up) reel. The right (supply) reel has a clutch and an encoder. If the E-BAM drives the take up reel motor for 20 seconds but senses no corresponding rotation of the supply reel, the error is generated and the E-BAM will not operate. The time and date of the error will be displayed.

BETA COUNT FAILED	This alarm indicates that the beta count signal was less than the minimum of 40,000 counts in a 1 minute period, during either a self-test or during normal operation. This can indicate that the beta detector window is dirty or obstructed, or that the detector has failed. The E-BAM will not operate until the count rate is above the threshold. The display will show the actual count total, and the time and date of the error. If the error cannot be fixed by cleaning the detector window, you will need to contact the Met One Service Department.
PRESSURE SENSOR FAILED	This alarm indicates that the internal barometric pressure sensors did not pass the static or dynamic criteria during the self-test process. The alarm is generated if the ambient and the filter pressure sensors are not within 2% of each other with the pump off, or if they are within 5% of each other with the pump on. The alarm display will show the INLET (ambient) pressure and the FILTER pressure, as well as the time and date of the error. Frequent alarms of this type generally indicate that one of the two digital pressure sensors inside the unit has failed. Contact the Met One Service Department.
FLOW FAIL or FLOW OUT OF REGULATION	This alarm indicates that the flow system failed one of two criteria during operation. The regulation alarm will be generated if the E-BAM flow is more than 0.4 lpm out of regulation for more than 5 minutes. If the 5 minute rolling average of the flow (checked once per minute) is less than 5.0 lpm or greater the 19.6 lpm, the failure alarm will be generated and the E-BAM will stop operating and attempt to auto restart. The alarm display will show the actual flow rate and the time and date of the error.
MEMBRANE FAILED	This alarm indicates that the E-BAM failed the manual span membrane test. This occurs if the mass measurement of the span foil does not match the expected value within 5%. The time and date of the error will be displayed. Press the down arrow key to view the measured span mass from the test. This can be compared to the known mass of the foil. Also shown is a zero reading which is not used. The Z and S values are also available in the error log download file. This alarm can indicate that the membrane is dirty or damaged, that the beta detector window is dirty or damaged, or that the detector tube is failing.
LOW BATTERY	This alarm indicates that the DC input voltage dropped below 10.0 volts, which is the minimum operating voltage for the unit. The E-BAM will stop operation and will not restart until the voltage is back above the user-selected restart threshold. The time and date of the error will be displayed, along with the actual voltage.
HIGH TAPE DELTA-PRES	This alarm indicates that the pressure drop across the filter tape has exceeded the maximum allowable limit, due to heavy particulate loading on the filter tape during normal operation. The E-BAM will stop sampling, advance the filter tape to a fresh spot, then resume sampling. The alarm display will show both the measured DELTA-P pressure drop, and the LIMIT value in mmHg. The time and date of the alarm will be displayed. The alarm can also be generated if the pressure drop exceeds a lower max limit while the ambient temperature is above 38 degrees C. If these alarms occur frequently, set the TAPE ADVANCE to a shorter interval.
SHORTENED SAMPLE	This alarm indicates that the sample was started sometime during the hour and not at that beginning, as expected. It is a warning that the concentration value is not comprised of the full sampling time
PUMP OVER TEMP	This alarm indicates that the internal DC pump was turned off because the ambient temperature exceeded 48 degrees C while the unit was sampling with the pump protection feature enabled. The E-BAM will not resume sampling until the temperature drops below 45 degrees. The display will show the ambient temperature and the time and date of the error. This feature can be used to prevent the pump from wearing out early due to high temperature operation, but is almost always just disabled in the SETUP menu.
SENSOR FAILURE	This alarm indicates that one of the sensors in the unit is not responding, or is measuring a value outside of its specified range. The display will show the time and date of the alarm, the type of sensor which has failed, and the faulty measurement from the sensor. The E-BAM will not operate until the sensor is operational. The most common sensor failures occur if the ambient temperature sensor is disconnected from the E-BAM, or if the filter RH sensor or one of the digital pressure sensors fail. The error can also occur if the SETUP menu has been set to expect an ambient RH sensor which is not connected. If the error occurs even though the indicated sensor is connected correctly, you will need to contact the Met One Service Department.

The following are some examples of how the alarm and error records appear when shown on the main E-BAM display as a current error or, when viewed as a historical error record in the user interface system:

```
16-DEC-2008  16:25:20
POWER OUTAGE
OFF: 0.00:02:10
 ON: 5.06:05:31
```

```
16-DEC-2008  16:25:20
BETA COUNT FAILED
15461
```

```
16-DEC-2008  16:25:20
FLOW FAIL
FLOW: 15.7 LPM
```

```
16-DEC-2008  16:25:20
TAPE BROKE!
```

```
16-DEC-2008  16:25:20
HIGH TAPE DELTA-PRES
DELTA-P: 300.1 mmHg
  LIMIT: 266.7 mmHg
```

```
16-DEC-2008  16:25:20
SENSOR FAILURE
AT
61.0 C
```

The normal E-BAM digital data array also contains an "alarm" code column to indicate if there were any alarm or error flags during that particular sample period. An example of an E-BAM data record is shown below. The alarm header and alarm code are shown in bold:

```
AutoMet Data Log Report
18-DEC-2008 16:22:45,
SN,F1768

Time,ConcRT(mg/m3),ConcHr(mg/m3),Flow(l/m),WS(m/s),WD(Deg),AT(C),RHx(%),RHi(%),BV(V),FT(C),Alarm,Type
03-DEC-2008 18:00:00,0.018,0.015,16.7,0.3,0,26.4,0,34,14.2,25.8,0,1
```

The following table defines the possible error codes that can appear in the "alarm" column of the E-BAM data records:

Code	Error/Alarm Type
0	No alarm
1	Tape Break
2	Beta Count Failure
4	High Tape Delta Pressure (Tape Advance)
8	Pressure Sensor Failure
16	Flow Failure
32	Nozzle Failure
64	Internal Hardware (SPI bus) Failure
128	Low Battery
256	Shortened Sample*
512	Pump Over Temp*

**Valid only for firmware revisions 1.50.0 and later*

Note: If multiple errors or alarms occur in the same data period, then the alarm code stored in the data array will be the *sum of the two individual code numbers*. This is a rare occurrence.

When the digital error log is retrieved from the E-BAM using Comet software or ESCAPE commands, the error report will contain the same information about the alarms as described above, only in the following format:

```
E-BAM Error Log Report
18-DEC-2008 16:25:56,
SN,F1768

20-NOV-2008 20:00:00, Power outage: 0.00:20:17 On: 5.02:30:22
20-NOV-2008 20:00:00, Internal Hardware: CS:2 Header:0
20-NOV-2008 20:00:00, Nozzle Failed UP!
20-NOV-2008 20:00:00, Shipping device inserted!
20-NOV-2008 20:00:00, Tape broke!
20-NOV-2008 20:00:00, Beta count failed: 13357
20-NOV-2008 20:00:00, Pressure test failed: %:4.87 Inlet: 267.01 Filter: 280.02
20-NOV-2008 20:00:00, Flow failed: Setpt: 16.7 Flow: 15.2
20-NOV-2008 20:00:00, Membrane failed: Z: 0.285 S: 0.705
20-NOV-2008 20:00:00, Low battery: 9.46
20-NOV-2008 20:00:00, High Tape Delta-Pressure: 270.1 mmHg Limit: 266.7 mmHg
20-NOV-2008 20:00:00, High Delta-T: 18.1 C Limit: 15.0 C
20-NOV-2008 20:00:00, Pump Over Temp: 49.1 C Limit: 48.0 C
20-NOV-2008 20:00:00, Sensor Failure: Inlet Pressure Value: 820.0
```

In each case, the alarm log record indicates the time and date of the error, and the specific parameter which generated the alarm. The measured value of the parameter, compared to the acceptable limits, is also recorded where applicable.

8.2 Contact Closure Alarm Relay Output

The E-BAM has a single channel contact closure alarm relay output available. This is used to signal an external datalogger that the E-BAM has encountered an unspecified error. The relay contacts are located on the main E-BAM power input connector (pins 3 and 4), so you will need a special power cable which has a break-out for the relay wires, as the standard power cables do not. The two relay contacts are normally closed (shorted together) when the E-BAM is operating correctly, and will open up whenever an error occurs. The relay is rated for up to $100V_{DC}$ @ 0.5A max. The only alarm flags which can cause the relay output to activate are:

- Tape Broken
- Beta Count Failure
- Sensor Failure
- Pressure Sensor Failure
- Flow Failure
- Nozzle Failure
- Internal Hardware Failure
- Low Battery
- Pump Over Temperature

8.3 Basic Problem and Cause/Solution Table

The following table contains information on some of the more common E-BAM problems which may be encountered, and some steps to identify and remedy the problems. Met One welcomes customer suggestions for new items to include in this section of future manual revisions! If the solution cannot be found in the following table, then contact one of our expert service technicians for help in resolving your problem.

Problem:	The E-BAM won't start a measurement cycle.
Cause/Solution:	• The E-BAM will not start a measurement cycle if it detects a hardware failure, such as low beta count signal, nozzle failure, pressure sensor failure, or pump failure. • The unit will not start a cycle if the input DC voltage is below the restart threshold, such as 10 volts DC. • The unit will not start a cycle if the zero membrane plate (shipping shim) is inserted. • The unit will not start a cycle if the ambient temperature sensor is not connected. • The unit will not start a cycle if the filter tape is not installed correctly. • The unit will usually display an error message on the display if it cannot start a cycle. • If the unit is left in a SETUP or FIELD CALIBRATION screen, it should still try to start a cycle after several minutes of inactivity, unless a failure is detected.

