

E-BAM PARTICULATE MONITOR OPERATION MANUAL

E-BAM-9800 REV P



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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.

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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 PM₁₀ 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 ¹⁴C (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 $60 \mu\text{Ci} \pm 15 \mu\text{Ci}$ (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 $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$, PM_{10} , or TSP monitoring:	yes	yes
Compatible with EPA PM_{10} inlets, cyclones, and WINS impactors:	yes	yes
U.S. EPA $\text{PM}_{2.5}$ 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/m ³ (-5 to 65,530 µg/m ³) 16 bit digital range.
Accuracy:	± 10% of indicated value for hourly measurements.
Data Resolution:	1 µg/m ³
Lower Detection Limit:† (2σ, 1 hour measurement)	Less than 6.0 µg/m ³
Lower Detection Limit:† (2σ, 24 hour average)	Less than 1.2 µg/m ³
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 10 ⁶ 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/m ³ . 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).

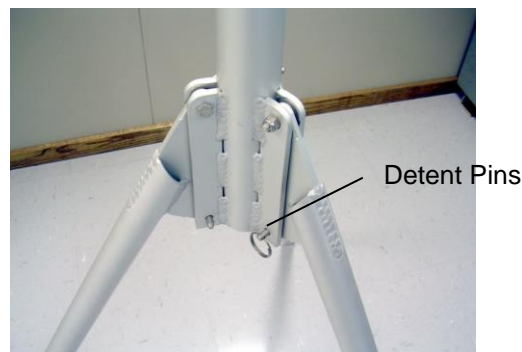
2 E-BAM UNIT ASSEMBLY AND START-UP

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

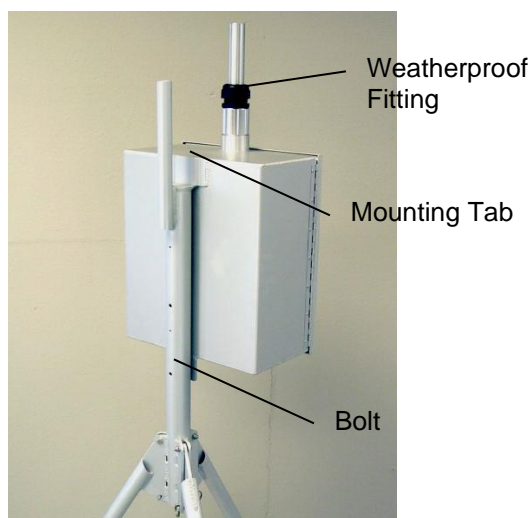
2.1 Assembling the E-BAM

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.



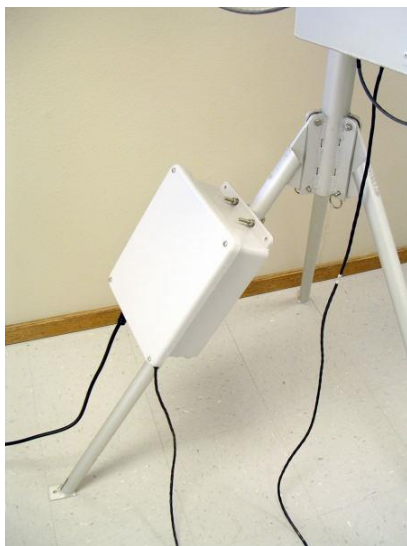
2. **Install the E-BAM onto the tripod:** Lift the E-BAM assembly and slide the slot on the back of the E-BAM over the tab on the top of the tripod. Insert the supplied $\frac{1}{4}$ -20 bolt through the tab on the bottom of the E-BAM and through the hole in the body of the tripod. Secure it with the supplied washers and nut. This prevents the E-BAM from shifting on the tripod.
3. **Install the inlet tube and the PM₁₀ 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 PM₁₀ monitoring, install the BX-802 PM₁₀ 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 PM₁₀ 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 $\frac{3}{4}$ " x $\frac{3}{4}$ " 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-15VDC 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.

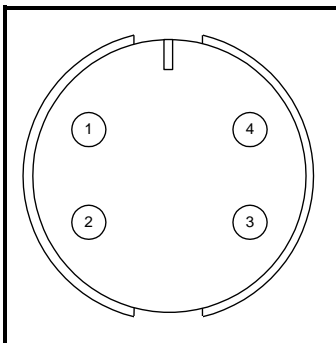
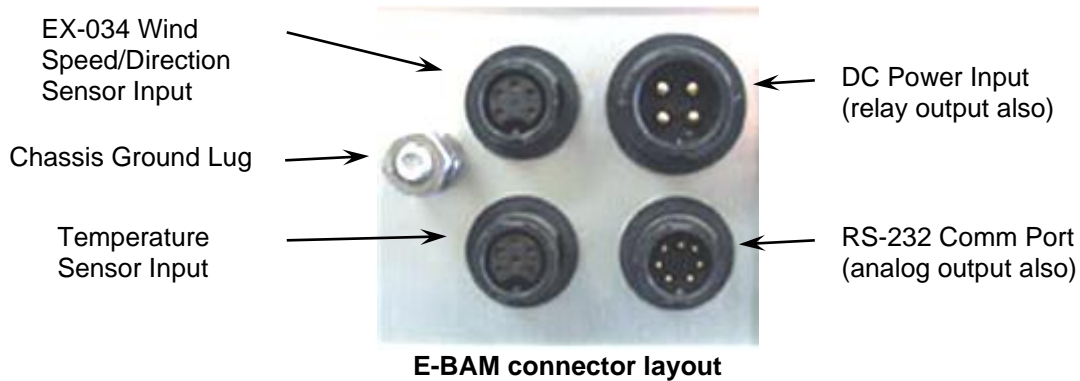


7. **Optional met sensors:** If the E-BAM is supplied with other optional met sensors such as ambient RH or barometric sensors, then these attach to the cross-arm and plug into the same connector as the temperature sensor, using a supplied splitter junction box.

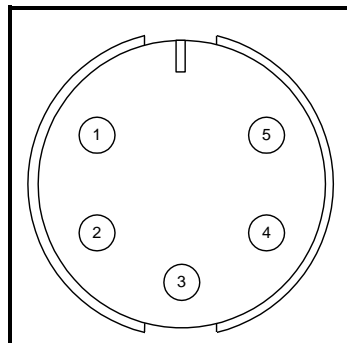
2.2 Electrical Connections

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.

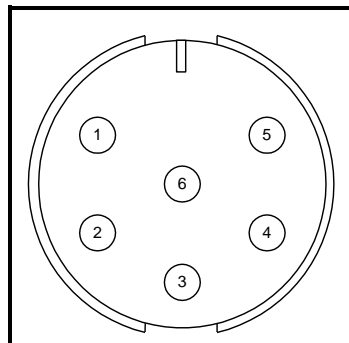
The E-BAM chassis ground lug should be connected to an earth ground whenever possible, to reduce electrical noise in the unit.