Problem:	The analog output voltage concentration readings are full-scale.
Cause/Solution:	• The unit will force the analog output to the full scale voltage (1, 2.5 or 5 volts) to indicate an error. Download the error log to view any possible errors. • The full-scale analog output is usually scaled to represent 1.000 mg/m3. If this concentration is recorded by an external datalogger which is measuring the E-BAM analog output, then either there is an error in the E-BAM, or the particulate concentrations have exceeded the range of the analog output.

Problem:	The E-BAM records frequent "Pressure Drop Excessive" errors.
Cause/Solution:	• This usually indicates that the filter tape is automatically advancing in response to being clogged due to heavy particulate loading. • If frequent pressure-drop errors are encountered, try setting the TAPE ADVANCE setting to a shorter interval.

Problem:	The E-BAM concentration indicates negative values.
Cause/Solution:	• It is possible for the unit to occasionally record negative hourly values if the actual particulate concentration is very low, such as below 3 micrograms. This is because the E-BAM has an hourly random noise band of several micrograms. • If the unit is reading negative numbers hour after hour, it is probably punching holes in the filter tape. These holes can be very small and hard to see. This is almost always caused by debris on the nozzle or vane. Clean the parts. • The real-time averages of the E-BAM (especially the 1 and 5 minute averages) are considerably noisier than the hourly measurements. These noise spikes may indicate negative concentrations unless the true concentrations are high. • The noise performance of the E-BAM may be audited. Met One supplies the BX-302 zero filter kit for auditing the zero readings of the unit.

Problem:	The airflow won't regulate at the correct rate of 16.7 lpm.
Cause/Solution:	• This usually indicates that the air pump is losing vacuum capacity due to wear. • The internal DC pump in the E-BAM will need to be replaced after about 6 to 9 months of continuous use. The internal DC pump cannot be rebuilt. • Check for leaks at the nozzle. This will often cause the inlet flow to be low even though the flow sensor is measuring the correct flow rate. This is because the flow sensor is downstream of the filter tape and nozzle. Clean the nozzle and vane. • The standard version of the E-BAM regulates the internal pump by pulse-width modulation. There are no valves or flow controllers inside the unit. • Perform a flow calibration. If the flow regulates at the lower calibration point, but not the higher point, the pump is probably worn out or there is a leak. • The gray plastic pump mufflers used on the Medo pump (external pump models only) clog up after several months. Replace it or drill a hole in the end of it. • External pump box models do have a flow controller inside the pump box.

	• Check the inlet and PM heads for obstructions. • The E-BAM pump may have difficulty regulating to 16.7 lpm under certain circumstances at very high altitudes due to the thin air.

Problem:	**The nozzle gets stuck in the UP position, or won't press down onto the tape fully.**
Cause/Solution:	• The nozzle o-ring eventually breaks down and needs to be replaced. Contact Met One for detailed instructions. No special tools are required. • With the nozzle down, lift it with your fingers and determine if it feels sticky or gritty. This often indicates that the nozzle o-ring needs to be replaced. • The nozzle motor lifts the nozzle with a cam, but the nozzle is lowered by the spring compression only. The nozzle is not driven down. The E-BAM monitors the nozzle motor position with photo sensors, but it is possible for the nozzle itself to become stuck in the up position, even if the motor is working and there are no alarms. • If the nozzle photo sensors or the nozzle motor fails, the E-BAM should generate frequent nozzle failure alarms.

Problem:	**The unit has flow leaks, even after cleaning the nozzle and vane.**
Cause/Solution:	• The nozzle may be sticking as described above. Verify that the nozzle up/down motion is smooth and complete. If the nozzle feels sticky or gritty, it will not seal properly. • Check the o-rings on the sharp-cut cyclone (if used). These frequently leak. • Check for bad o-rings on the E-BAM inlet receiver. • Make sure the two fittings on the ends of the short internal tube are seated correctly. This is the short tube directly above the nozzle assembly. It is sealed with o-rings • The E-BAM transport assembly may be removed from the enclosure to inspect the air fittings inside the unit. This should only be done after all other leak points up stream of the vane are eliminated as possibilities.

Problem:	**The unit over-measures or under-measures concentrations compared to a collocated FRM filter sampler.**
Cause/Solution:	• Moisture may be getting onto the filter tape or being absorbed by the particulate. Review the inlet heater settings for proper operation. • Test the filter RH sensor calibration, and download the RHi values. The filter RH should be effectively controlled to the setpoint, typically 45%. • Verify the flow rate and temperature and pressure calibrations. • Check for leaks at the nozzle. A leak can cause either a positive or a negative measurement bias depending if the air leaking around the nozzle is cleaner or dirtier than ambient air. • Verify the collocation setup requirements, especially making sure the inlets are spaced correctly and the same height. • If the analog output of the E-BAM is being logged by an external datalogger, make SURE the logger's scaling of the E-BAM output is correct! A 0.000 volt analog output on the E-BAM equals 0.000mg. There is no -0.005 or -0.015 offset value in the E-BAM analog output, unlike the BAM-1020! See Section 7.4. Periodically verify that the digital data log from the E-BAM matches the external logger data. • Perform a 48-hour BX-302 zero filter test to verify the average zero reading. If the average is not close to zero, it can appear as an offset of several micrograms in the E-BAM concentration data. The background value cannot be edited in the E-BAM without special instructions. Contact Met One. • Single event FRM samplers often perform better than multi-channel FRM samplers. If a multi-channel unit is used, then filter collection should still be performed on a daily basis. If the FRM filters are not properly collected and retained every day, then correlation results with the E-BAM can suffer. • Make sure that no error-flagged hours are included in your 24 hour E-BAM averages. • Sometimes very large particles can become stuck inside the E-BAM nozzle where the air flows around the beta source. This can cause slight under-reporting of TSP

	concentrations under certain atmospheric conditions. Do not disassemble the nozzle! It must be cleaned with compressed air only. Section 8.6.

Problem:	**The unit will not pass the span membrane test.**
Cause/Solution:	• This often just indicates the membrane foil surface is dirty or damaged. It can be cleaned with water rinse. Damaged membranes must be replaced. • If the membrane is in good condition, but the unit fails span tests, then the most common problem is debris on the beta detector window. Carefully blow through the vane with canned dusting air to blow debris off of the detector window and try again. • Newer E-BAM beta detectors can be removed and cleaned. Older detectors cannot be cleaned or damage will result. Consult Section 8.7 of this manual about cleaning the detector before attempting to remove it from the E-BAM. • If the detector is clean and the membrane is in good condition, then failed span tests can indicate that the detector is wearing out. Contact the Service Department.

Problem:	**The clock settings are lost when the unit is powered down.**
Cause/Solution:	• There is a large lithium battery inside the unit which maintains the clock and other settings when the unit is powered off. After several years the battery may need to be replaced if the clock resets when the E-BAM is powered off. • The lithium battery may simply have become unplugged from the 3210 board. The battery is a black module inside the E-BAM which is retained with a strip of hook-and-loop material. It has a two-wire harness. • It is normal for the clock to drift as much as 2 minutes per month.

8.4 Met One Suggested Periodic Maintenance

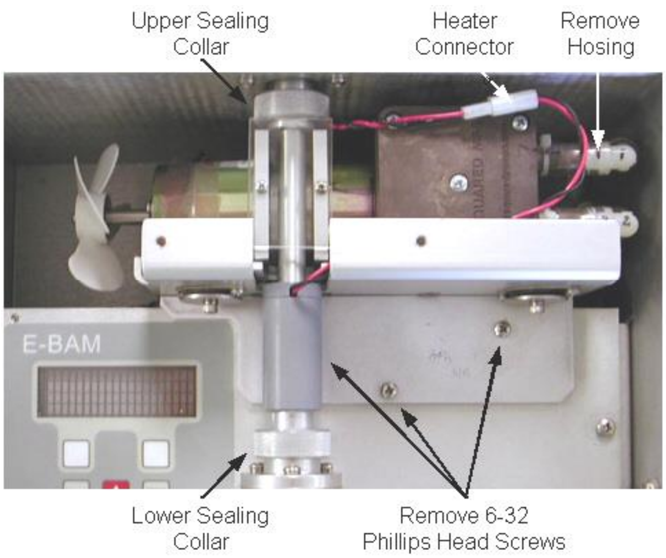
The following table shows the Met One recommended periods for routine maintenance items. Some of these items will need to be performed more or less often depending on the exact characteristics of your location. The program administrator should review these items and establish SOPs appropriate for your application.

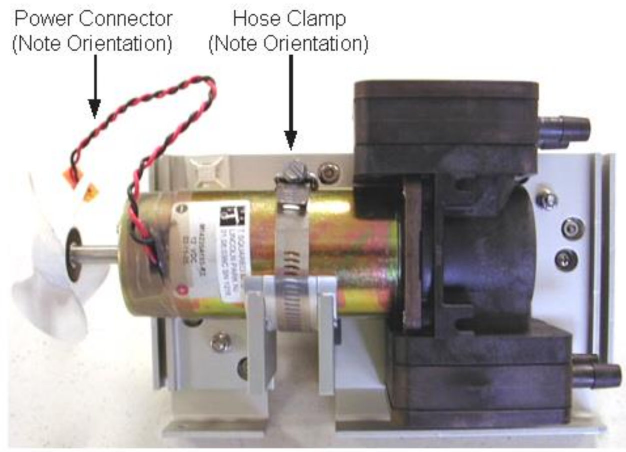
Maintenance Item	Suggested Period
Replace the filter tape (depends on the TAPE ADVANCE setting)	**As needed**
Leak check	**Monthly**
Nozzle and tape vane cleaning	**Monthly**
Flow audit (and calibration if needed) including ambient temperature and pressure	**Monthly**
Clean PM10 inlet particle trap	**Monthly**
Clean PM2.5 cyclone particle trap	**Monthly**
Check error log	**Monthly**
Download digital data log	**Monthly**
Set the E-BAM clock	**Monthly**
Span membrane test	**Monthly**
Clean the inside of the sample nozzle with compressed air	**2 Months**
Check pump capacity	**2 Months**
Replace the pump muffler (external pump box versions only)	**6 Months**
Test filter RH and filter temperature sensors	**6 Months**
Test analog output voltage (if used)	**6 Months**
Replace internal DC vacuum pump (or as needed)	**12 Months**
Rebuild AC pump (external pump box versions only)	**24 Months**
Factory recalibration. Not required except for units sent in for major repairs.	**---**

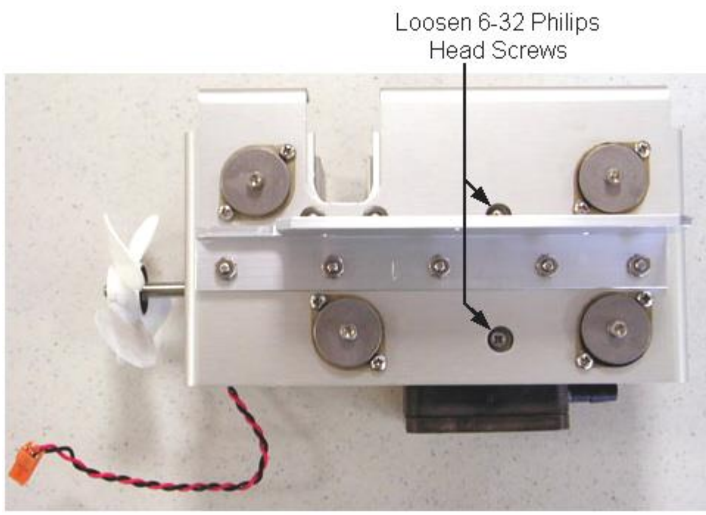
8.5 DC Pump Replacement

The internal DC dual diaphragm pump used in the standard version of the E-BAM is one of the smallest and lowest power consuming models available which can still maintain a 16.7 lpm flow rate under load. The pump is rated for at least 4000 hours of operation under normal conditions. The typical area of wear on these pumps are the motor brushes and motor bearings. The pump is not rebuildable, so it will need to be replaced approximately every 6 to 9 months of continuous operation when it can no longer regulate at the normal 16.7 lpm flow rate. The exact lifetime of the pump will vary depending on concentration levels and ambient temperatures. The E-BAM is designed for fairly easy pump replacement without having to remove the transport assembly from the enclosure. Consult the Service Department if difficulty is encountered.

1. Turn off power from the E-BAM before accessing the pump.
2. Remove the two 8-32 screws which fasten the pump cover plate. Unplug the door switch harness which is mounted in the cover plate and set the plate aside.
3. Remove the two small screws which fasten the small clear plastic cover in front of the vertical sample tube. Set the parts aside.
4. Remove the vertical sample tube and inlet heater assembly by sliding the two sealing collars upward. The collars have o-ring seals and are compression fit only. Unplug the inlet heater harness and set the sample tube and heater assembly aside.
5. Unplug the pump from the J17 connector on the 3610 PCB.
6. Remove the three 6-32 screws which mount the pump assembly to the transport plate. The pump assembly will be loose except for the tube connections.
7. Unplug the four 3/8” ID tube connections from the front of the pump. Mark the tubes if necessary to make sure they are replaced in the exact same positions.
8. Completely remove the hose clamp which clamps the pump to the mounting bracket.
9. Turn the pump assembly upside down and locate the two 6-32 screws which are visible through the holes in the sheet metal bracket. Loosen but do not remove the screws. The pump should now slide away from the bracket assembly. Set aside the old pump. You may have to cut a zip tie which retains the harness.
10. Orient the new pump onto the bracket assembly and slide it into place so that the slots on the pump fully engage the two square nuts that you just loosened to remove the old pump. Tighten the two screws/square nuts securely. Make sure the pump harness is on top as shown in the drawings.
11. Reattach the hose clamp to tightly secure the pump to the bracket.
12. Reinstall the pump assembly into the E-BAM making sure the tube connections are in the same positions they were for the old pump. Fasten the three mounting screws.
13. Reinstall the sample tube heater assembly. Make sure to plug the heater back into its harness and to reposition the two sealing collars.
14. Plug the new pump harness into J17 of the 3610 PCB. Make sure the harness does not interfere with the fan blades. Replace the pump cover plate.







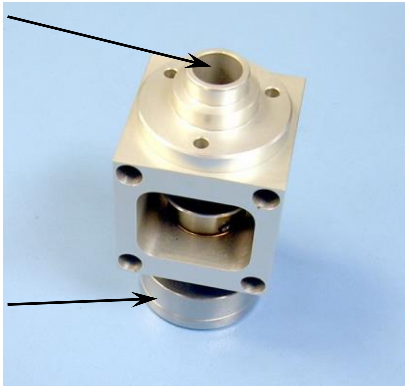
Pump Replacement Diagrams

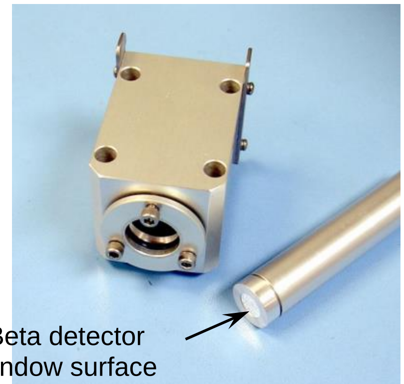
8.6 Cleaning the Inside of the Sample Nozzle Assembly

The inside of the E-BAM sample nozzle should be periodically cleaned to remove any particulate which may have settled on the inside surfaces. This cleaning prevents any buildup of particulate which could result in artifacts falling out of the nozzle and onto the tape, causing undesired positive concentration spikes. The cleaning involves blowing low pressure compressed air through the nozzle assembly only. **CAUTION: Never attempt to remove or disassemble the nozzle assembly! The beta source is housed inside the nozzle.**

1. Advance the filter tape to a fresh spot.
2. Remove the pump cover plate, clear heater cover, and sample tube/heater assembly as described above for pump removal. You now have access to the top of the nozzle assembly.
3. Use a can of dusting air with a long plastic nozzle to blow through the nozzle and filter tape. This will dislodge any particulate from the inside of the nozzle and deposit it onto the tape.
4. Repeat the process until the tape spot no longer shows signs of particulate. You may need to advance the spot to determine this.

5. Replace the sample tube and cover plates when finished.





8.7 *Cleaning the Beta Detector Assembly*

The beta particle detector in the E-BAM is located directly underneath the filter tape support vane. The entry window of the detector can occasionally become covered with a layer of fine white filter tape debris (glass fibers) or particulate deposits. This debris can reduce the beta signal to the point where the E-BAM cannot function correctly. The first attempt to clean the detector window is simply to blow canned air through the vane to dislodge the debris. This is often adequate to solve the problem. In some cases, the debris may be stuck to the detector window to the point where the detector tube will need to be removed and cleaned thoroughly. This involves removing the E-BAM transport from the weatherproof enclosure.

Important Note: E-BAMs built before July, 2006 should never have the beta detector window touched or cleaned with any kind of solvent, unless the detector has been upgraded by Met One! The detector window on these older units is coated with a thin reflective coating which will be badly damaged if it is rubbed or abraded in any way. The only way to clean these windows is with a very soft sable lens brush. E-BAMs built after July, 2006 (some units with serial prefix F, and all units with serial prefix G or later) have an improved detector assembly with a hardened window which may be carefully cleaned with solvent such as water or alcohol. If you are unsure about which type of detector you have, contact the Met One Service Department before proceeding! Use the following steps to remove and clean the detector:

1. Turn of the E-BAM power and remove the power cord. Remove any other cables or connections from the bottom of the unit.
2. Remove the pump cover plate and the vertical sample tube/heater assembly from the inside of the E-BAM.
3. Unscrew the four large screws which retain the transport plate to the inside of the enclosure. Remove the two smaller screws on the bottom of the E-BAM near the connectors.
4. Carefully remove the transport assembly from the enclosure by rocking the top of the transport out first. Be careful not to damage any wires or tubing, as the fit is tight!
5. Set the transport on a static-free flat surface.
6. Loosen but do not remove the three hex head screws in the compression collar at the base of the detector tube. The detector tube should slide out of the bottom of the flow block. Carefully pull out the detector without stressing the harness.

7. Inspect the silver window on top of the detector before doing any cleaning. Make sure the window is not broken or damaged.
8. If the E-BAM has an older style detector, *very carefully* clean the window with canned air and a soft lens brush only, but no solvent of any kind. If the E-BAM has a newer style detector, clean the window with a soft cotton-tipped applicator wet with distilled water. If water does not work, isopropyl alcohol may be used. Do not scrub the window with any force.
9. Make sure the vane area is completely clean before reinserting the detector.
10. Reinsert the beta detector into the flow block. The detector will slide up until it contacts a stop pin which will not allow the detector to go any further. **Note: It is critical that the detector be fully inserted!**
11. Tighten the three screws in the compression collar to secure the detector in place. Do not over-tighten the compression collar!
12. Replace the E-BAM transport assembly into the enclosure and fasten with the screws.
13. Power up the E-BAM and perform allow it to warm up for at least one hour. Perform a span membrane test. The unit should pass the test if the detector is working properly. If difficulty is encountered contact the Met One Service Department.