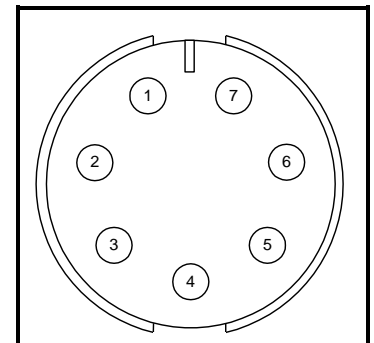
DC Power Input	
Pin	Function
1	+12-16VDC Power Input
2	Ground/Common
3	Alarm Relay IN
4	Alarm Relay OUT



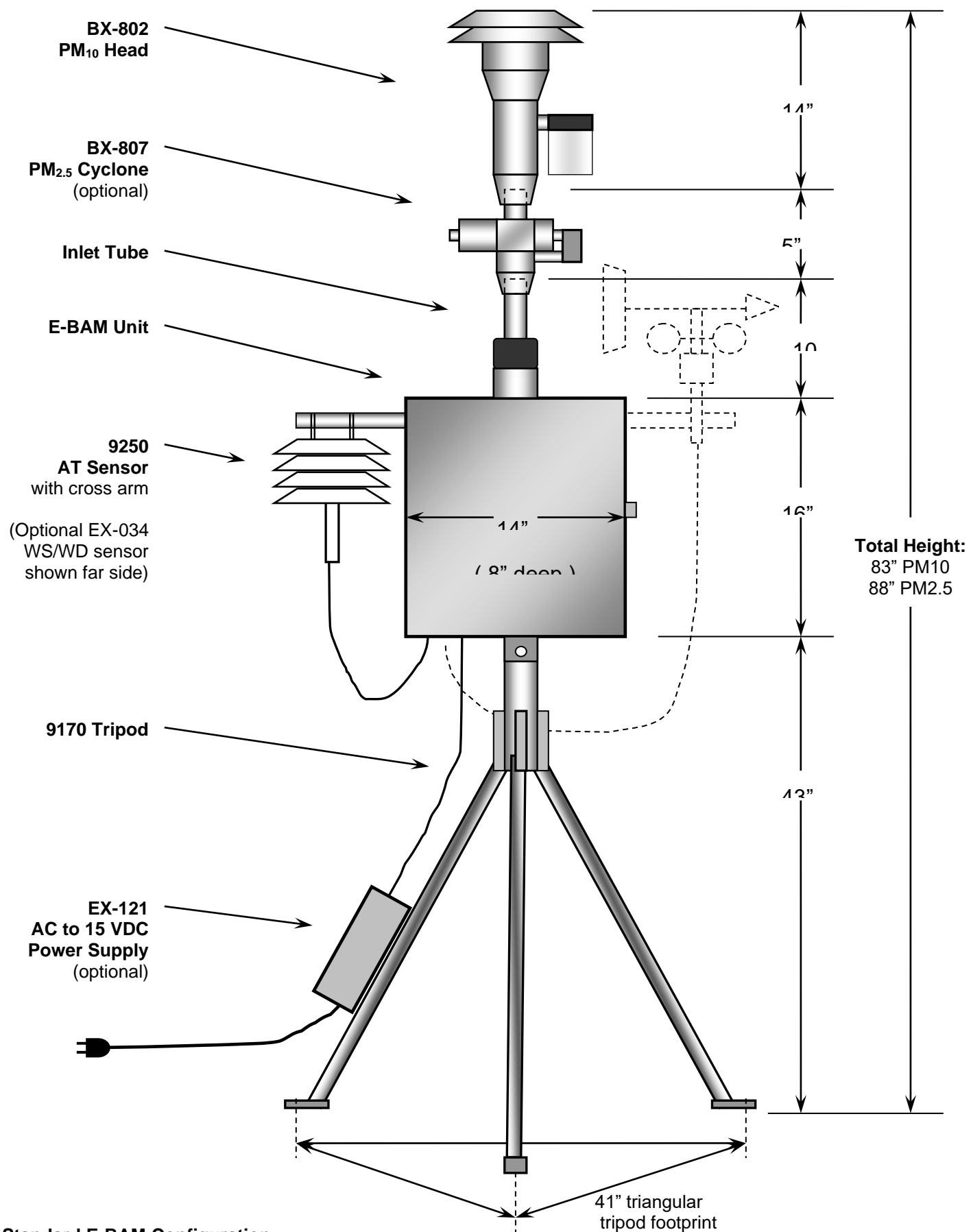
WS/WD Sensor In	
Pin	Function
1	Wind Direction Ref.
2	Ground/Common
3	Wind Direction Input
4	Wind Speed Input
5	Shield



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.