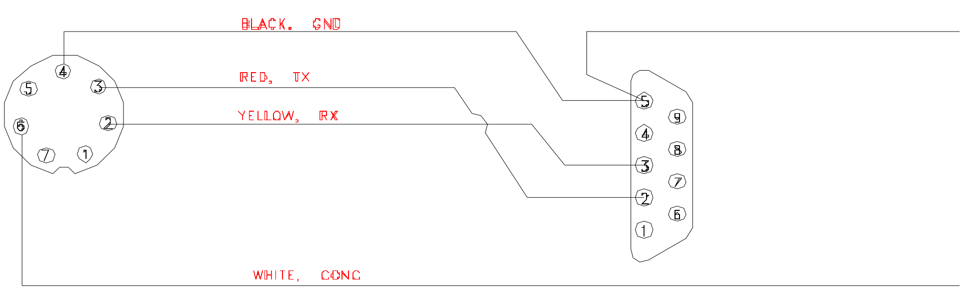
Note: Units which have the older style detector window can be factory upgraded with the new style detector, if the unit is located in an environment where frequent detector fouling is encountered. Contact the Service Department for details.

9 DATA RETRIEVAL and COMMUNICATIONS

This section describes the methods used to retrieve data files from the E-BAM. The unit has an RS-232 two-way serial port which may be used with a computer, laptop, modem, or digital datalogger. This serial port handles all digital data transfer, and can be directly connected to a computer, or can be used with an optional modem for remote communications through a phone line, cell system, radio link, or IP addressable serial converter. Access to the data through the serial port is a simple command driven interface. An analog voltage output is also available for special applications.

9.1 Analog Voltage Output

The E-BAM has an analog voltage output available which represents the hourly or real-time concentration values. The analog output signal is located on the same E-BAM connector as the serial data output, due to limited connector availability. The analog output is rarely used because of the portable nature of the E-BAM, so the standard E-BAM serial cable that comes with the unit does not have access to the analog output signal. If the analog output is to be used, you will need to acquire a special cable which has a breakout for the white voltage output wire (CONC signal) and the black (ground) wire as shown in the cable drawing below. These two wires are then routed to your analog datalogger input to record the output. The E-BAM analog output can be set to 0-1, 0-2.5, or 0-5 volts, which represents a fixed range of 0 to 1.000 milligrams of concentration. **Note:** Negative concentrations cannot be represented on the analog output. See Section 7.4 for details about how to set up and configure the analog output. See Section 5.8 for instructions about how to test the output voltage.



E-BAM Serial Cable Wiring, (with Analog Output)

9.2 Serial Port Connections to a Computer

The E-BAM can be directly connected through the supplied E-BAM serial cable to most standard desktop computers that have a 9-pin (DB-9) RS-232 serial port connector (COM1 to COM4). The E-BAM can also be connected to most laptop computers, though newer laptops do not usually have 9-pin serial ports, so a converter may have to be used. The simplest type is a USB-to-RS232 serial adapter. Met One recommends the Belkin F5U109, available from Met One or a local electronics store. You will still need the standard E-BAM serial cable. Certain laptops occasionally have difficulty communicating through this type of adapter. Another option is an RS-232 serial PCMCIA card, such as the Quatech SSP-100 which installs in an expansion card slot in the laptop and provides a serial port for the E-BAM. This type of adapter is very reliable, but more expensive and takes longer to install and configure. See www.quatech.com for more information.

The E-BAM settings are 9600 Baud, 8 data bit, no parity, one stop bit. The baud rate is a default setting which may be changed to a faster value. The other communications settings are fixed.

9.3 Comet™ Data Retrieval Software

The Comet™ program and manual is available free from www.metone.com. It is a simple Windows-based communications terminal program developed by Met One Instruments. This is the recommended method for all E-BAM data retrieval, since Comet allows the user to easily download the data logs, error logs, and settings (EEPROM) files from the E-BAM without the user having to know any of the underlying communications protocols. Install the program onto the computer that you will be using for data retrieval, and review the manual for complete data examples. Comet replaces the obsolete TUS (Terminal Utility Software) program. **Note:** If you use Comet for E-BAM data retrieval, you will not need to use any of the terminal program setups or “AutoMet” commands shown in the following two sections of this manual.

9.4 Downloading Data Using HyperTerminal or other Terminal Programs

E-BAM data can also be easily downloaded through the serial port using HyperTerminal® or other simple terminal programs. Most PCs running Microsoft Windows 95® or later operating systems (except Vista®) already include the HyperTerminal program. This section describes how to set up HyperTerminal for communication with the E-BAM.

1. Connect the RS-232 port on the bottom of the E-BAM to your computer or laptop Com1 serial port using the E-BAM serial cable. A USB adapter may be required for laptops.
2. Open HyperTerminal. (Usually located in the Programs\Accessories\Communications directory). The program will ask you to type a name for the connection. Type “E-BAM” or another name of your choice, then click “OK”.
3. The “Connect To” window will open. Select COM1 (or another serial port if used) from the drop-down menu in the “Connect using:” field. Click “OK”. Note: You could also set up the program to dial the BAM through a modem in this window.
4. The “COM1 Properties” window will open. Set the following values in the drop-down menus, then click “Apply” and “OK”.

Bits per second:	**9600 (or set to match E-BAM baud setting)**
Data bits:	**8**
Parity:	**None**
Stop bits:	**1**
Flow control:	**None**

5. The main HyperTerminal connection window should now be open. Press the ENTER (carriage return) key three times. The E-BAM should respond with an asterisk (*) command prompt indicating that the terminal program has established communication with the unit.
6. Once communication is established, retrieve the desired files from the E-BAM using the appropriate “AutoMet” commands shown in the next section.
7. HyperTerminal will only display 100 lines of data in the window. To capture larger files (such as All Data), first select Transfer > Capture Text from the drop-down menu. Select a location for the file, then click the “Start” button. Retrieve the desired files, and HyperTerminal will automatically store them to the text file as they are downloaded. Click the “Stop” button in the same drop-down menu to stop the text capture when finished.

8. When you exit HyperTerminal, it will ask if you want to save your connection. Click “Yes” and a file named “E-BAM.ht” (or other connection name) will be created in the HyperTerminal folder, which will have all of the communication settings saved. You can use this connection for future communications with the unit.

Importing the text file into a spreadsheet: The data saved in a text file from a terminal download can be viewed by simply opening the text file. However, the data is often somewhat hard to view in the raw text format due to the comma-separated layout of the data fields. The easiest way to analyze the data is to import it as a .csv file into a spreadsheet program such as Excel®:

1. Open the text file of the data, located in the directory you selected for the text capture.
2. Delete all of the title text rows (download date, serial number, etc.) and the empty rows at the top of the file, down to the data header row which defines each of the columns of data. **Do not delete the data header row**, since you will want it to appear in the spreadsheet. There must be no blank spaces or other characters before the data header.
3. Scroll to the end of the data and make sure there are no blank spaces or empty rows after the last data record. If so, delete them.
4. Save the text file and close it.
5. Rename the file extension from **.txt** to **.csv** . This will change the file from a text file to a “comma-separated values” data file.
6. The .csv file should be able to be opened directly by Excel. Each data parameter should appear in its own spreadsheet column, with the correct data header at the top of each column. You can then save the file as a .xls or other spreadsheet file if desired.

9.5 “AutoMet” Data Retrieval Commands Through the Serial Port

When a serial connection between the computer terminal program and the E-BAM has been established, you will have access to the E-BAM data files by sending the following commands through serial port with keyboard strokes or ASCII characters. **Note:** After a few minutes, the E-BAM will stop waiting for a command and you will have to send another series of three carriage returns to reestablish the command prompt connection.

Command	Function
2	Prints **all records** in the Data Log file.
3	Prints all **new records** in the Data Log file since the last data download.
4	Prints the **last record** in the Data Log file only.
5	Prints all records in the Data Log file in 24 hour daily format.
c	Clears all records in the Data Log file.
d	Set date.
t	Set time.
? or h	Identifies unit type and firmware type. Example: “E-BAM 3613-01 R1.50”

The following is an example of the data response from the E-BAM after a “2” command (all data records) was sent to the unit. The report starts with a printout of the time and date of the download and the serial number of the E-BAM. Then a data header row is printed which defines each of the columns in the data field. The column are separated by commas to make it easy to import the data into a spreadsheet, or to parse out data fields in an automatic data collection system. Each column is a certain data parameter. Each row is one complete data record consisting of all stored parameters. In this example, the real-time average is set to 10 minutes, so there was a complete record stored to memory every 10 minutes. Data parameters such as wind speed/direction and external RH will always appear in the data array even if no sensors were connected for those channels. In this example, only a couple of hours worth of data was stored in the memory:

```
* 2

AutoMet Data Log Report
18-DEC-2008 16:22:36,
SN,F1768

Time,ConcRT(mg/m3),ConcHr(mg/m3),Flow(l/m),WS(m/s),WD(Deg),AT(C),RHx(%),RHi(%),BV
(V),FT(C),Alarm,Type
03-DEC-2008 16:40:00,0.016,0.013,16.7,0.3,0,26.2,0,33,14.2,25.5,0,1
03-DEC-2008 16:50:00,0.012,0.013,16.7,0.3,0,26.2,0,32,14.2,25.6,0,1
03-DEC-2008 17:00:00,0.015,0.018,16.7,0.3,0,26.5,0,33,14.2,25.6,0,1
03-DEC-2008 17:10:00,0.022,0.018,16.7,0.3,0,26.6,0,33,14.2,25.7,0,1
03-DEC-2008 17:20:00,0.020,0.018,16.7,0.3,0,25.2,0,32,14.2,26.3,0,1
03-DEC-2008 17:30:00,0.017,0.018,16.7,0.3,0,26.4,0,33,14.2,25.7,0,1
03-DEC-2008 17:40:00,0.013,0.018,16.7,0.3,0,26.6,0,33,14.2,25.8,0,1
03-DEC-2008 17:50:00,0.019,0.018,16.7,0.3,0,26.7,0,34,14.2,25.8,0,1
```

If a “3” command is sent (new data records), the data response from the E-BAM is formatted as shown above, but includes only the data logged since the last time the data was downloaded, based on the position of a data pointer. This command saves time by not retrieving old data that has already been downloaded before.

If a “4” command is sent (last data record), then the data response from the E-BAM is formatted the same, except that only the latest data record in memory is printed as shown below:

```
* 4

AutoMet Data Log Report
18-DEC-2008 16:22:45,
SN,F1768

Time,ConcRT(mg/m3),ConcHr(mg/m3),Flow(l/m),WS(m/s),WD(Deg),AT(C),RHx(%),RHi(%),BV
(V),FT(C),Alarm,Type
03-DEC-2008 18:00:00,0.018,0.015,16.7,0.3,0,26.4,0,34,14.2,25.8,0,1
```

The following table defines the data parameters as they appear in the header of the data reports:

Field	Description
Time	Time and data stamp of the data record.
ConcRT	Real-time average concentration in mg/m3.
ConcHr	Last hourly concentration in mg/m3.
Flow (l/m)	Average air flow for the data logging period in liters per minute.
WS (m/s)	Average wind speed for the data logging period in meters per second.
WD (Deg)	Average wind direction for data logging period in degrees.
AT (C)	Average ambient temperature for the data logging period in ºC.
RHx (%)	Average external RH for the data logging period in %.
BV (V)	Average battery or input voltage for the data logging period in volts.
FT (C)	Average filter temperature for the data logging period in ºC.
Alarm	Error code. 0 = no errors. See Section 8.1 for error descriptions.
Type	E-BAM machine type: 0 = PM2.5, 1 = PM10.

9.6 Advanced Communications – Escape Commands

The communications "escape" command set shown in the table below is not typically used except for advanced data transfer or custom data retrieval software applications. Each command and response string must begin with an Escape character (27, 0x1B) and end with a carriage return (13, 0x0D) and a line feed character (10, 0x0A). An ASCII check sum follows each response (X9999). The hardware protocol is RS-232, 8 data bits, no parity, 1 stop bit.

The E-BAM supports five data files: The EEPROM file (**E**), the Channel Descriptor file (**1**), the AutoMet data log file (**2**), the Error log file (**3**), and the One-Minute diagnostic data log file (**4**). The lowercase **x** in the following commands specifies one of these five files. File modes can be linear (L) or circular (C). All files are record based.

Function	Command	Response
Read Model and Version	RV	RV E-BAM V1.23
Read File Info (FCB)	RFI	RFI Then print the FCB.
Read record index.	RFx R	RFx R n L RFx R n C
Read data file starting with absolute record index or the last (-n) records from the current record index.	RFx D n RFx D -n	RFx D n Then XMODEM file transfer
Print File Report starting with absolute record index or the last (-n) records from the current record index.	PFx n PFx -n	PFx n Then print the report.
Stop printing report.	PFS	PFS
Clear File Data (x: 2, 3, 4)	WFx C	WFx C
Read Date (mm-dd-yy)	RD	RD 05-10-01
Write Date (mm-dd-yy	WD 05-10-01	WD 05-10-01
Read Time (hh:mm:ss)	RT	RT 09:08:02
Write Time (hh:mm:ss)	WT 09:08:02	WT 09:08:02

9.7 Modem Options for Remote Data Retrieval

The Met One Instrument EX-996 modem is recommended for use with the E-BAM, as it is designed to reliably communicate when other modems may not. Other brands of modems must be set in "dumb" or pass-through mode with no handshaking. If you are using one of the Met One Instruments data acquisition programs such as Air Plus, or MicroMet Plus, you need only enter the telephone number of the site in the system setup menu of the program. Multiple telephone numbers can be entered for connection to multiple remote sites.

If you are communicating with a terminal program such as HyperTerminal® you will need to define the serial port configuration in the setup of the terminal program. Set the baud rate to 9600, with 8 data bits, no parity, and 1 stop bit. Use the terminal program's internal dialing command sequence to dial up the E-BAM. Verify the connection to the unit by pressing the <Enter> key until the command prompt asterisk (*) appears. If not, verify the cabling and communications settings. Once connected, the access to the E-BAM is the same command driven interface as used for the direct PC connection. Cell phone, radio, and TCP/IP addressable modems are also available for the E-BAM. Because these technologies are always changing, they are handled on a semi-custom basis. Contact Met One for details.

9.8 Flash Firmware Upgrades

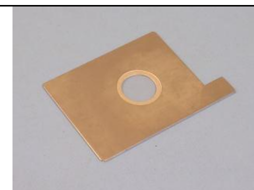
The E-BAM has the capability for flash firmware upgrades. This allows the field operator to reprogram or update the E-BAM flash EEPROM through the serial port using the Firmware Update Utility program. A Met One technician may supply the firmware update files on a CD or by e-mail if a bug fix is released or if additional features are added to the firmware program that controls the E-BAM operation. The following tasks must be performed whenever the E-BAM firmware is upgraded:

1. Download and save the data log and error log from the E-BAM before proceeding. These will be cleared from memory during the upgrade process!
2. Firmware Update Utility is a PC-based utility program which used to update firmware in Met One products equipped with FLASH memory technology. You will need a PC or laptop with an available RS-232 COMM port. Install the Firmware Update Utility program onto the computer by following the prompts after the CD is inserted.
3. Connect the E-BAM serial port to the computer COMM port (usually COMM 1) with the serial cable that came with the E-BAM.
4. Make sure that the computer and the E-BAM are both set to the 9600 baud rate.
5. Take great effort to ensure that the power source to the E-BAM and the computer will not be interrupted during the update process! A power interruption may cause the E-BAM firmware to become inoperative! If this happens the unit will have to be returned to the factory. Be especially careful with laptops and USB serial converters to make sure the serial connection does not come loose for the same reason.
6. Run the Firmware Update Utility. From the computer "Start" menu, go to: `Programs/Met One/E-BAM/E-BAM Master Program Installer`.
7. The program will prompt you for the COMM port number. Enter the number (usually 1) and press ENTER to begin the update.
8. A "**Done!**" message will be displayed at the end of the update process. Execution time is approximately five to fifteen minutes.
9. The E-BAM can now be operated with the new firmware.

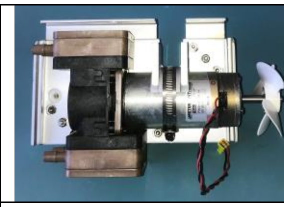
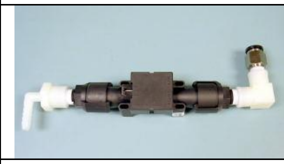
10 ACCESSORIES and PARTS

10.1 Consumables, Replacement Parts, and Accessories

The following parts are available from Met One for maintenance, replacement, service, and upgrades. If unsure about a part you need, please contact the Service department. Some of these parts require technical skills or special considerations before use or installation.

Description	Part Number	Graphic
Consumables		
Filter Tape Roll, Glass Fiber, 30mm x 25m	**460180**	
Filter Tape Core Tube, Gray Plastic	**8150**	
Cotton-Tipped Applicators, nozzle cleaning, 100 pack Solon #362	**995217**	
Tools		
Span Membrane Assembly, 0.800 mg/cm2 Replacement part	**9325**	
Membrane Assembly, Mid-Range, 0.500 mg/cm2	**EX-301**	
Zero Membrane Shim, Nozzle Shipping Shim	**9166**	
Flow Inlet Adapter Kit (Leak Test Valve)	**BX-305**	
Zero Filter Calibration Kit, with valve Same as BX-305 but with 0.2 micron filter	**BX-302**	
Volumetric Flow Calibration Kit (BGI deltaCal™) Flow, Temp, and Pressure Reference Standards Met One recommended flow audit meter	**BX-307**	

Flow System Components

E-BAM Internal DC Pump Replacement Assembly	**8967**	
Pump Cover, Sheet Metal	**9233**	
Pump Purge Tank Filter, 2 per unit	**580255**	
Flow Sensor, Mass, 0-20 LPM, Internal Assembly	**80425**	
Filter RH Sensor, Replacement Only	**8624**	
Filter Temperature Sensor, Replacement Only	**8131**	
Flow Sensor Debris Filter, Sintered Bronze Element	**580299**	
O-Ring, Nozzle, 1 required	**720066**	
O-Ring, Inlet Tube Receiver, 2 required	**720069**	

Inlet Components

PM10 Inlet Head, EPA Specified	**BX-802**	
TSP Sampling Inlet Cap, Harsh Environment with insect screen and rain cap	**BX-803**	
PM2.5 Sharp Cut Cyclone	**BX-807**	
PM2.5 WINS Impactor	**BX-804**	
Inlet Tube Coupler Assembly, with o-rings Connects two inlet tubes together Inlet tube sold separately	**BX-821**	
Inlet Tube Extension Kit, 4 foot, with coupler and tube	**BX-822**	
Inlet Tube Extension Kit, 8 foot, with coupler and tube	**BX-823**	
Standard Inlet Tube, E-BAM, Aluminum, 9 inch	**9187**	
Inlet Tube, Custom Length Dash number is length in feet, 8’ max per tube	**8112-X**	

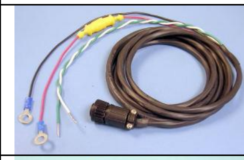
Cross-arm Clamp, ¾" x ¾", Aluminum Mounts cross-arms to the E-BAM tripod	**1552**	
Inlet Tube Seal, Black Plastic, Weatherproof	**480509**	
O-Ring Kit, for BX-807 Cyclone, set of 6	**720097**	
O-Ring Kit, for BX-802 PM10 Head, set of 3	**8965**	

Meteorological Sensors

Wind Speed and Wind Direction Combination Sensor For use with E-BAM and E-SAMPLER.	**EX-034**	
9250 Ambient Temperature Sensor Standard E-BAM Accessory	**9250**	
Ambient Relative Humidity Sensor	**EX-593**	

Miscellaneous Accessories

Display, Vacuum Fluorescent, 4x20 Character	**8966**	
Gear Motor Assembly Used for nozzle and tape reel	**8968**	
Wall Mount Bracket for E-BAM. Mounts the E-BAM enclosure to a mast, post, wall, or other vertical surface.	**CALL**	
Power Supply, E-BAM, 120/220V AC input, 12V DC output, Weatherproof	**EX-121**	

Tripod Assembly, E-BAM/E-SAMPLER	**EX-905**	
Tape Spool Cover, Replacement, 2 per unit	**82148**	
E-BAM Phone Line Modem Kit	**EX-996**	
E-BAM Cell Modem Kit	**EX-911**	
Power Cable, E-BAM to Battery	**9638**	
Power Cable, E-BAM to Battery, with relay output wires	**9638-1**	
Serial Cable, E-BAM	**9321**	
Serial Cable, E-BAM, with analog output wires	**9321-1**	
Belkin F5U109 USB-to-RS-232 Adapter	**550067**	

11 THEORY OF OPERATION and MATHEMATICAL ANALYSIS

When the high-energy electrons emanating from the radioactive decay of ^{14}C (carbon-14) interact with nearby matter they loose their energy and, in some cases, are absorbed by the matter. These high-energy electrons emitted through radioactive decay are known as beta rays and the process is known as beta-ray attenuation. When matter is placed between the radioactive ^{14}C source and a device designed to detect beta rays, the beta rays are absorbed and/or their energy diminished. This results in a reduction in the number of beta particles detected. The magnitude of the reduction in detected beta particles is a function of the mass of the absorbing matter between the ^{14}C beta source and the detector.