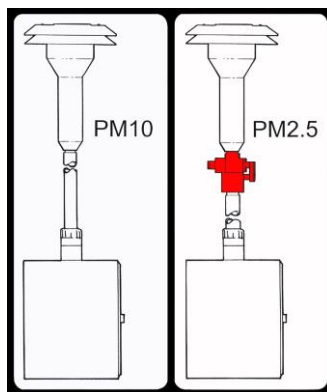
After the real-time settings are verified, the E-BAM will go on to display the MACHINE TYPE screen. Press EDIT to change the setting with the arrow keys, or press OK to go on without changes:

```

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 PM₁₀. *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 PM₁₀. 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

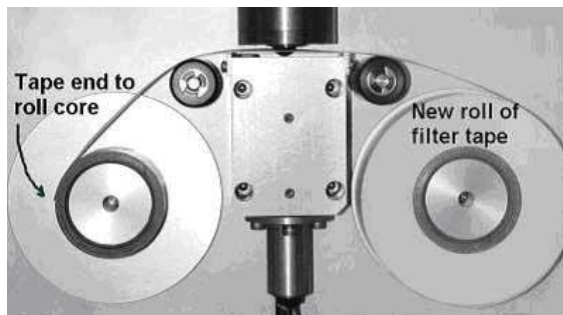
WARNING
START OPERATION?
MENU YES

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

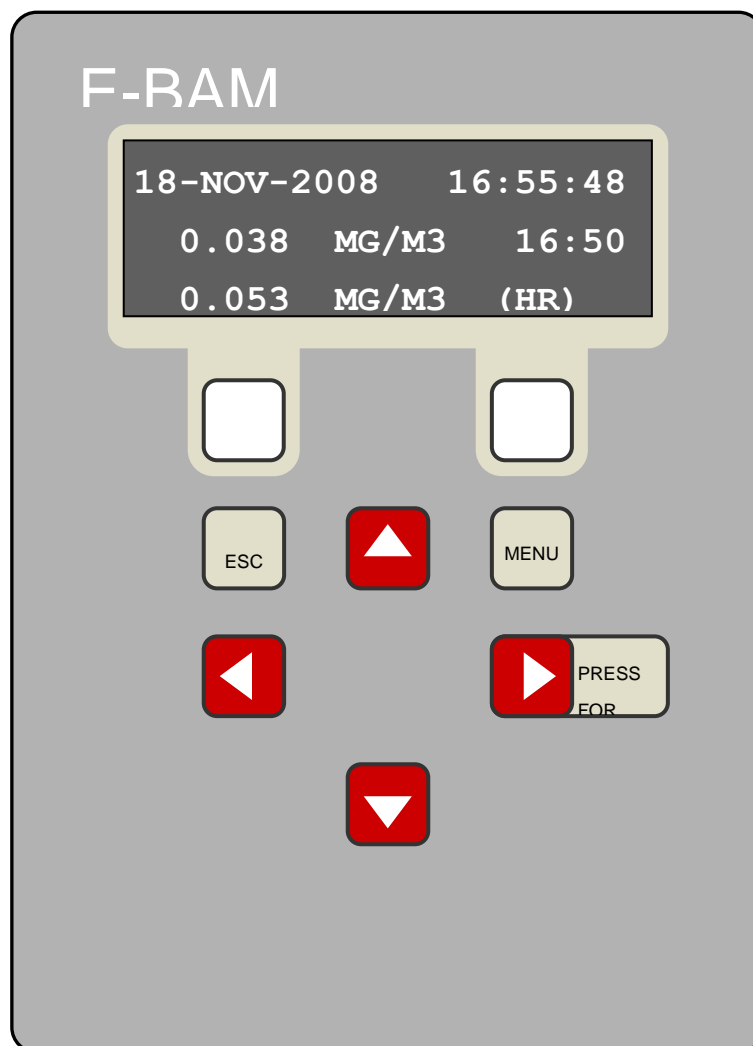
This section describes the E-BAM user interface system, and describes the functions of the main menu options, including how to view data and errors.

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.

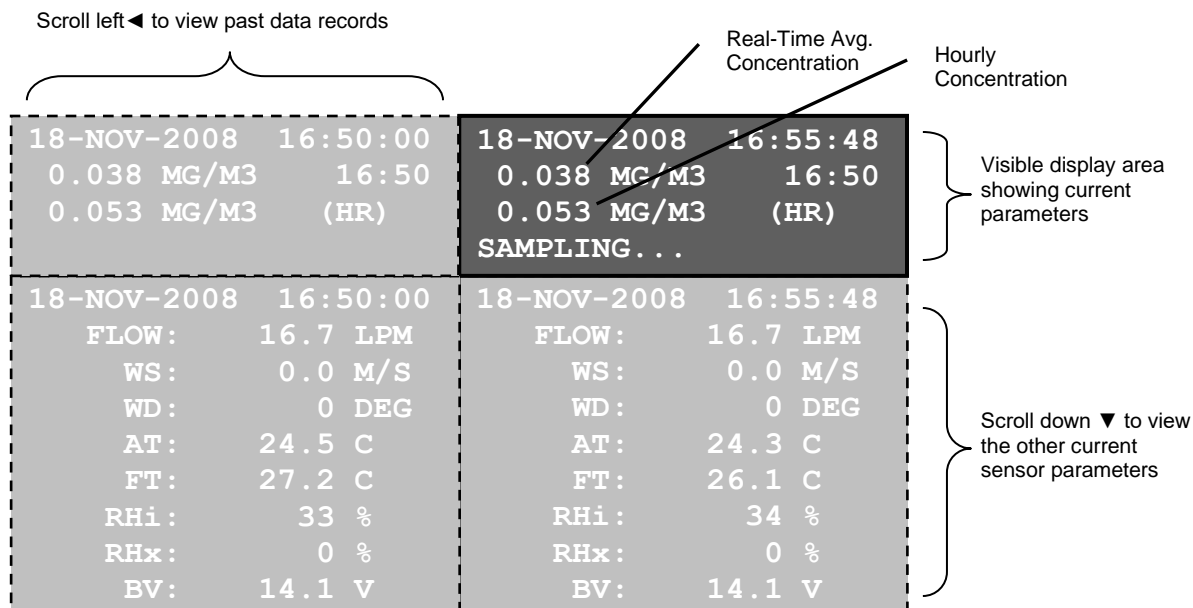


E-BAM User Interface

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.



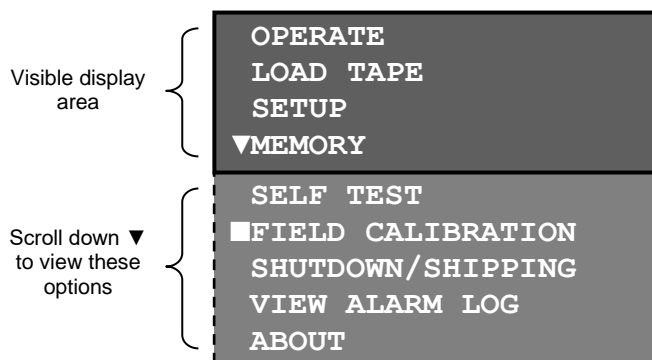
Main Sampling Screen Format

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.



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

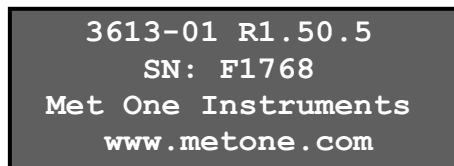
SELF TEST: This menu option starts the E-BAM on an automatic self-test cycle, just like the self-test it performs when powered on. Press the ESC key to escape from the self-test and return to the main menu.

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.

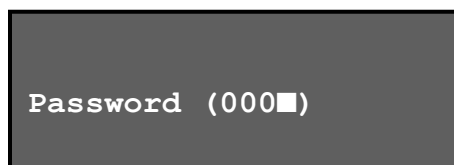
VIEW ALARM LOG: This menu option allows you to quickly view the error log entries in the E-BAM without having to download the digital data. The screen will display the type or error, as well as the time and date when the error occurred. Scroll through the error records using the ◀▶ arrow keys. Press 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 PM₁₀ 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 PM₁₀ 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:

$$((110\text{Ah} / 4.1\text{A}) * .67) = \mathbf{18.0} \text{ hours of run time per battery.}$$

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:

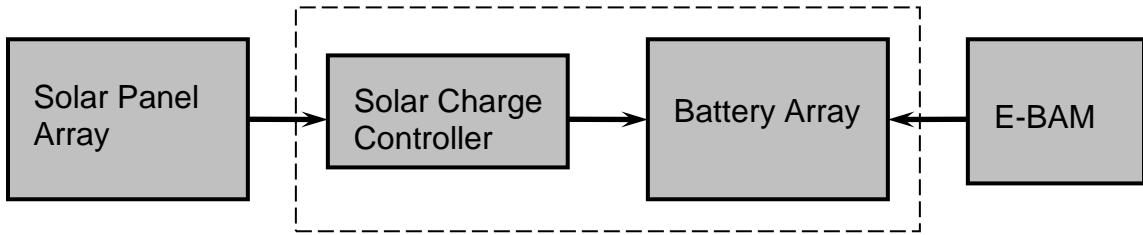