The number of beta particles passing through absorbing matter, such as dust deposited on a filter tape, decrease nearly exponentially with the mass through which they much pass. Equation 1 shows this relationship.

Equation 1

$$I = I_0 e^{-\mu x}$$

In Equation 1, I is the measured beta ray intensity (counts per unit time), of the attenuated beta ray (dust laden filter tape), I_0 is the measured beta ray intensity of the un-attenuated beta ray (clean filter tape), μ is the absorption cross section of the material absorbing the beta rays (cm^2/g), and x is the mass density of the absorbing matter (g/cm^2).

Equation 1 very closely resembles the Lambert-Beers Law, which is used in spectrometric analysis. Just as the Lambert-Beers Law is an idealization of what is actually observed, Equation 1 is also an idealized simplification of the true processes occurring meant to simplify the corresponding mathematics. However, experimental measurement shows that in properly designed monitors, such as the BAM-1020, the use of this equation introduces no substantial error.

Equation 1 may be rearranged to solve for x, the mass density of the absorbing matter. This is shown in Equation 2.

Equation 2

$$-\frac{1}{\mu}\ln\left[\frac{I}{I_0}\right] = \frac{1}{\mu}\ln\left[\frac{I_0}{I}\right] = x$$

In practice, the absorption cross section is experimentally determined during the calibration process. Once I and I_0 are experimentally measured, it is a simple matter to calculate x, the predicted mass density.

In practice, ambient air is sampled at a constant flow rate (Q) for a specified time Δt. This sampled air is passed through a filter of surface area A. Once x, the mass density of collected particles, has been determined, it is possible to calculate the ambient concentration of particulate matter ($\mu g/m^3$) with Equation 3.

Equation 3

$$c\left(\frac{\mu g}{m^3}\right) = \frac{10^6 A(cm^2)}{Q\left(\frac{liter}{min}\right)\Delta t(min)\mu\left(\frac{cm^2}{g}\right)}$$

In Equation 3, c is the ambient particulate concentration ($\mu g/m^3$), A is the cross sectional area on the tape over which dust is being deposited (cm^2), Q is the rate at which particulate matter is being collected on the filter tape (liters/minute), and Δt is the sampling time (minutes). Combining these equations yields to the final expression for the ambient particulate concentration in terms of measured quantities. This is shown in Equation 4.

Equation 4

$$c\left(\frac{\mu g}{m^3}\right) = \frac{10^6 A(cm^2)}{Q\left(\frac{liter}{min}\right)\Delta t(min)\mu\left(\frac{cm^2}{g}\right)} \ln\left(\frac{I_0}{I}\right)$$

The key to the success of the beta attenuation monitor is due in part to the fact that μ, the absorption cross-section, is almost insensitive to the nature of the matter being measured. This makes the BAM-1020 very insensitive to the chemical composition of the material being collected.

It is instructive to perform a conventional propagation of errors analysis on Equation 4. Doing so, one can develop an equation for the relative measurement error (σ_c/c) as a function of the uncertainty in each of the parameters comprising Equation 4. This leads to Equation 5.

Equation 5

$$\frac{\sigma_c}{c} = \sqrt{\frac{\sigma_A^2}{A^2} + \frac{\sigma_Q^2}{Q^2} + \frac{\sigma_t^2}{t^2} + \frac{\sigma_\mu^2}{\mu^2} + \frac{\sigma_I^2}{I^2 \ln\left[{I}/{I_0}\right]^2} - \frac{\sigma_{I_0}^2}{I_0{}^2 \ln\left[{I}/{I_0}\right]^2}}$$

Inspection of Equation 5 reveals several things. The relative uncertainty of the measurement (σ_c/c) is decreased (improved) by increasing the cross sectional area of the filter tape (A), the flow rate (Q), the sampling time (t), the absorption cross-section (μ), I and I_0.

In practice, the uncertainty associated with the filter area (σ_A/A), may be minimized by ensuring that the tape is in exactly the same position during the I_0 measurement as in the I measurement phase. Careful design of the shuttle and tape control mechanisms inside of the BAM-1020 results in minimal error here.

The uncertainty in the flow rate (σ_Q/Q) may be minimized by properly controlling the flow of the instrument. For BAM-1020 units with a manual flow valve, this value is on the order of ± 3%. For BAM-1020 units equipped with the mass flow controller device, (σ_Q/Q) decreases to ± 1%.

The relative error due to the uncertainly in the absorption cross section (σ_μ/μ), is due to its slight variation as a function of the chemical composition of the matter being monitored. Generally, this relative error is on the order of ± 2-3%, with judicious selection of the calibrated value of μ.

The uncertainty associated with the measurement of I and I_0 has to do with the physical nature of the process leading to the emission of beta particles from the decay of ^{14}C. This process follows

Poisson statistics. Poisson statistics show the uncertainty in the measurement of I (σ_I/I) and I_0 (σ_{I0}/I_0) are minimized by increasing the sampling time. Mathematical analysis shows that doubling the sampling time and hence the measured intensity of I or I_0 will reduce the uncertainty of the measurement by a factor of 1.41 (square root of 2).

11.1 Converting Data Between EPA Standard and Actual Conditions

As described in this manual, the BAM-1020 can obtain concentration data using either actual or standard values for ambient temperature and pressure. In some cases, it is necessary to convert past concentration data collected in standard conditions to actual conditions, or the other way around. Note: temperature is in degrees Kelvin (C+273) and pressure is in mmHg.

Equation 6

$$C_{std} = C_{amb} * (P_{std} / P_{amb}) * (T_{amb} / T_{std})$$

Equation 6 can be used to calculate the standard concentration (C_{std}) from the ambient concentration (C_{amb}) data using ambient barometric pressure and temperature data (P_{amb} and T_{amb}) from the same time period in which the ambient concentration was recorded. P_{std} and T_{std} are the values of standard barometric pressure and standard ambient temperature. These values are usually the EPA mandated 760 mmHg and 298 degrees Kelvin (25 C). **Note:** Some other countries use different values for standard temperature and pressure.

Equation 7

$$C_{amb} = C_{std} * (P_{amb} / P_{std}) * (T_{std} / T_{amb})$$

Equation 7 can be used to calculate the ambient concentration (C_{amb}) from the standard concentration (C_{std}) data using the ambient temperature and pressure. It is necessary to have access to valid data for the ambient temperature and pressure for the desired sample hour in order to be able to make the calculations.

Example: You have a data value of 27µg from a BAM which was configured to report data in EPA Standard conditions (298K and 760 mmHg), but you need to know what the concentration would have been in actual conditions. The actual average temperature for the hour in question was 303K and the average pressure was 720mmHg.

$$C_{amb} = C_{std} * (P_{amb} / P_{std}) * (T_{std} / T_{amb})$$

$$C_{amb} = 27 * (720/760) * (298/303)$$

$$C_{amb} = 27 * 0.9474 * 0.9835$$

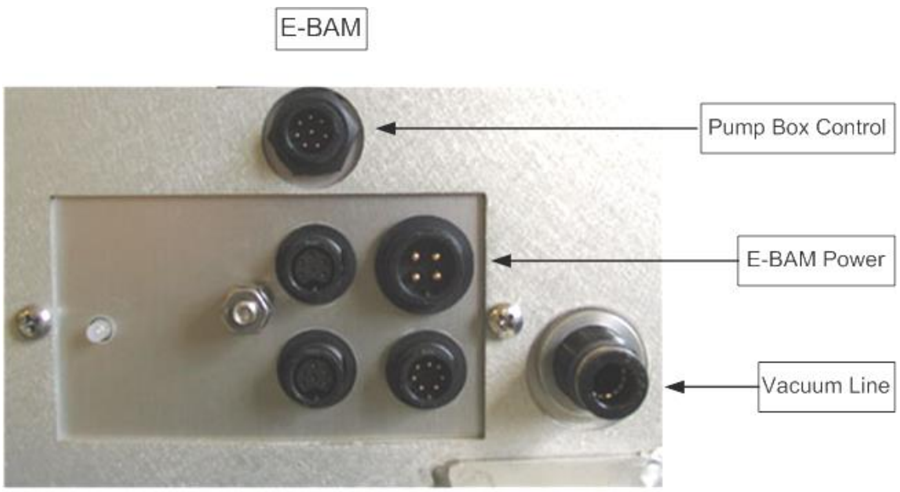
12 SPECIAL E-BAM CONFIGURATIONS

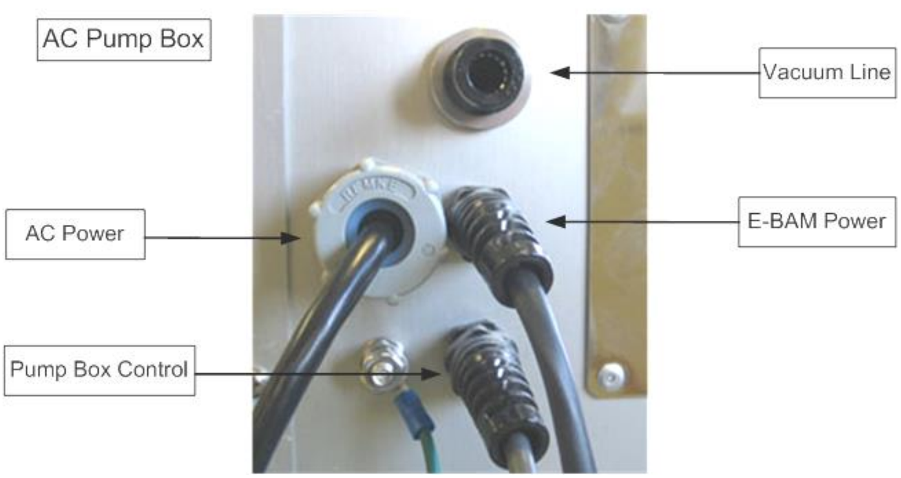
Because of its modular nature, the E-BAM is often supplied in custom configurations in order to meet specific monitoring needs.

12.1 External Pump Box Configurations for the E-BAM

The E-BAM can be factory configured to use an external AC powered pump box module which replaces the internal pump that is included with standard E-BAM units. The E-BAM used for this configuration is a special model number E-BAM/9770, and the external pump box assembly has a model number EX-125 (115V) or EX-126 (220V). This gives the E-BAM longer pump life at the expense of portability. The general functionality of this version as the same as the regular E-BAM.

The external pump box sits on the ground under the E-BAM tripod. The E-BAM has the same four standard electrical connectors on the bottom, with the addition of a pump box control connecter. This connection provides signals to the pump box so that the E-BAM can turn the pump on and off and drive the flow controller motor. Plug the Pump Box Control cable into the extra connector on the E-BAM. The pump box also has a built in power supply to power the E-BAM. Plug the power cable from the pump box into the normal E-BAM power input. Plug the pump box power cord into an AC outlet to power up the E-BAM and to supply power to the pump. A length of 10mm OD vacuum tubing must also be connected between the E-BAM and the pump box.





Another variation of the external pump box option is the E-BAM-5LPM model. This is a special E-BAM that runs at 5.0 liters per minute with a special PM10 inlet configuration. The external pump box used for this option contains a special pump and flow controller for the lower flow rate, and the E-BAM has special firmware to allow flow regulation and calibration at 5 LPM. This is for extreme particulate conditions only, where the ambient concentration can exceed several milligrams in only a few minutes. The detection limit of the E-BAM-5LPM is not suitable for normal ambient monitoring. This model is sold on a semi-custom basis only.

12.2 AIRSIS Satellite Uplink Option

The E-BAM can be equipped with an optional Iridium satellite communications module which can download digital data from the E-BAM serial port and upload it through a satellite system. The module is designed by AIRSIS specifically for use with the E-BAM, and mounts directly onto the tripod. The system is widely used for remote deployments. Contact Met One for details about this configuration.

13 E-BAM AUDIT SHEET

Model: E-BAM **Serial Number:**

Audit Date: **Audited By:**

Flow Audits			
Flow Reference Standard Used:	Model:	Serial No:	Calibration Date:
Temperature Standard Used:	Model:	Serial No:	Calibration Date:
Barometric Pressure Standard Used:	Model:	Serial No:	Calibration Date:

Leak Check Value: as found: lpm as left: lpm

		E-BAM	Ref. Std.		E-BAM	Ref. Std.
Ambient Temperature:	as found:	C	C	as left:	C	C
Barometric Pressure:	as found:	mmHg	mmHg	as left:	mmHg	mmHg
16.7 lpm Flow Rate (Actual):	as found:	lpm	lpm	as left:	lpm	lpm
16.7 lpm Flow Rate (Standard):	as found:	slpm	slpm	as left:	slpm	slpm

Mechanical Audits

Sample nozzle clean:	as found ☐	as left ☐	PM10 particle trap clean:	as found ☐	as left ☐
Tape support vane clean:	as found ☐	as left ☐	PM10 drip jar empty:	as found ☐	as left ☐
Tape spool covers tight:	as found ☐	as left ☐	PM10 bug screen clear:	as found ☐	as left ☐
______	as found ☐	as left ☐	PM2.5 particle trap clean:	as found ☐	as left ☐

Analog Voltage Output Audit N/A ☐

DAC Test Screen	E-BAM Volt Output
0.010 Volts	Volts
0.500 Volts	Volts
0.990 Volts	Volts

Manual Span Membrane Test

Expected Span Mass (mg/cm2:	
Measured Span Mass (mg/cm2):	
Difference (mg/cm2):	
% Difference:	

Pump Test

Flow Setpoint	E-BAM Flow
14.0 lpm	
16.7 lpm	
17.5 lpm	

Setup and Calibration Values

Parameter	Expected	Found	Parameter	Expected	Found	Parameter	Expected	Found
Clock			Analog Mode			Flow Type		
Location			Baud Rate			Restart Voltage		
Tape Advance			RH Setpoint			Std Cond Temp		
Realtime Avg			Delta-T Setpoint					
Machine Type			RH Control					
Analog FS			Flow Setpoint					

Last 6 Errors in E-BAM Error Log

Error	Date	Time	Error	Date	Time
1			4		
2			5		
3			6		

Audit Notes:

OPERATOR NOTES:

Appendix C – Continuous $PM_{2.5}$ Local Conditions Validation Template, EPA QA Handbook Volume II

Met One BAM PM10/PM2.5 Data Review Table

Station Name & Monitoring Period Dates

Criteria (PM2.5/PM10)	2) Frequency	3) Acceptable Range	Comments
Critical Criteria PM10/PM2.5 Continuous			
Data Reporting Period	Report every hour	A 24-hr period is calculated in AQS if 18 or more valid hours are reported for a day	40 CFR Part 50 App N sec 3(c)
Average flow rate	Every 24 hour of ops; alternatively each hour can be checked	Average within 5% of 16.67 L/min at local conditions	
Variability in flow rate	Every 24 hour of ops	CV ≤ 2%	
One-point Flow Rate Verification	Every 30 days each separated by 14 days	< ± 4.1% of transfer standard & < ± 5.1% of flow rate design value	
Design Flow Rate Adjustment	After multi-point calibration or verification	< ± 2.1% of design flow rate	
External Leak check	Before each flow rate verification/calibration and before and after PM2.5 separator maintenance	< 1.5 L/min	
PM10 inlet	At setup	Louvered PM10 size selective inlet as specified in CFR	40 CFR App L, figs L-2 through L-19
PM2.5 inlet	At setup	BGI VSCC or equivalent second stage separator approved for the method	
Operational Criteria PM10/PM2.5 Continuous			
Temperature multi-point verification/calibration	On installation, then every 365 days and 1/calendar year	< ± 2.1° C	
One-point temperature verification	Every 30 days	< ± 2.1° C	
Pressure verification/calibration	On installation, then every 365 days and 1/calendar year	< ± 10.1 mm Hg	
One-point pressure verification	Every 30 days	< ± 10.1 mm Hg	
Flow rate multi-point verification/calibration	Following any electromechanical maintenance or transport, or every 365 days and 1/calendar year	< ± 2.1 % of transfer standard	
72-hour zero test	1/yr. (1/6 mo. recommended)	Std dev of the data from a 72-hr zero test < 2.4 $\mu g/m^3$	
Precision			

Met One BAM PM10/PM2.5 Data Review Table

Station Name & Monitoring Period Dates

Criteria (PM2.5/PM10)	2) Frequency	3) Acceptable Range	Comments
Collocated samples	Every 12 days for 15% of sites by method designation	CV < 10.1% of samples ≥ 3 $\mu g/m^3$	
Accuracy			
Temperature audit	Every 180 days and at time of flow rate audit	< ± 2.1° C	
Pressure audit	Every 180 days and at time of flow rate audit	< ± 10.1 mm Hg	
Flow Rate audit	Twice a calendar year and 5-7 months apart	< ± 4.1 % of transfer standard & < ± 5.1 % of design flow rate	
Shelter Temperature			
Temperature range	Daily	20 to 30° C (hourly avg.) or per manufacturer's specifications if designated to wider temp. range (0 to +50° C for BAM 1020, shelter temp stable to within ± 2° C per hour)	
Temperature control	Daily (hourly values)	< 2.1° C Std Dev over 24 hours	
Temperature device check	Every 180 days and twice a calendar year	< ± 2.1° C	
BAM routine inspection, cleaning, and maintenance			
Inlet Head	Every 30 days	Inspect, clean if necessary	
$PM_{2.5}$ separator (VSCC)	Every 30 days	cleaned/changed	
Down tube	Every 90 days	cleaned	
Nozzle & vane	1/mo. or more often as needed	Inspect and clean	
Capstan shaft & roller	1/mo.	Inspect and clean	
Smart heater	1/yr.	Inspect and maintain	
Replace or clean pump muffler	1/6 mo.	Inspect, clean or replace	
Rebuild or replace pump	1/yr.	Rebuild or replace	
Clean or replace internal debris filter	1/yr.	Clean, replace as needed	
Membrane span foil check	1/yr.	Avg. < ± 5 % of ABS value	
Beta detector count rate	1/yr.	Between 600,000 to 1,100,000 counts 4-min. test	
Dark Count Value	1/yr.	< 50 (recommended < 10)/4-min. test	
Data comparison internal data logger to external data logger	Every 30 days 10 randomly selected values	Digital – exact match, analog ± 1 $\mu g/m^3$	
Systematic Criteria PM10/PM2.5 Continuous			
Monitor	-	Meets requirements listed in the FEM designation	