Some remote applications require operating the E-BAM with a solar array. Care must be taken to ensure that the solar array is designed correctly, and is specified to meet the power requirements of the unit. Many people greatly underestimate the amount of solar wattage required to run a particular load 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.

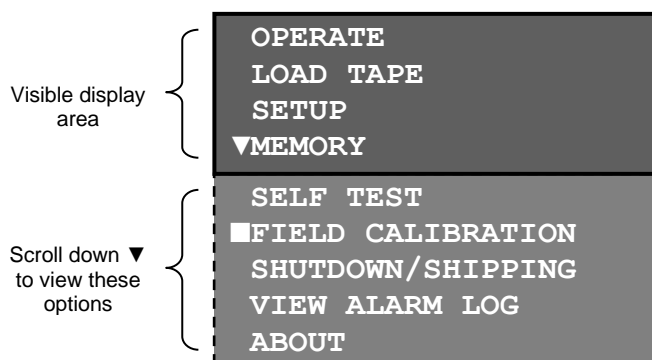
A solar array for the E-BAM tends to end up being fairly large, heavy, and expensive. It is usually easiest and cheapest to contact your local solar shop for help in building the array. You may also contact a service representative at Met One for assistance. Met One Instruments can also supply complete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



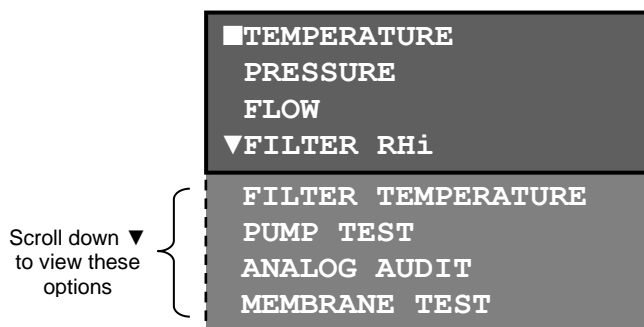
Simplified E-BAM Solar System Block Diagram

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 PM₁₀ 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 PM₁₀ 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:

$$\text{WithoutTape} - \text{WithTape} = \text{LeakRate}$$

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.**

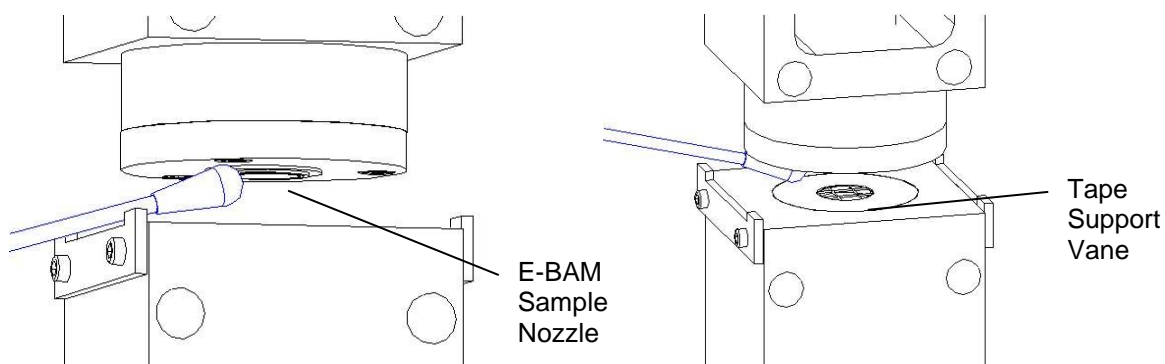
The 1.5 lpm leak check allowance is due to the test conditions. With the inlet shut off, the vacuum in the flow system is several times greater than during normal sampling, which exaggerates any leaks. If the leak reading during this test is less than 1.5 lpm, there should not be a significant leak during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

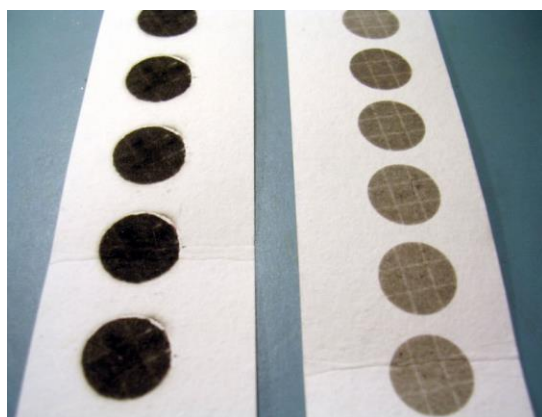
The nozzle and vane (located under the tape) must be cleaned regularly to prevent leaks and measurement errors. The cleaning must be done at least each time the filter tape is changed, though monthly cleaning is highly recommended. Some sites will require more frequent cleaning as determined by the site 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.

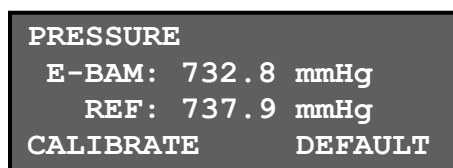
The E-BAM parameter is the instantaneous output from the unit’s ambient temperature sensor. This is the parameter that you are auditing.

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
```

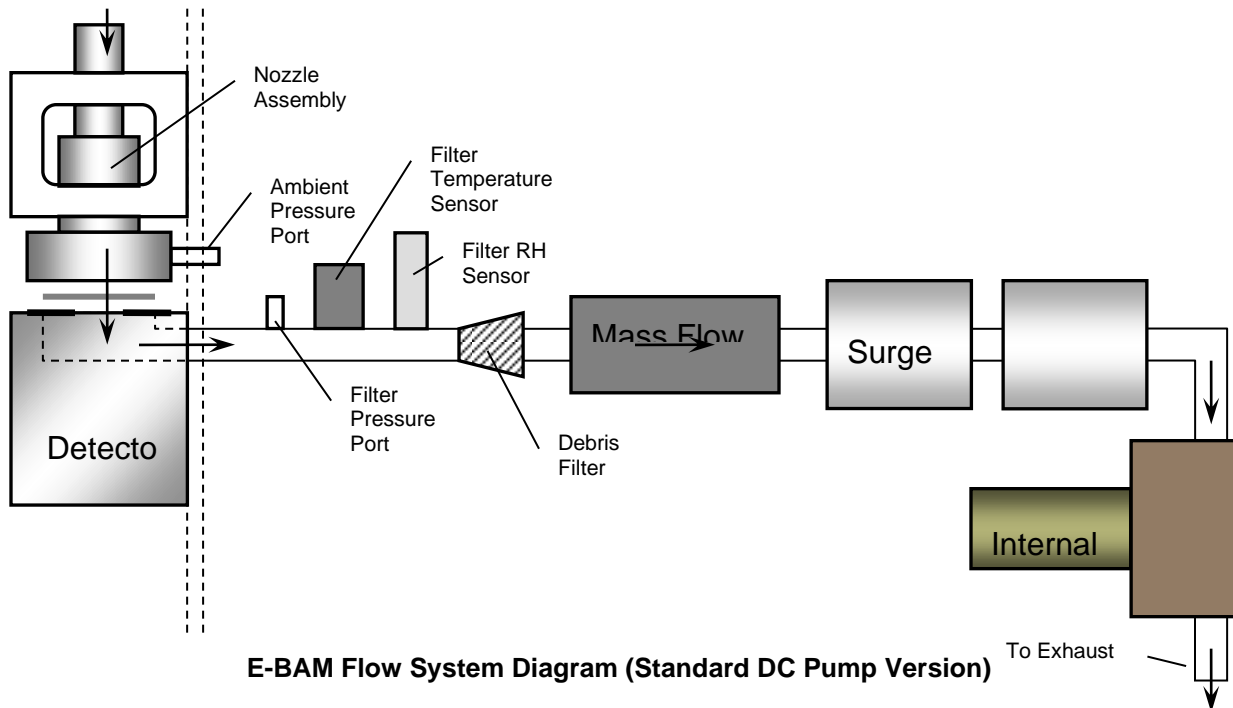
The E-BAM parameter is the instantaneous output from the unit's ambient barometric pressure sensor. This is the parameter that you are auditing.

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 PM₁₀ 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.



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 (Q_s) and ACTUAL (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 (Q_s) using a formula:

$$Q_s = Q_a * (P_a / T_a) * (298 / 760)$$

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 RH (RH internal) line and press the MENU/SELECT key to enter the filter RH sensor calibration menu:

```
FILTER RH
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 $\pm 4\%$ 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 PM₁₀ 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.

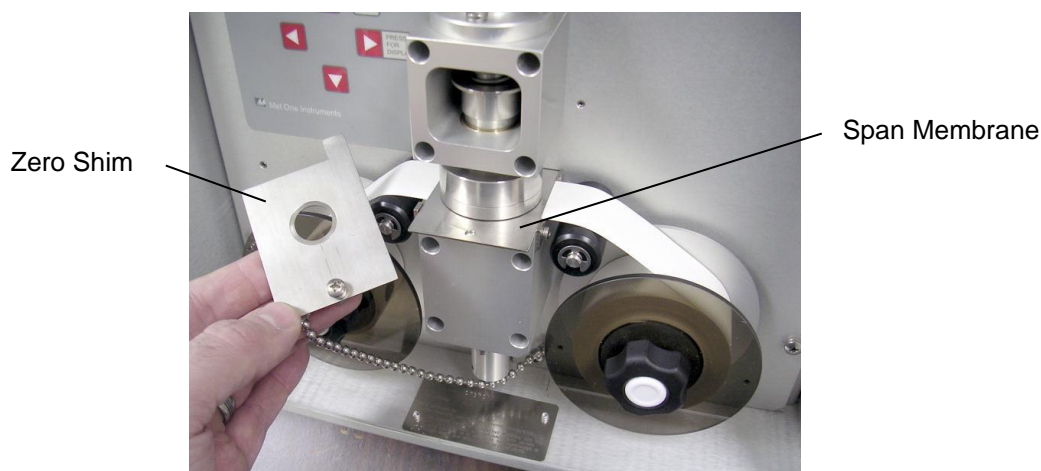
Notes About the Analog Output Tests: Only a high quality voltmeter should be used for this test. Cheap voltmeters usually do not give accurate measurements at millivolt levels. The E-BAM analog output should also be checked with the external datalogger connected, in order to make sure that the logger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

<p>INSERT SPAN MEMBRANE</p> <p>CANCEL</p>	<p>CAL SPAN COUNT</p> <p>■■■■ 184</p> <p>CANCEL</p>	<p>MEMBRANE TEST RESULT</p> <p>SPAN MEMBRANE: PASS</p> <p>OK</p>
---	---	--

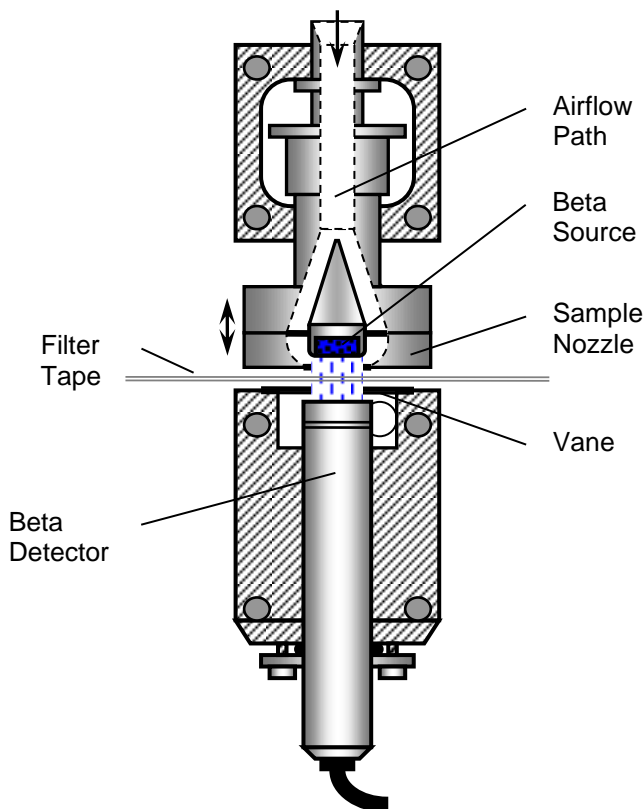
This is a pass/fail test in which the E-BAM will compare the measured mass of the span membrane to the expected mass (ABS) for that exact foil which has been programmed into the E-BAM memory. See Section 7.12. If the measured and expected values are within 5%, the test will pass. If the values are outside 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.

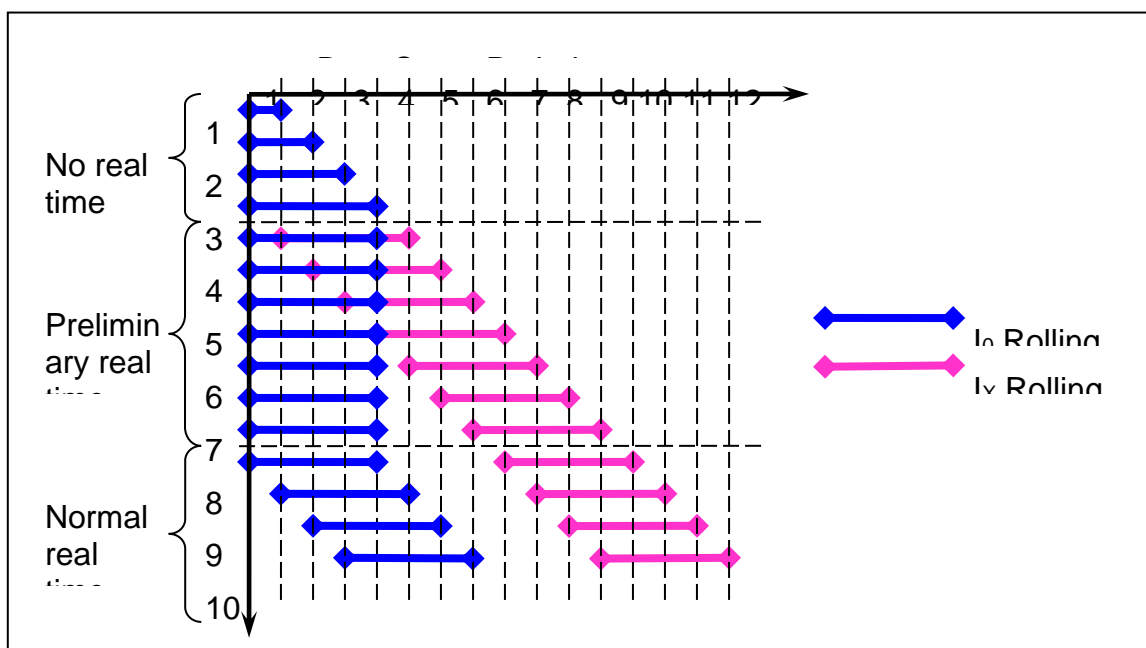
Several factors conspire to make real-time beta measurement difficult. First, very little particulate is deposited on the filter tape in such a short time, resulting in a poor signal-to-noise ratio except in high concentrations. Second, very little air is sampled in such a short time, increasing the 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 I_0 rolling average (minute 4) and the end of the I_x 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.

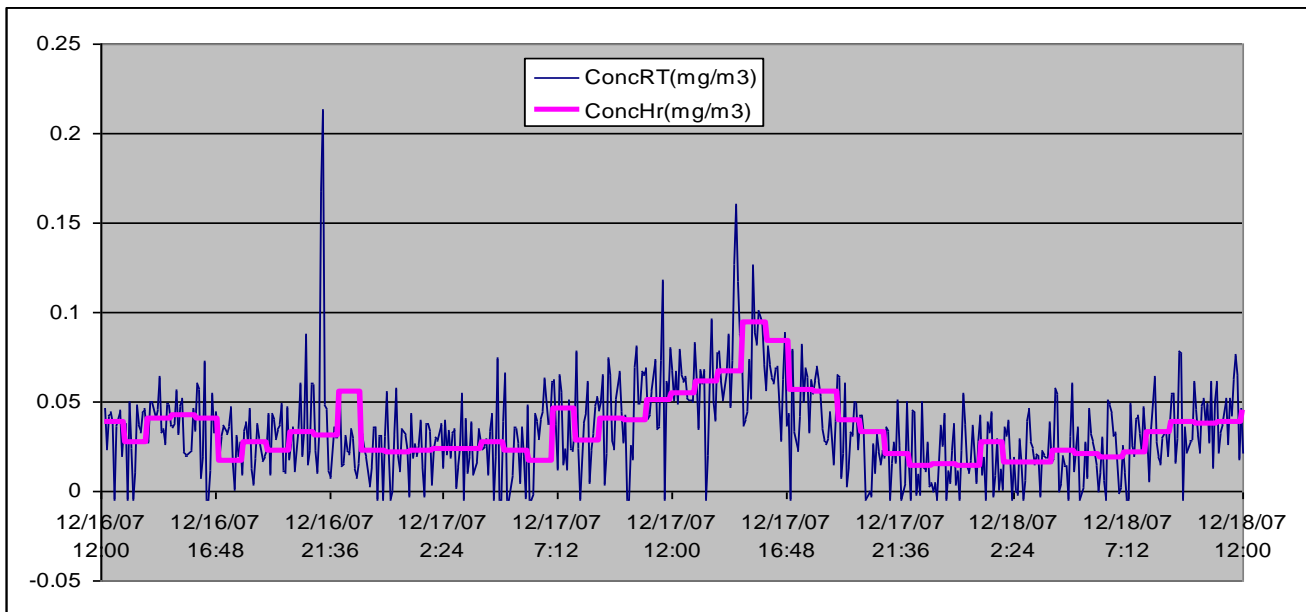


The table below shows the relationship between the I₀ and I_x four minute rolling average counts, the 60-second raw real-time concentration values, and the resulting real-time averages. Notice how the real-time values load up after the tape advance as described above. In this example, after fifteen minutes 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.

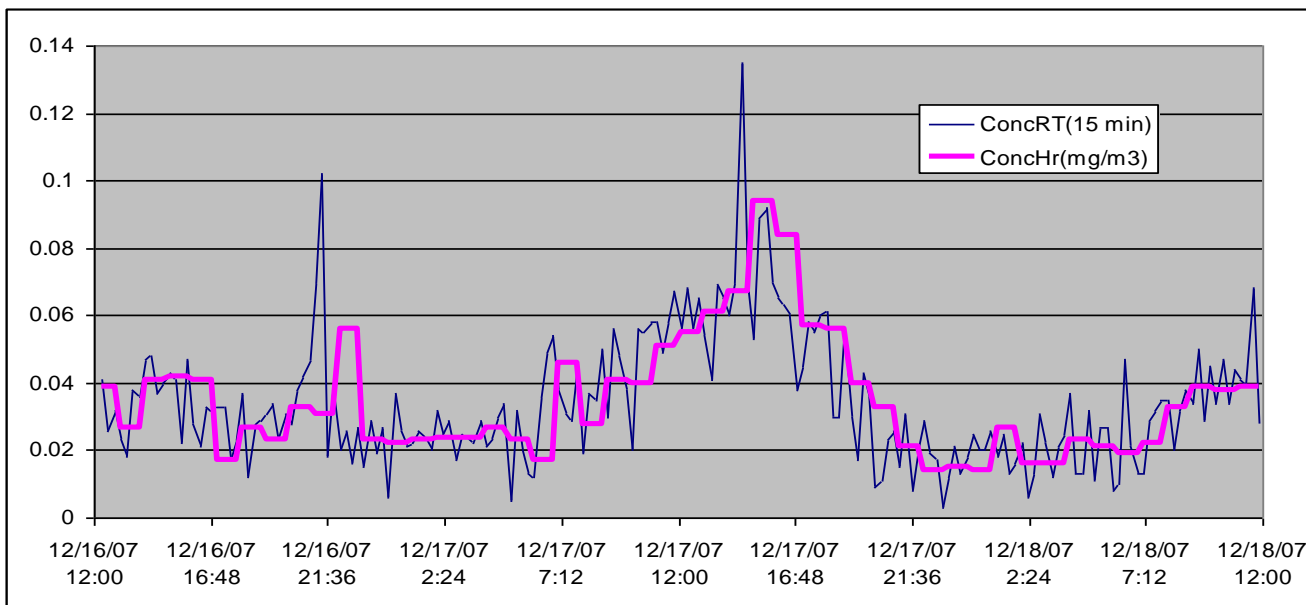
	Real-Time	Real-Time	Real-Time	15-Min
	I ₀	I _x	60-sec Conc	RT Average
Minute	Minutes	Minutes	mg/m3	mg/m3
1	---	---	None	---
2	---	---	None	---
3	---	---	None	---
4	1-4	---	None	---
5	1-4	2-5	preliminary	---
6	1-4	3-6	preliminary	---
7	1-4	4-7	preliminary	---
8	1-4	5-8	preliminary	---
9	1-4	6-9	preliminary	---
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 PM₁₀/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 PM₁₀. *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 PM₁₀. 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/m³ concentration on the output. **Note:** The analog output concentration range is always 0.000 to 1.000 mg/m³ regardless of the full scale voltage setting. Concentration values higher than this range must be downloaded from the digital data file.

MODE sets whether 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 PM₁₀ 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 PM₁₀ 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:

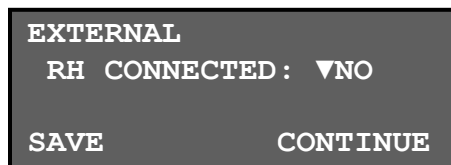
ACTUAL (volumetric) flow type is the most accurate flow control mode, and is required for all PM_{2.5} monitoring. The actual flow type is also the easiest and fastest to calibrate and audit. The unit uses actual ambient air temperature and barometric pressure to calculate the flow rate, and the flow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

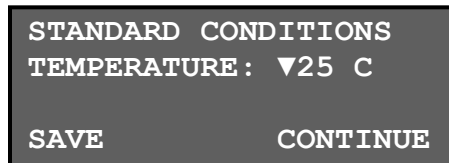


```
MINIMUM RESTART
VOLTAGE: 12.0V

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.

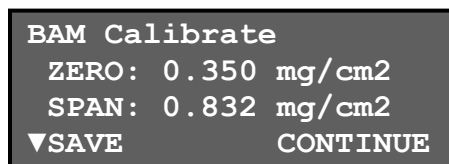


```
STANDARD CONDITIONS
TEMPERATURE: ▼25 C

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/cm². 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/cm². 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	<p>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.</p> <p>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.</p>
INTERNAL HARDWARE	<p>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.</p>
NOZZLE FAILED UP or NOZZLE FAILED DOWN	<p>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.</p>
SHIPPING DEVICE INSERTED	<p>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.</p>
TAPE BROKE	<p>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.</p>

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 (%), RHl (%), 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:	<ul style="list-style-type: none"> • 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:	<ul style="list-style-type: none"> • 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:	<ul style="list-style-type: none"> • 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:	<ul style="list-style-type: none"> • 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:	<ul style="list-style-type: none"> • 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 <u>do</u> have a flow controller inside the pump box.

	<ul style="list-style-type: none"> • 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.
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Problem:	The nozzle gets stuck in the UP position, or won't press down onto the tape fully.
Cause/Solution:	<ul style="list-style-type: none"> • 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:	<ul style="list-style-type: none"> • 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:	<ul style="list-style-type: none"> • 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 RH_i 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 <u>analog output</u> 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:	<ul style="list-style-type: none"> • 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:	<ul style="list-style-type: none"> • 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.

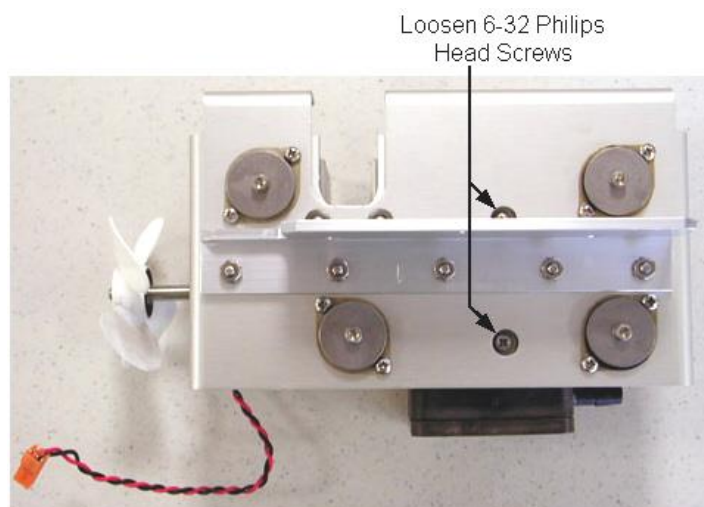
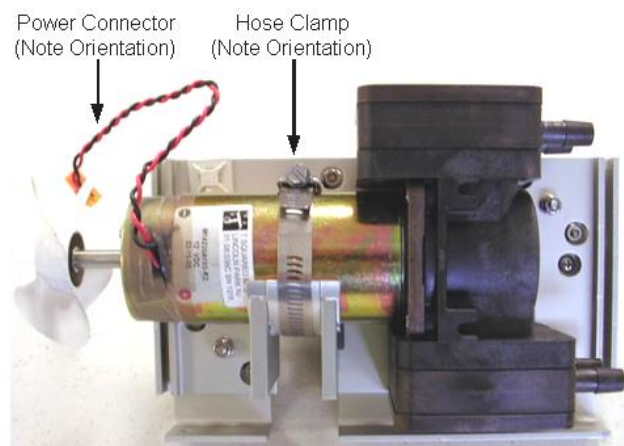
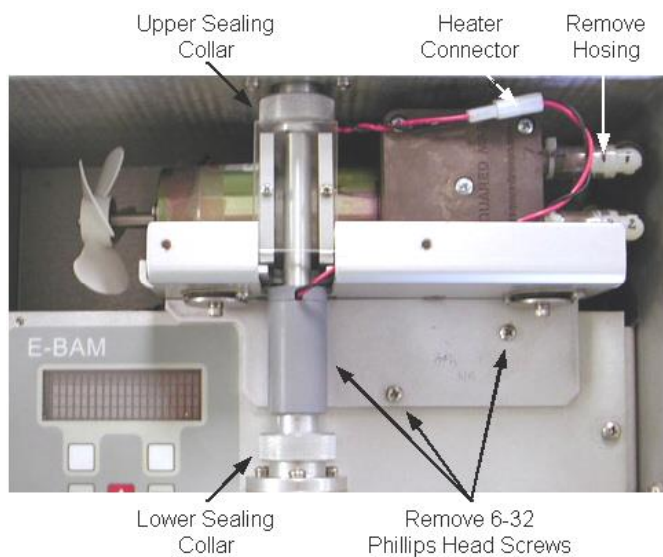
Maintenance Item	Suggested Period
Replace the filter tape (depends on the TAPE ADVANCE setting)	As needed
Leak check	Monthly
Nozzle and tape vane cleaning	Monthly
Flow audit (and calibration if needed) including ambient temperature and pressure	Monthly
Clean PM10 inlet particle trap	Monthly
Clean PM2.5 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

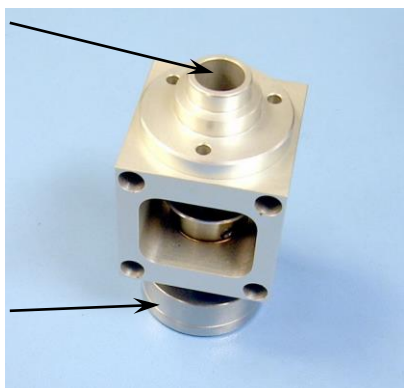
8.6 Cleaning the Inside of the Sample Nozzle Assembly

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.**

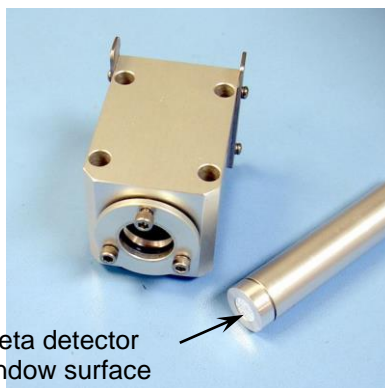
1. Advance the filter tape to a fresh spot.
2. Remove the pump cover plate, clear heater cover, and sample tube/heater assembly as described above for pump removal. You now have access to the top of the nozzle assembly.
3. Use a can of dusting air with a long plastic nozzle to blow through the nozzle 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.

Blow air here to
clean inside the
nozzle assembly



Do not
disassemble the
sample nozzle



Beta detector
window surface

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 off 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.

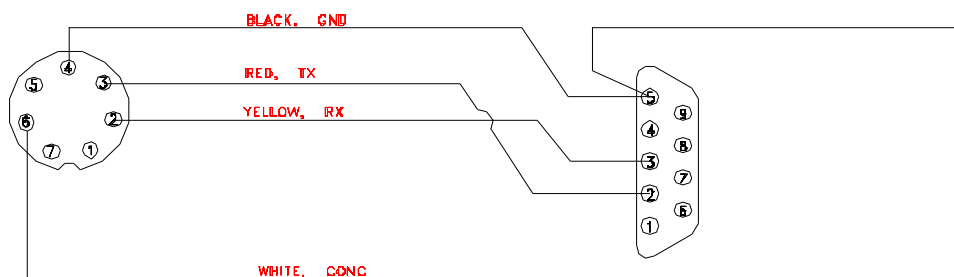
Note: Units which have the older style detector window can be factory upgraded with the new style detector, if the unit is located in an environment where frequent detector fouling is encountered. Contact the Service Department for details.

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 (%) ,RHl (%) ,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 (%) ,RHl (%) ,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 °C.
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 °C.
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.

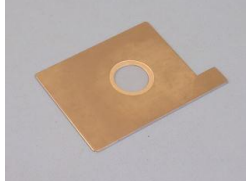



10 ACCESSORIES and PARTS

10.1 Consumables, Replacement Parts, and Accessories

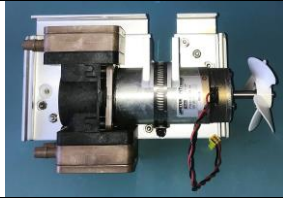

The following parts are available from Met One for maintenance, replacement, service, and upgrades. If unsure about a part you need, please contact the Service department. Some of these parts require technical skills or special considerations before use or installation.

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

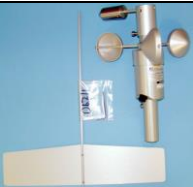


E-BAM Internal DC Pump Replacement Assembly	8967	
Pump Cover, Sheet Metal	9233	
Pump Purge Tank Filter, 2 per unit	580255	
Flow Sensor, Mass, 0-20 LPM, Internal Assembly	80425	
Filter RH Sensor, Replacement Only	8624	
Filter Temperature Sensor, Replacement Only	8131	
Flow Sensor Debris Filter, Sintered 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, $\frac{3}{4}$ " x $\frac{3}{4}$ ", 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, 110-120VAC input, 15VDC output, Weatherproof	EX-121	
Power Supply, E-BAM, 220-240VAC input, 15VDC output, Weatherproof	EX-122	

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 lose 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 must 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 ($\mu\text{g}/\text{m}^3$) with Equation 3.

Equation 3

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

In Equation 3, c is the ambient particulate concentration ($\mu\text{g}/\text{m}^3$), 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

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

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

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

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 $\pm 3\%$. For BAM-1020 units equipped with the mass flow controller device, (σ_Q/Q) decreases to $\pm 1\%$.

The relative error due to the uncertainty 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 $\pm 2\text{-}3\%$, 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_{I_0}/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 $27\mu\text{g}$ 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.

$$\begin{aligned} C_{amb} &= C_{std} * (P_{amb} / P_{std}) * (T_{std} / T_{amb}) \\ C_{amb} &= 27 * (720/760) * (298/303) \\ C_{amb} &= 27 * 0.9474 * 0.9835 \end{aligned}$$

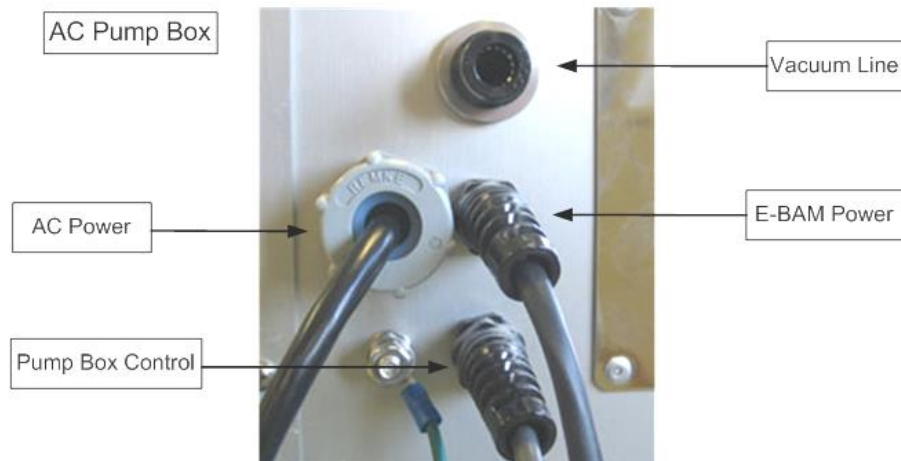
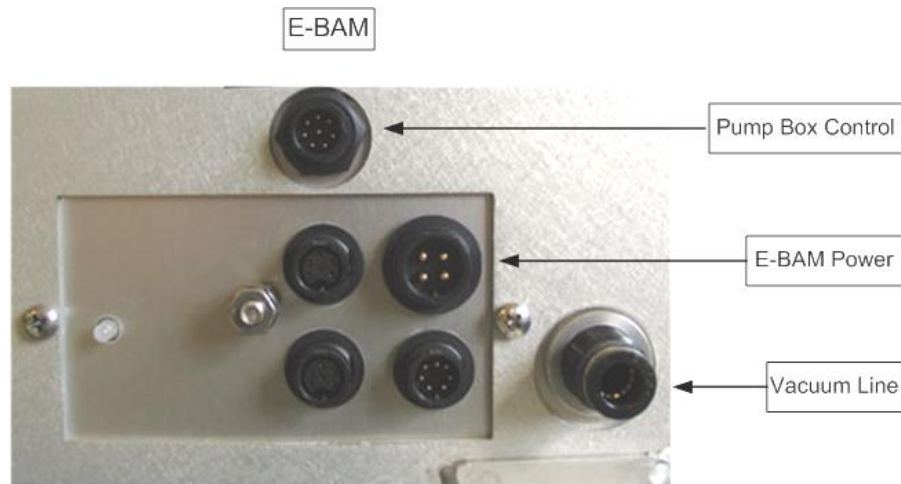
12 SPECIAL E-BAM CONFIGURATIONS

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 is 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 connector. 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: 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:	<input type="text" value="lpm"/>	as left:	<input type="text" value="lpm"/>
Ambient Temperature:	as found:	<input type="text" value="C"/>	as left:	<input type="text" value="C"/>
Barometric Pressure:	as found:	<input type="text" value="mmHg"/>	as left:	<input type="text" value="mmHg"/>
16.7 lpm Flow Rate (Actual):	as found:	<input type="text" value="lpm"/>	as left:	<input type="text" value="lpm"/>
16.7 lpm Flow Rate (Standard):	as found:	<input type="text" value="slpm"/>	as left:	<input type="text" value="slpm"/>

Mechanical Audits									
Sample nozzle clean:	as found	<input type="checkbox"/>	as left	<input type="checkbox"/>	PM10 particle trap clean:	as found	<input type="checkbox"/>	as left	<input type="checkbox"/>
Tape support vane clean:	as found	<input type="checkbox"/>	as left	<input type="checkbox"/>	PM10 drip jar empty:	as found	<input type="checkbox"/>	as left	<input type="checkbox"/>
Tape spool covers tight:	as found	<input type="checkbox"/>	as left	<input type="checkbox"/>	PM10 bug screen clear:	as found	<input type="checkbox"/>	as left	<input type="checkbox"/>
	as found	<input type="checkbox"/>	as left	<input type="checkbox"/>	PM2.5 particle trap clean:	as found	<input type="checkbox"/>	as left	<input type="checkbox"/>

Analog Voltage Output Audit		N/A	<input type="checkbox"/>
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):	<input type="text"/>
Measured Span Mass (mg/cm2):	<input type="text"/>
Difference (mg/cm2):	<input type="text"/>
% Difference:	<input type="text"/>

Pump Test	
Flow Setpoint	E-BAM Flow
14.0 lpm	<input type="text"/>
16.7 lpm	<input type="text"/>
17.5 lpm	<input type="text"/>

Setup and Calibration Values								
Parameter	Expected	Found	Parameter	Expected	Found	Parameter	Expected	Found
Clock	<input type="text"/>	<input type="text"/>	Analog Mode	<input type="text"/>	<input type="text"/>	Flow Type	<input type="text"/>	<input type="text"/>
Location	<input type="text"/>	<input type="text"/>	Baud Rate	<input type="text"/>	<input type="text"/>	Restart Voltage	<input type="text"/>	<input type="text"/>
Tape Advance	<input type="text"/>	<input type="text"/>	RH Setpoint	<input type="text"/>	<input type="text"/>	Std Cond Temp	<input type="text"/>	<input type="text"/>
Realtime Avg	<input type="text"/>	<input type="text"/>	Delta-T Setpoint	<input type="text"/>	<input type="text"/>			
Machine Type	<input type="text"/>	<input type="text"/>	RH Control	<input type="text"/>	<input type="text"/>			
Analog FS	<input type="text"/>	<input type="text"/>	Flow Setpoint	<input type="text"/>	<input type="text"/>			

Last 6 Errors in E-BAM Error Log					
Error	Date	Time	Error	Date	Time
1	<input type="text"/>	<input type="text"/>	4	<input type="text"/>	<input type="text"/>
2	<input type="text"/>	<input type="text"/>	5	<input type="text"/>	<input type="text"/>
3	<input type="text"/>	<input type="text"/>	6	<input type="text"/>	<input type="text"/>

Audit Notes:

OPERATOR NOTES:

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.