Met One BAM PM10/PM2.5 Data Review Table

Station Name & Monitoring Period Dates

Criteria (PM2.5/PM10)	2) Frequency	3) Acceptable Range	Comments
Siting	Every 365 days and 1/calendar year	Meets citing criteria or waiver documented	
Data Completeness	Quarterly	≥ 75% scheduled sampling days in each quarter	
Reporting Units			
PM2.5	All concentrations	$\mu g/m^3$ at ambient temperature & pressure	
PM10L (local conditions)	All concentrations	$\mu g/m^3$ at ambient temperature & pressure	
PM10S (standard conditions)	All concentrations	$\mu g/m^3$ corrected to standard temperature at 25° C & standard pressure at 760 mm Hg	
Rounding convention for data reported to AQS	All concentrations	To one decimal place, with additional digits to the right truncated, or as reported by instrument	
Annual 3-yr. average	All concentrations	Nearest 0.1 $\mu g/m^3$ (≥ 0.05 round up)	
24-hour, 3-yr. average	All concentrations	Nearest 1 $\mu g/m^3$ (≥ 0.5 round up)	
Detection Limits			
Lower detection limit	24-hour avg.	< 1 $\mu g/m^3$.	
	1-hour avg.	< 4.8 $\mu g/m^3$.	
Upper detection limit	All hourly avgs.	1000 $\mu g/m^3$	
Verification/calibration standards recertification		All standards should have multi-point certifications against NIST-traceable standards	
Flow rate transfer standard	Every 365 days and 1/calendar year	< ± 2.1% of NIST-traceable standard	
Field thermometer	Every 365 days and 1/calendar year	± 0.1° C resolution, ± 0.5° C accuracy	
Field barometer	Every 365 days and 1/calendar year	± 1 mm Hg resolution, ± 5 mm Hg accuracy	
Clock/timer verification	Every 30 days	1 minute/mo.	
Data Precision			
Single analyzer (collocated monitors)	Every 90 days	Coefficient of variation (CV) < 10.1% for values ≥ 3.0 $\mu g/m^3$	
Primary Quality Assurance Org.	Annual and 3 yr. estimates	90% CL of CV < 10.1% for values ≥ 3.0 $\mu g/m^3$	
Data Bias			
Performance Evaluation Program (PEP)	5 audits for PQAOs with ≤ 5 sites 8 audits for PQAOs with > 5 sites	< ± 10.1% for value > 3$\mu g/m^3$	

Data Management Procedures and Documentation	
1st Level Review	**Comments and/or required actions**

Met One BAM PM10/PM2.5 Data Review Table

Station Name & Monitoring Period Dates

Daily review for limit checking, anomalies and irregularities		
Review for data flags indicating out of limit conditions or instrument errors		
PM coarse data comparison (PM10-PM2.5) for invalidation of negative values < - 5 µg/m^3		
Logbook review: Station Logbook hardcopy and digital log entries		
1st Level Data Editing		
Explanation of missing or invalidated data		
Appropriate use of AQS null codes		
Appropriate use of AQS data qualifiers		
General Notes		
Critical and operational QC forms and NIST Traceable Certifications	**Archived in Air Tools.**	**Comments and/or required actions**
Most recent QA audit report and data sheets		
1-point QC forms for all leak, flow, pressure, temperature and time checks.		
BAM multi-point verification/calibration data sheets		
BAM 72-hour zero air background checks data sheets		
Images of station logbook notes and/or digital record of electronic log entries		
Images of current NIST traceable certifications for all reference devices and transfer standards.		
Date & Performed by:		

Appendix D – CFR Part 58 Site Evaluation Form for $PM_{2.5}$ and PM_{10}

PART 58 SITE EVALUATION FORM FOR PM2.5 and PM10					
SITE NAME: SITE ADDRESS: AQS ID: EVALUATION DATE: EVALUATOR:					
APPLICABLE SECTION	REQUIREMENT	OBSERVED	CRITERIA MET?		
			YES	NO	N/A
2. HORIZONTAL AND VERTICLE PLACEMENT	2-15 meters above ground level for neighborhood or larger spatial scale, 2-7 meters for microscale spatial scale sites and middle spatial scale $PM_{10-2.5}$ sties. 1 meter vertically or horizontally away from any supporting structure, walls, *etc.*, and away from dusty or dirty areas. If located near the side of a building or wall, then locate on the windward side relative to the prevailing wind direction during the season of highest concentration potential.				
3. SPACING FROM MINOR SOURCES	(a) For neighborhood or larger spatial scales avoid placing the monitor near local, minor sources. The source plume should not be allowed to inappropriately impact the air quality data collected at a site. Particulate matter sites should not be located in an unpaved area unless there is vegetative ground cover year round.				
4. SPACING FROM OBSTRUCTIONS	(a) To avoid scavenging, the inlet must have unrestricted airflow and be located away from obstacles. The separation distance must be at least twice the height that the obstacle protrudes above the probe inlet.				
	(b) The inlet must have unrestricted airflow in an arc of at least 180 degrees. This arc must include the predominant wind direction for the season of greatest pollutant concentration potential. For particle sampling, a minimum of 2 meters of separation from walls, parapets, and structures is required for rooftop site placement.				
5. SPACING FROM TREES	(a) To reduce possible interference the inlet must be at least 10 meters or further from the drip line of trees.				
	(c) No trees should be between source and probe inlet for microscale sites.				
6. SPACING FROM ROADWAYS	Spacing from roadways is dependent on the spatial scale and ADT count. See section 6.3(b) and figure E-1 for specific requirements.				
Are there any changes that might compromise original siting criteria?					
Other Comments:					

Appendix E – E-BAM 1-Pt QC Form and Audit Form

ADEC - Air Quality
1-pt QC Report ~ E-BAM Monitor PM ____

Date:

Time: Site:

Last Audit:

Sampler Info	Sampler Type	EBAM	Recheck of Results after Corrections	Operator:
	M/N			
	Serial #			Criteria & Information
Clock Time & Date	Traceable Std:			±1 min of NIST-AST Time
	Sampler:			
	Difference:	0:00:00	Corrected Y/N	
Vacuum Leak Check	Flow Reading	slpm	slpm	< 1.5 L/min for basic leak check < 0.3 L/min for advanced leak check
Ambient Temperature	Traceable Std:	°C	°C	< ±2.1°C
	Sampler:	°C	°C	
	Difference:	0.0 °C	0.0 °C	
Barometric Pressure	Traceable Std:	mm Hg	mm Hg	< ±10.1 mm Hg
	Sampler:	mm Hg	mm Hg	
	Difference:	0.0 mm Hg	0.0 mm Hg	
Traceable Sampler Flow Check	Traceable Std:	lpm	lpm	Reference Std make & S/N
	Sampler:	lpm	lpm	Cert. Date ____ Exp. Date ____
	% Difference from **Q** act	%	%	Accuracy: % Δ < ±4.1%
	% Difference from Design	%	%	Design Condition: % Δ < ±5.1%

Maintenance Items Date: ____________

- [ ] 1: Inspect/clean: PM10 Inlet & Seals
- [ ] 2: Inspect/clean: Nozzle & Vane
- [ ] 3: Inspect/clean: Capstan & Pinch Roller
- [ ] 4: Inspect Nozzle & Tape for Burrs & Holes
- [ ] 9: Installed New Tape Roll
- [ ] 5: Inspect/clean: VSCC/SCC (PM2.5)
- [ ] 6: Cleaned Compartment
- [ ] 7: Inspect/clean: AC Filter & Heat Exchanger Fins
- [ ] 8: Tape Self Test Passed

Notes:

ADEC - Air Quality
Audit Report ~ E-BAM Monitor PM ____

Date:

Time: Site:

Last Audit:

Sampler Info	Sampler Type	EBAM	Recheck of Results after Corrections	Operator:
	M/N			
	Serial #			Criteria & Information
Clock Time & Date	Traceable Std:			±1 min of NIST-AST Time
	Sampler:			
	Difference:	0:00:00	Corrected Y/N ☐	
Vacuum Leak Check	Flow Reading	slpm	slpm	< 1.5 L/min for basic leak check < 0.3 L/min for advanced leak check
Ambient Temperature	Traceable Std:	°C	°C	< ±2.1°C
	Sampler:	°C	°C	
	Difference:	0.0 °C	0.0 °C	
Barometric Pressure	Traceable Std:	mm Hg	mm Hg	< ±10.1 mm Hg
	Sampler:	mm Hg	mm Hg	
	Difference:	0.0 mm Hg	0.0 mm Hg	
Traceable Sampler Flow Check	Traceable Std:	lpm	lpm	Reference Std make & S/N
	Sampler:	lpm	lpm	Cert. Date ____ Exp. Date ____
	% Difference from **Q** act	%	%	Accuracy: % Δ < ±4.1%
	% Difference from Design	%	%	Design Condition: % Δ < ±5.1%

Maintenance Items Date: ____________

- ☐ 1: Inspect/clean: PM10 Inlet & Seals
- ☐ 2: Inspect/clean: Nozzle & Vane
- ☐ 3: Inspect/clean: Capstan & Pinch Roller
- ☐ 4: Inspect Nozzle & Tape for Burrs & Holes
- ☐ 9: Installed New Tape Roll
- ☐ 5: Inspect/clean: VSCC/SCC (PM2.5)
- ☐ 6: Cleaned Compartment
- ☐ 7: Inspect/clean: AC Filter & Heat Exchanger Fins
- ☐ 8: Tape Self Test Passed

Notes: