STANDARD OPERATING PROCEDURES

DRAFT VERSION, JANUARY 2005

FOR

MET ONE INSTRUMENTS
E-BAM
MASS MONITOR

AND

AIRSIS
AQEB-2000 TELEMETRY SYSTEM

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ACRONYMS

AC	alternating current
BAM	beta attenuation monitor
DC	direct current
$PM_{2.5}$	particulate matter with an aerodynamic diameter <2.5 μm
PM_{10}	particulate matter with an aerodynamic diameter <10 μm
PMT	photo multiplier tube
RH	relative humidity
SCC	sharp cut cyclone
SOP	standard operating procedure
TSP	total suspended particulate
TUS	terminal utility software

1.0 GENERAL INFORMATION

1.1 INTRODUCTION

The purpose of this draft Standard Operating Procedure (SOP) is to document the Met One E-BAM and the AIRSIS satellite modem procedures used by the U.S. EPA, state/local agencies, and federal land management agencies during wildfire emergency air monitoring episodes. The goal of this draft SOP is twofold:

- to formalize E-BAM installation, configuration, and operation procedures in order to ensure comparability among all E-BAM data

- to describe supplemental information and modifications to the Met One E-BAM Operation Manual necessary to successfully integrate the E-BAM at national air monitoring sites during wildfire events.

The Operation Manual[1] for Met One Instrument's E-BAM contains a significant source of information pertinent to the operation, maintenance, and understanding of this instrument. A thorough review of the E-BAM Operation Manual is recommended prior to use of the E-BAM.

1.2 PRINCIPLE OF OPERATION

The E-BAM is a portable real-time beta attenuation monitor (BAM) for automated $PM_{2.5}$ and PM_{10} measurement. The E-BAM is based upon the principle of beta attenuation, which is defined as the decrease in the number of beta particles due to absorption by a medium. The E-BAM uses ^{14}Carbon (^{14}C), a naturally occurring radioactive isotope, as the source for beta particles. Due to the low mass and low energy, beta particles can only travel a foot or two through the air and can be completely attenuated with a few sheets of notebook paper. It is this property of attenuation of beta particles that allows the measurement of mass.

In the E-BAM, a three-step process measures the mass of the suspended particulate matter. Step one is to make a first count of beta particles across a clean piece of filter paper. Next, the filter paper is advanced, particle-laden air is passed through the paper, and the particulate matter is deposited on the paper. In step three, the filter paper is moved back and a second count of beta particles is made across the filter paper with the deposited particulate matter. This second count will be less than the first count due to the absorption of beta particles by the deposited particulate matter. Knowing the volume of air sampled and the difference in the measured beta counts, some simple calculations can be made to determine the concentration of particulate matter in the sampled air, expressed in mass per unit volume.

1.3 SAFETY PRECAUTIONS

The following precautions should be followed when installing, operating, or performing maintenance on the E-BAM. Only properly trained personnel should perform E-BAM testing, installation, operation, maintenance and calibration procedures.

- As with all monitoring equipment, precautions should be taken when working around electricity, power tools, and at above ground-level elevations.

- The ^{14}C radioactive source should never be dismantled, removed, or tampered with. It will never be necessary for any field personnel to adjust, replace, or touch the ^{14}C source. All ^{14}C issues will be handled by the manufacturer.

- Operators should wear long sleeves and laboratory gloves when working with the E-BAM door open and in the immediate vicinity of the ^{14}C beta source, in order to reduce possible exposure to ^{14}C beta rays.

1.4 INTERFERENCES/LIMITATIONS

Moisture is the primary interference of concern when monitoring $PM_{2.5}$ using the E-BAM. To alleviate the effects of moisture on the E-BAM measurements, all Met One E-BAMs are equipped with a moisture-controlled inlet heater. The inlet heater is used to prevent condensation on the filter paper and is controlled through a feed-back loop using temperature and relative humidity sensors that are located downstream of the filter. The presence of condensation on the filter paper can result in a positive bias in the mass measurements. By heating the air stream in a controlled manner, condensation is avoided and proper mass measurements are calculated. The Met One E-BAM is equipped with a Smart Heater. **NOTE: Moisture entering and running down the inlet tube will not be dried using this heater; therefore, additional care must be taken to avoid moisture intrusion to the inlet tube. The use of the PM_{10} sampling inlet typically minimizes intrusion of water into the inlet.**

2.0 INSTALLATION PROCEDURE

The E-BAM installation procedure has been separated into the following four areas. Each area is described in further detail in Sections 2.1 through 2.4.

1. List of Tools and Supplies
2. Physical Inspection
3. Siting
4. Assembly

2.1 LIST OF TOOLS AND SUPPLIES

The following tools and supplies are needed for the installation, calibration, and operation of the E-BAM:

- Allen wrench
- Phillips head screw driver
- NIST-traceable flow audit device
- NIST-traceable temperature standard
- NIST-traceable barometric pressure standard for calibrations and/or audits.

2.2 PHYSICAL INSPECTION

Upon receipt of an E-BAM, inspect equipment and accessories for completeness and for shipping damage. If components are missing or damage is found, contact the Met One service department at service@metone.com or (541)471-7111.

List of E-BAM Components:

a. E-BAM Console
b. ambient temperature probe
c. inlet adaptor tube
d. tripod
e. communication cable

f. filter tape, 1 roll

g. E-BAM operation manual

h. PM_{10} head (BX-802)

i. cross arm support

j. TUS software

k. external power cable

l. zero calibration plate

m. span calibration plate

n. E-BAM calibration sheet.

The following options may also be included:

a. $PM_{2.5}$ sharp cut cyclone (SCC) (BX-807)

b. total suspended particulate (TSP) sampling head

c. BX-305 flow test inlet valve

d. battery 12 Volt DC

e. battery charger

f. AC power module.

2.3 SITING

The E-BAM monitor has specific physical requirements that should be considered prior to installation. In addition, all E-BAM monitors (TSP, PM_{10}, and $PM_{2.5}$), should be deployed using the same regulatory requirements to ensure data continuity. More detailed information about instrument siting can be found in the U.S. EPA Document EPA-450/4-87-007, May 1987, "Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)." Information specific to PM_{10} and $PM_{2.5}$ monitoring can also be found in the U.S. EPA Document 40 CFR part 58, Appendix E.

The standard configuration of the E-BAM is a self-contained aluminum weatherproof enclosure placed on a tripod. This system can be permanently installed on rooftops, near roads, industrial sites, or deployed rapidly to monitor emergency situations.

The E-BAM monitor can be and should be readily assembled in the area where the aerosol is to be sampled. Transportation of the E-BAM when it is assembled is not recommended. The most desirable height for TSP and PM_{10} monitoring is near the breathing zone. However, practical considerations, such as prevention of vandalism, security, accessibility, and availability of electricity, generally require the sampler to be elevated. Therefore, a range of acceptable heights will need to be used. In addition, the type of source (i.e., elevated or ground level) predominantly influencing the area of impact must be considered when locating the monitor. For purposes of determining elevated source impact, the sample air intake must be located 2 to 15 meters above ground level. For ground-level sources with steep vertical concentration gradients, the air intake must be as close to the breathing zone as practical.

<u>NOTE</u>: Whenever the E-BAM is to be installed at a height greater than 3 meters, it is recommended that it be securely bolted in place. If the E-BAM is accidentally dropped from a height greater than 3 meters, there is a chance that containment of the radioactive source may be compromised. If this occurs, it is highly recommended that the E-BAM be sent back to the factory for radiation leak testing.

In general, when selecting the location for the E-BAM monitor, it may help to consider the following items:

1. ***Spacing from Obstructions***: If the sampler is located on a roof or other structure, there must be a minimum of 2 meters of separation from walls, parapets, penthouses, etc. Trees provide surfaces for particulate deposition and also restrict airflow; therefore, the sampler should be placed at least 20 meters from the drip line of trees. Obstacles, such as buildings, also must be avoided so that the distance between obstacles and the sampler is at least twice the height that the obstacle protrudes above the sampler. In addition, there must be unrestricted airflow in an arc of at least 270 degrees around the sampler, and the predominant direction for the season of greatest pollutant concentration potential must be included in the 270 degree arc.

2. ***Spacing from Roads*:** Ambient monitors for TSP and PM_{10} should be located beyond the concentrated particulate matter plume generated by traffic, and not so close that the heavier re-entrained roadway particles totally dominate the measured ambient concentration. Roads with lower traffic (less than approximately 3,000 vehicles per day) are generally not considered to be a major source of vehicular-related pollutants. In this case, the monitor must be located greater than 5 meters from the edge of the nearest traffic lane and 2 to 15 meters above ground level. In the case of elevated roadways where the monitor must be placed below the level of the roadway, the monitor should be located no closer than approximately 25 meters from the edge of the nearest traffic lane. This separation distance applies for those situations where the road is elevated greater than 5 meters above the ground level and applies to all traffic volumes.

The E-BAM should not be installed in an unpaved area unless there is vegetative ground cover year around so that the impact of re-entrained or fugitive dusts will be kept to a minimum.

2.4 ASSEMBLY

Figure 2.1 illustrates the E-BAM setup assembly. The six basic steps to assembling the E-BAM monitor are given below:

1. Assemble tripod:
   - 1.1 Lift the tripod and remove the three lock pins.
   - 1.2 Spread the tripod legs and re-insert the three lock pins.
   - 1.3 If the E-BAM is to be used under conditions that require additional stability, the tripod may be bolted to a firm surface using the 1/4-inch holes in the tripod feet.

2. Install E-BAM cabinet:
   - 2.1 Lift up the E-BAM enclosure with the aerosol inlet oriented upwards.
   - 2.2 Slide the slot on the back of the cabinet down over the tab on top of the tripod.
   - 2.3 Attach the bottom of the cabinet to the tripod using the 1/4-inch nut and bolt provided.

3. Install E-BAM inlet adaptor tube:
   - 3.1 Remove the plastic end caps from the inlet adaptor tube and push the tube into the E-BAM inlet. It must go through two O-rings so push and twist it all the way in until it stops.
   - 3.2 Hand-tighten the large black lock screw located at the top of the E-BAM enclosure.

4. Install $PM_{2.5}$ and PM_{10} inlet:
   - 4.1 Push the $PM_{2.5}$ sampling inlet onto the inlet adaptor tube. It must go through an O-ring seal so push and twist it all the way in until it stops. **NOTE: The O-rings are factory lubricated, but with frequent removal/replacement they will need to be re-lubricated with silicone O-ring grease.**
   - 4.2 Push the PM_{10} sampling inlet onto the $PM_{2.5}$ inlet. It must go through an O-ring seal so push and twist it all the way in until it stops. **NOTE: The O-rings are factory lubricated, but with frequent removal/replacement they will need to be re-lubricated with silicone O-ring grease.**

5. Install cross arm and temperature sensors:
    5.1 Install the cross arm on the pipe at the top of the tripod and tighten the two Allen screws.
    5.2 Clip the temperature sensor onto one arm of the tripod, and plug the signal cable into the 5-pin plug under the cabinet.
    5.3 Attach any accessory sensors to the other arm of the cross arm.

6. Connect the power source. **NOTE: The standard E-BAM is supplied without a power source. However, several options exist for supplying power to the E-BAM. The selection and acquisition of an appropriate power source should be made prior to field deployment. The use of a solar panel may be particularly attractive in remote locations where long-term monitoring may be conducted. The power requirements for the E-BAM are 11-16 Volts DC at 3 amps continuous during operation but must also be able to provide 10 amps during the initial start up of the pump. These requirements mean the E-BAM can be operated off a standard 12 Volt DC battery or off an AC power source using an AC to DC converter.**

    If a reliable source of 110 Volt AC power is available, it is recommended that this source be used to power the E-BAM.
    6.1 Locate the 110 Volt AC power cord configured with an AC to DC converter. This cord has a standard 110 Volt AC plug on one end and a six-pin connector that fits into a matching socket on the bottom of the E-BAM as depicted in Figure 2.2.
    6.2 Connect the power cord to the power source and to the E-BAM.

    If no source of 110 Volt AC power is available, any 12 Volt DC power source, such as a car battery, can be used to power the E-BAM.
    6.2.1 Locate the external power cable that has a six-wire connector on one end and four terminated wires at the other end.
    6.2.2 Connect the red wire with a terminal lug to the positive pole of the battery.
    6.2.3 Connect the black wire with a terminal lug to the negative pole of the battery. The white and blue wires are the contact closure for the E-BAM and are not needed for normal operation.
    6.2.4 Connect the six-wire connector to the matching socket on the bottom of the E-BAM as depicted in Figure 2.2.

    Met One supplies various power sources as accessories including a solar panel (call Met One for this information.) that may be used to charge a 12 Volt battery.

According to the Operation Manual, the E-BAM can be taken out of the box, assembled, and be collecting data in less than 30 minutes.

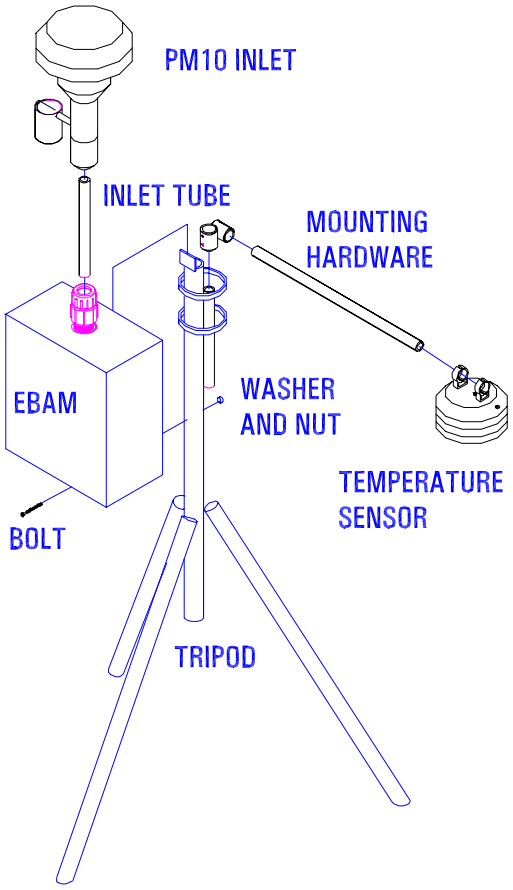


Figure 2.1. E-BAM Assembly.

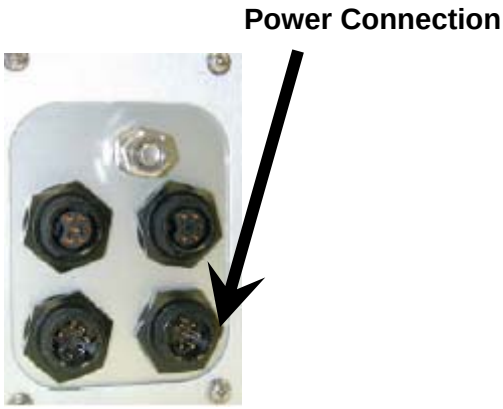


Figure 2.2. E-BAM Power Connection.

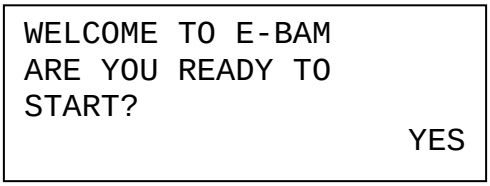
NOTE: When power is applied to the E-BAM, it will begin to operate after certain set-up instructions are answered. If the set-up instructions are not answered, the E-BAM will use default answers and begin operation automatically after 30 minutes.

3.0 INITIAL E-BAM START-UP PROCEDURE

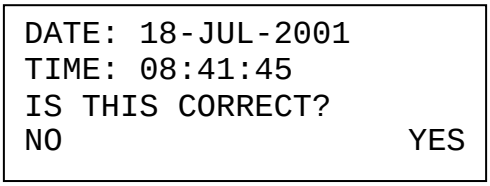
After the E-BAM is assembled and the power is connected, the E-BAM is ready to be operated. During start up, the E-BAM quickly runs through a minimum of eight start-up screens. These screens verify that the time, date, and averaging period are correct. They also check for filter tape and proper operation of vital subsystems during the E-BAM Self Test. The following procedures describe the steps to be followed to start up the E-BAM.

1. Undo the latch and swing open the E-BAM door.

2. Note that the display is on and displaying, **ARE YOU READY TO START?** Press the white "hot" key under YES to proceed.



3. If the time and date on the display are correct, push the right "soft" key on the keypad directly under where **YES** is displayed. Press **NO** to make a change. Use the arrow keys to make changes. When finished, press **SET** to save the changes. Press **CONTINUE** to exit without making changes.



4. The next screen depicts the E-BAM location filter advance and averaging start-up screen. **LOCATION** is a description for the E-BAM. Data that are downloaded will have a location ID number to enable tracking of measurement information. This may be a value from 0 to 99. To make changes, press EDIT. Press OK to proceed to the next screen. Press EDIT to make changes. Use the arrow keys to make changes.

   FILTER ADVANCE is how often the E-BAM will advance to a new spot of filter paper. The filter tape advances according to the value at which it is set. This value can be any of the following times: 1, 2, 3, 4, 6, 8, 12, or 24 hours. Note: the filter advance does not change how often the concentration is calculated. The real-time concentration is always updated every minute and the hourly concentration is always updated each hour. **NOTE: The filter tape will also automatically advance if the concentration is too high or the ambient temperature exceeds safe operation. When the filter tape is advanced due to high concentrations, an event is written to the alarm log. When the filter**

tape is advanced due to ambient temperature, an event is written to the alarm log.

REALTIME AVG is the averaging period for the real-time concentration value. The real-time concentration is calculated every minute from two 4-minute counts. The REALTIME AVG takes the mean value for the selected time period for the real-time concentration. The REALTIME AVG may be set to the following time periods: 1, 5, 10, 15, 30, or 60 minutes. Press **SAVE** to save the changes, or press **CONTINUE** to proceed and not make changes.

```
LOCATION:       01
TAPE ADVANCE:   24 HRS
REALTIME AVG:   1 MIN
EDIT              OK
```

5. If the nozzle packing material has not been removed, the nozzle will move upward and the display screen, as shown below, will ask you to remove nozzle-packing material.

```
     PLEASE REMOVE
    NOZZLE PACKING
      MATERIAL.
            CONTINUE
```

Remove the stainless steel nozzle-packing material from under the nozzle and press **CONTINUE**. Note: this nozzle-packing slide is also the zero adjustment membrane.

6. The next screen will be shown while the unit checks to see if the filter paper is loaded.

```
      CHECKING FOR
      LOADED TAPE.

     PLEASE WAIT...
```

If the unit finds that the filter tape is **not loaded**, the following screen will ask you to load the filter tape.

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

Remove both of the clear plastic spool covers by unscrewing the captive knobs. An empty tape roll core tube must be installed on the hub of the take-up spool. Special care should be taken when handling unused filter tape because it tears easily. Figure 3.1 illustrates filter tape installation. Place a full roll of filter tape on supply (right) spool, with the tape feeding upward and counter-clockwise. Feed end of filter tape so that it enters the take-up spool in a counter-clockwise direction. Using any available adhesive tape, attach the leading end of the filter tape to the core tube to prevent slipping. Gently tension the tape. Reinstall both spools. When finished, answer **CONTINUE**. The filter tape will move and take up tension.

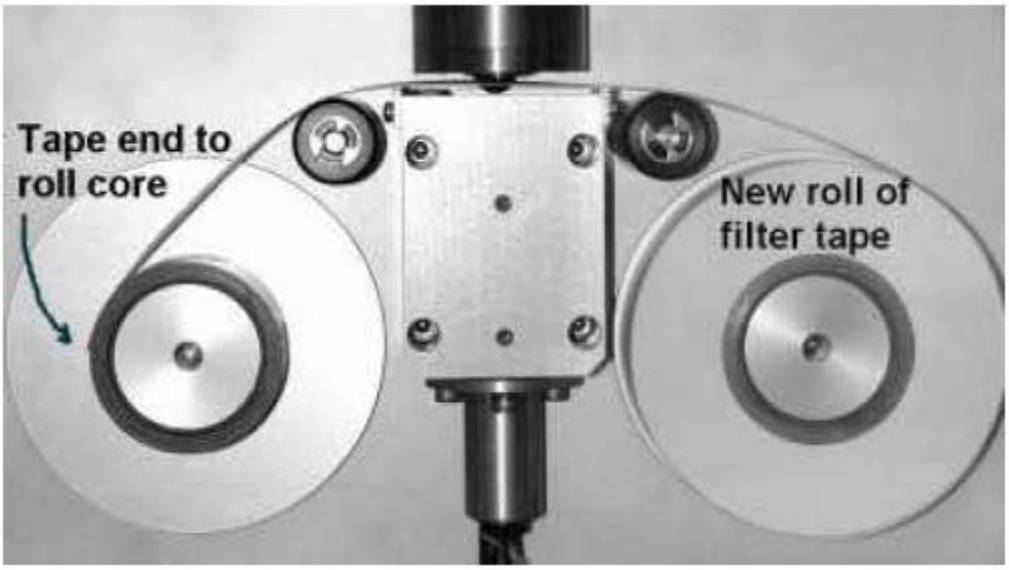


Figure 3.1. Filter Tape Installation.

7. After the tape is checked, the BATTERY condition is displayed in the power start-up screen, as shown below. Press **CONTINUE** to proceed.

```
BATTERY: 13.0 VOLTS
ESTIMATED OPERATION
TIME FOR 100 AMP-HRS
IS 42 HRS.     CONTINUE
```

8. Next, the Self Test start-up display will indicate SELF TEST RUNNING. The SELF TEST will take several minutes and cannot be bypassed by the operator.

```
SELF TEST RUNNING...


*****************999
```

9. After SELF TEST is complete, the following screen is displayed. Press **CONTINUE** and the E-BAM will **begin sampling**.

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

The Self Test can fail during any of the following sub-tests:

1. Tape Broken
2. Nozzle Motor Failed
3. Beta Counts Failed
4. Flow System Failed
5. Pressure Sensor Failed

If any fault is located during Self Test, the name and type of fault will be shown. If there is a reasonable expectation that the operator could correct the fault, an instruction for correction will be shown on the E-BAM display with step-by-step instructions to test and verify the system integrity. The operator must acknowledge any errors within one minute or the unit will automatically begin operation. **NOTE: When the E- BAM is first powered on it will require a one-hour warm-up period. Data acquired during the first hour should be discarded.**

After moving through the start-up screen process, the E-BAM defaults to the **OPERATE** screen, on which the date and time, concentration, and sampling condition are displayed.

4.0 E-BAM OPERATION

4.1 REVIEW OPERATING SETTINGS

The default sampling screen for the E-BAM is shown below. The E-BAM sampling screen is 13 lines long, but only four lines are visible due to the display size. Using the UP ▲ and DOWN ▼ arrow key will move the window so the other lines (shown underneath the box below) can be viewed. During normal operation, the OPERATE SCREEN will come on and display the following:

```
08-JUL-2001 08:23:41
  9.999 MG/M3 01:00
  9.999 MG/M3 (HR)
SAMPLING...
```

```
FLOW:  99.9 LPM
WS:  999.9 M/S
WD:  999.9 DEG
AT:  -99.9 C
FT:  -99.9 C
RHi:  999 %
RHx:  999 %
BV:  99.9 V
FLOW:  99.9 SLPM
```

The lines consist of the following information:

Line	Description
1	Date and Time
2	Real-Time Concentration
3	Hourly Concentration
4	E-BAM Status
5	Sample Flow Rate
6	Wind Speed
7	Wind Direction
8	Ambient Temperature
9	Filter Temperature
10	Relative Humidity Internal
11	Relative Humidity External
12	Battery Voltage
13	Secondary Flow

It is recommended that the operator view each line to ensure proper operation of the E-BAM.

4.1.1 Date and Time

Check to ensure that the date and time are correct. The date and time can be changed during start up as described in Chapter 3, or by using the procedure given below. **NOTE: The date and time are displayed as the DAY-MONTH-YEAR, and cannot be modified.**

1. Press the **MENU** key on the E-BAM keypad. Pressing this key will bring up the main MENU for the E-BAM.

2. Press the DOWN ▼ arrow to highlight the SETUP selection and press MENU/SELECT. The first SETUP screen is the DATE/TIME screen with two identical dates and times showing on the first two lines of the display.

3. Using the RIGHT/LEFT arrow keys highlight the value(s) that need to be changed.

4. Use the UP/DOWN arrow keys to increase or decrease the selection to a higher or lower value.

5. Once the date and time are correct, press **SET** and continue until the main menu is displayed.

4.1.2 Real-Time Concentration

During normal sampling, the real-time mass concentration is updated on the display every 60 seconds. However, the concentration recorded in the datalogger is based on a user-selectable time period. This selectable time period is called the **REALTIME AVG** and it may be any of the following values: 1, 5, 10, 15, 30, or 60 minute(s).

The REALTIME AVG setting can be modified in the E-BAM start up as described in Chapter 3, or by using the procedure given below.

1. Press MENU/SELECT

2. Highlight SETUP with the curser and press MENU/SELECT again.

3. Press CONTINUE to bypass the DATE/TIME screen.

4. The next screen is the Location Averaging Period screen. Modify the settings by highlighting the value(s) and incrementing the reading with the UP/DOWN keys. Press SET to select the desired setting.

4.1.3 Hourly Concentration

Hourly concentration is computed from an initial count compared to a second count. These two counts are separated by 60 minutes. This means that there are 60 minutes from the start of the initial count until the end of the final count. The hourly concentration value

displayed is computed from a fixed calculation that is NOT adjustable. At the beginning of an hour, the last hour's calculation is written to the datalogger. This value is held constant until the start of the next hour when it is updated with the new calculation of concentration.

4.1.4 E-BAM Status

The status line is an indicator of the current E-BAM operation. The E-BAM status messages will display either **SAMPLING** or **UNIT OFF**. Press the hot key directly under the message to initiate sampling if the display reads **UNIT OFF**.

4.1.5 Sample Flow Rate

The sample flow rate displays the instantaneous flow rate. The E-BAM flow rate may be set to a value from 10 LPM to 17.5 LPM. The flow can be controlled to **ACTUAL** or **STANDARD** conditions. The flow settings can be modified in E-BAM start up as described in Chapter 3, or in the SETUP menu as described below.

1. Press MENU/SELECT
2. Highlight SETUP with the curser and press MENU/SELECT again.
3. Press CONTINUE twice to bypass the DATE/TIME screen and the LOCATION screen. The next screen is the FLOW RATE screen. Modify the settings by highlighting the value(s) and incrementing the reading with the UP/DOWN keys. Press SET to select the desired setting.

4.1.6 Wind Speed and Direction

This is an optional accessory for the E-BAM. Units are displayed in meters per second (m/s) and degrees. The sensor can be mounted directly to the E-BAM tripod or remotely on an existing structure. It plugs directly into the E-BAM without the need for programming.

4.1.7 Ambient Temperature

Every E-BAM comes equipped with an ambient temperature sensor. This sensor allows the E-BAM to control the flow to **ACTUAL** conditions and report the concentration in actual conditions. The ambient temperature sensor mounts directly to the E-BAM tripod. The sensor has a temperature range of –50 to 50 Celsius and an accuracy of 0.1 Celsius. Check to ensure that the temperature value displayed seems appropriate for the ambient conditions. **NOTE: The pump will not come on in OPERATE mode if the temperature sensor is not connected.**

4.1.8 Relative Humidity Internal and Filter Temperature

These are standard measurements of the E-BAM. Both sensors are located downstream of the filter paper. By adding heat to the air stream in a controlled manner, condensation is avoided and proper mass measurements are calculated. To ensure that the sample does not get over heated, filter temperature is also measured. The filter temperature and the ambient temperature are used to calculate a Delta-Temperature. The Delta-Temperature is the Filter Temperature minus the Ambient Temperature. A maximum Delta-Temperature can be set to

limit the heat applied to the sample air. The set points for the moisture-controlled heater can be modified during E-BAM start up as described in Chapter 3, or in the SETUP menu as described below.

1. Press MENU/SELECT
2. Highlight SETUP with the cursor and press MENU/SELECT again.
3. Press CONTINUE three times to bypass the DATE/TIME screen, the LOCATION screen, and the FLOW screen.
4. The next screen is the **HEATER** screen. Modify the settings by highlighting the value(s) and incrementing the reading with the UP/DOWN keys. Press SET to select the desired setting.

NOTE: Set Delta-T to NO unless it is required, otherwise the E-BAM will turn off the heater even though the humidity is high.

4.1.9 Relative Humidity External

This is an optional accessory for the E-BAM. The relative humidity (RH) external sensor has a measurement range from 0 to 100 percent with an accuracy of 3 percent. The sensor can be mounted directly to the E-BAM tripod or remotely to an existing structure.

4.1.10 Battery Voltage

This is a measurement of the incoming power. If the unit is connected to a battery, this will allow the logging of the power during the sample period. If the unit is connected to AC power through a DC power supply, this should be a constant number.

4.1.11 Secondary Flow

This channel is used only when the FLOW type is selected as STANDARD flow. Standard flow will be displayed on line five of the sampling screen. This channel will display ACTUAL flow. If ACTUAL flow is selected this line will be blank.

4.2 E-BAM INLET HEATER

To ensure the sample does not get over heated, filter temperature is measured. As described in Section 4.1.8, the filter temperature and the ambient temperature are used to calculate a Delta-Temperature. The Delta-Temperature is calculated as the difference between the filter temperature and the ambient temperature. A maximum Delta-Temperature can be set to limit the heat applied to the sample air. The set points for the moisture-controlled heater can be modified in the SETUP menu as described below.

1. Press MENU/SELECT
2. Highlight SETUP with the curser and press MENU/SELECT again.
3. Press CONTINUE three times to bypass the DATE/TIME screen, the LOCATION screen, and the FLOW screen. The next screen is the HEATER control screen. Modify the settings by highlighting the value(s) and incrementing

the reading with the UP/DOWN keys. Met One recommends using an RH set point of 45 percent and a Delta-T set point of 8 Celsius with RH control set to **ON**.

```
RH SETPOINT: 45 %
DELTA-T SETPT: 10 C
RH CONTROL: ON
SAVE CONTINUE
```

The Inlet Heater operates according to the following parameters:

- When RH control is ON, the heater will be turned ON when the RH is above set point and will turn OFF 1 percent below set point.

- When the Delta-T set point is exceeded by 1 C, the heater is turned **OFF**. The Delta-T control overrides the RH set point control.
    - Delta-T is the result of the filter temperature minus the ambient air temperature.

- Anytime the pump is OFF, the heater is OFF.

- Delta-T violations are reported to the Alarm log, which sets the alarm relay.
    - A violation occurs when the RH control is ON and the Delta-T reading exceeds the Delta-T set point by 1 C.
    - Reset the alarm at power up and beginning of tape advance.

<u>NOTE</u>: As with any instrument, it is always important to exit out to the Main Menu and then return to check if the changes were in fact saved.

5.0 SELF TEST

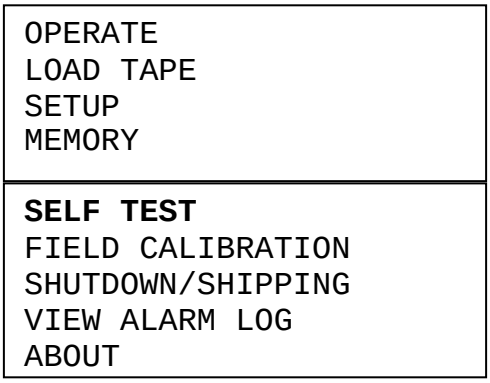
The E-BAM has a **SELF TEST** mode that will automatically test all parameters. If any fault is located, the name and type of fault will be shown. If there is a reasonable expectation that the operator could correct the fault, an instruction for correction is shown.

The following procedures should be used to conduct a SELF TEST.

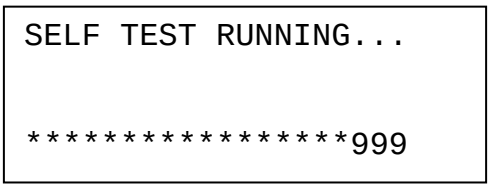
1. Go to the **MENU SCREEN**

2. Use the UP/DOWN arrow keys to select SELF TEST.

3. Press the SELECT key.

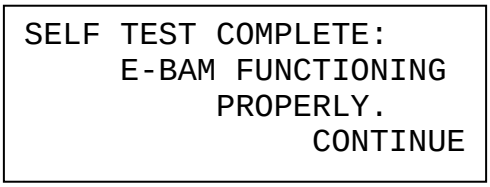


The E-BAM display will indicate **SELF TEST RUNNING**.



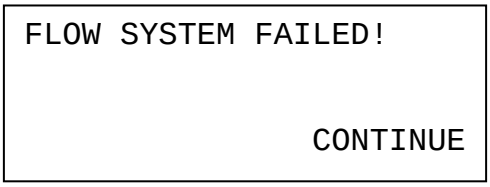
The **SELF TEST** will take several minutes and cannot be bypassed by the operator.

After **SELF TEST** is finished, the following screen is displayed.



Answer **CONTINUE** and the E-BAM will **begin sampling**.

If **SELF TEST** failed (e.g., if the pump failed to turn on), the following screen will appear.

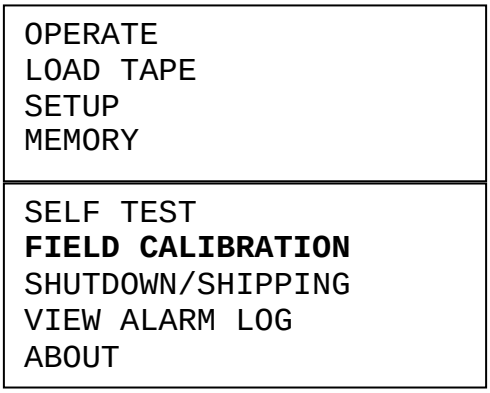


6.0 CALIBRATION

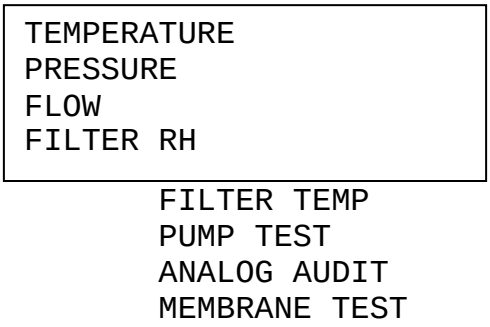
6.1 CALIBRATION OVERVIEW

Calibration of the E-BAM is done using the same calibration standard used for the calibration of BAM1020. The BAM1020 is certified by the U.S. EPA as an Equivalent Method for PM_{10} and is calibrated with NIST-traceable transfer standards.

The following screen is used to verify the operation of the E-BAM. Each FIELD CALIBRATION test is explained in Sections 6.2.2 through 6.2.6 of this SOP.



Selecting **FIELD CALIBRATION** opens the following screen:



6.2 FLOW SYSTEM

After initial installation or relocation of the E-BAM, two checks required to verify the operation of the E-BAM are a **LEAK CHECK** and **FLOW AUDIT** procedure. The flow system should be audited periodically to insure that accurate data are being collected.

6.2.1 Leak Check

During normal operation, the flow system is under a vacuum of 160 mmHg (6 in Hg). The leak check procedure increases this vacuum to 400 mmHg (16 in Hg). This 2.5 times increase in vacuum finds problems before they can affect the data. To perform a valid leak test, follow the step-by-step procedure below.

1. E-BAM is in the PUMP TEST screen located in the MAIN MENU/FIELD CALIBRATION/PUMP TEST. This screen has two modes – LEAK CHECK and PUMP TEST. Select **LEAK CHECK.**

2. Remove the PM_{10} inlet and replace with a leak test valve (BX-305). **NOTE: When looking for a leak, it might be necessary to remove both the PM_{10} inlet and the $PM_{2.5}$ inlet. This would help pinpoint the leak more accurately.**

3. Close the valve on the leak test valve.

4. Flow rate should drop to under 1.5 liters per minute (LPM). If the flow is under 1.5 LPM, remove the leak test valve and replace the PM_{10} head. If the flow is greater than 1.5 LPM, proceed to Section 6.2.1.1, Fixing a Leak.

6.2.1.1 Fixing a Leak

If you have performed the steps of a leak check and found that the E-BAM fails to have a flow rate less than 1.5 LPM, there is a problem with the integrity of the flow system. If a leak is detected, the most likely cause is build up of material on the nozzle or vane. During normal operation, the nozzle of the E-BAM can have a build up of filter material on the sealing surface. Build up can also occur on the vane, which is the crosshatch-piece under the filter paper. Both of these must be cleaned periodically using alcohol and a Q-tip. Met One suggests cleaning these areas at least every two months of continuous operation.

6.2.2 Flow Audit/Calibration

6.2.2.1 Flow Audit

After the leak check, the next procedure to validate a flow system is a **FLOW AUDIT**. In an E-BAM, the flow audit process has been simplified to allow quick and accurate flow audits. The following procedure should be followed to conduct a flow audit of the E-BAM.

1. Connect the audit device (i.e., flow transfer standard) to the E-BAM inlet. If the flow standard uses tubing, a BX-305 will allow easy connection to the E-BAM inlet. Be sure that the flow standard and the E-BAM are measuring the flow on the same units and type.

2. Compare the reading of the audit device with the flow rate value displayed by the E-BAM. If the difference between the E-BAM flow rate and the audit device reading is greater than 2 percent, a **FLOW CALIBRATION** will need to be done. **NOTE**: The E-BAM reports the flow rates as either ACTUAL flow (i.e., reported at actual ambient conditions), or as STANDARD flow (i.e., reported at standard conditions). Ensure that the audit device and the E-BAM report flow under the same conditions. To check the setting of the flow type in the E-BAM, go the SETUP screen in the MAIN MENU.

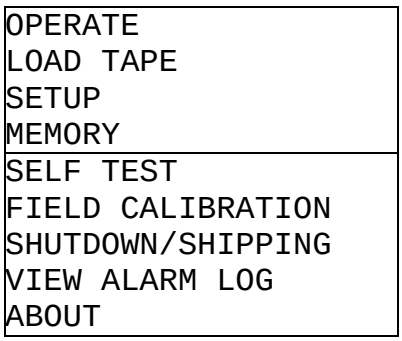
6.2.2.2 Flow Calibration

A flow calibration includes an audit of the temperature and pressure sensors. To perform a valid flow calibration, follow the step-by-step procedure below. **NOTE: Before a flow calibration is completed, a temperature and pressure audit must first be conducted.**

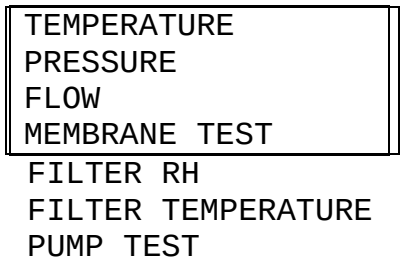
TEMPERATURE

The temperature sensor audit is typically conducted at two temperatures. One is at ambient conditions where the E-BAM and audit temperature sensors measure the ambient air. The second is at low temperature when the E-BAM and audit temperature sensors are submersed in an ice bath.

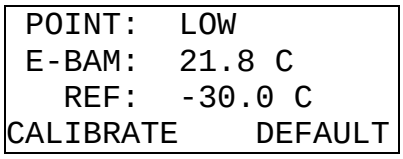
1. Go to the MENU SCREEN and use the UP/DOWN arrow keys to select FIELD CALIBRATION, then press the SELECT key.



2. The FIELD CALIBRATION screen has seven selections. The first three selections (TEMPERATURE, PRESSURE, and FLOW) are used in a flow audit. Actual Flow is calculated from all three components. Select TEMPERATURE from the FIELD CALIBRATION screen.



3. The calibration screens for TEMPERATURE, PRESSURE, and FLOW are all similar. Each screen has a set point, E-BAM, REF, CALIBRATE, and DEFAULT entry, as shown below.



Set point: This is the intended value for the sensor. In the TEMPERATURE screen, two values are selectable — **HIGH** and **LOW**. These correspond to ambient and ice bath values.

E-BAM: This is the measurement that the E-BAM is calculating for the selected sensor.

REF: This is the value that the Reference sensor is calculating. By entering the reference value into this entry and pressing CALIBRATE, the E-BAM measurement will be calibrated to the entered value.

CALIBRATE: Press this key to recalibrate the E-BAM sensor to the inputted REF value.

DEFAULT: Press this key to restore factory default values.

4. Place a NIST-traceable temperature sensor in close proximity to the E-BAM temperature sensor.

5. Allow an equilibration period of at least 15 minutes when the E-BAM and Reference temperatures are at the same location. If the test is an ambient test [above 20 Celsius (68 F)], select POINT:HIGH. If the test is an ice bath test, select POINT:LOW. **NOTE: It is recommended that the ambient point (HIGH) be done first, due to the long equilibration period required for the temperature sensors to warm up.**

6. Compare the reference temperature reading to the E-BAM reading on the LCD. If the readings are within 0.5 C (1 F), no recalibration is necessary.

7. If the readings differ by more than 0.5 C (1 F), enter the reference temperature measurement into the REF:XX.X field and press **CALIBRATE**.

8. Repeat steps 4 through 7 for the second point.

PRESSURE

The same protocol is used for PRESSURE, but with a single-point calibration. Repeat the above steps using a reference pressure sensor. If the pressure values are within 2 mmHg, no recalibration is necessary.

FLOW

1. In the FIELD CALIBRATION screen, select FLOW. **NOTE**: TEMPERATURE and PRESSURE must be audited prior to the FLOW.

```
 TEMPERATURE
 PRESSURE
>FLOW
 MEMBRANE TEST
```

2. The FLOW calibration screen is similar to all E-BAM calibration screens.

```
FLOW SP:  16.7 LPM
  E-BAM:  16.7 LPM
    REF:  16.4 LPM
CALIBRATE    DEFAULT
```

FLOW SP: This is the flow rate value. In the FLOW screen, three points are selectable — 14.0, 16.7, and 17.5 LPM.

E-BAM: This is the measurement that the E-BAM is calculating for the selected sensor.

REF: This is the value that the Reference sensor is calculating. By entering the reference value into this entry and pressing CALIBRATE, the E-BAM measurement will be calibrated to the entered value.

CALIBRATE: Press this key to recalibrate the E-BAM sensor to the inputted REF value.

DEFAULT: Press this key to restore factory default values.

3. Once a set point is selected, the E-BAM will automatically turn on the pump and regulate to the flow set point.

4. Remove the PM_{10} inlet and place the reference flow audit device on the inlet tube. Wait for 5 minutes for the flow to equilibrate.

5. Compare the reference flow to the E-BAM flow. If the flows are within 2 percent, no recalibration is necessary.

6. To recalibrate the flow, enter the Reference Flow Meter reading into the REF:XX.X LPM entry and press CALIBRATE.

7. Repeat the above procedure for the remaining FLOW SP.

The FLOW system is checked and verified by the Leak and Flow tests. When the E-BAM passes both these tests, the FLOW system will work correctly.

6.2.3 Membrane Test

Verification is accomplished using two calibration plates that represent a ZERO and SPAN factory set calibration points. The set of calibration plates are unique to each E-BAM. Always check that the serial number on the calibration plates matches the serial number of the E-BAM to be calibrated. The SPAN calibration plate has a fragile membrane covering the hole. The membrane calibration will take approximately 16 minutes. Figure 6.1 shows the ZERO and SPAN plates being inserted.

<u>NOTE</u>: Never bump or touch the membrane. Always keep the membrane in their protective plastic case when not in use. When inserting the membrane into the E-BAM, be careful that you do not scrape or rub the filter tape with the metal plate or a calibration error may result.

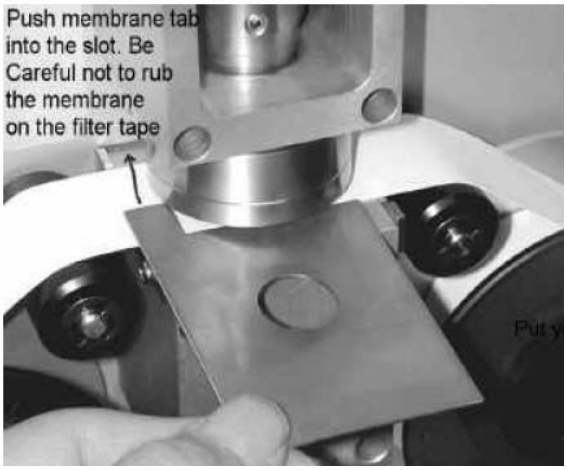
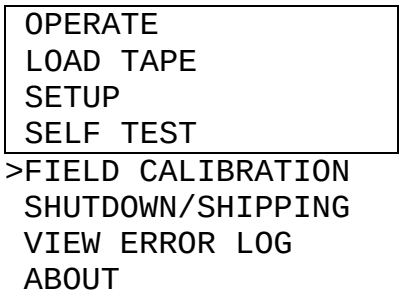
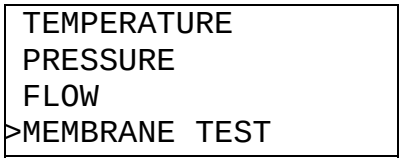


Figure 6.1. Inserting the Span/Zero Plates.

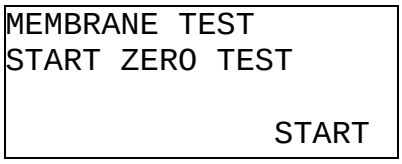
1. With the E-BAM door still open, turn on the display and press any key. Go to the MENU SCREEN and use the UP and DOWN arrow keys to select FIELD CALIBRATION, then press the SELECT key.



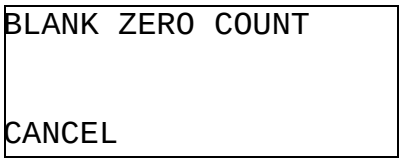
2. From the FIELD CALIBRATION MENU, select MEMBRANE TEST and press the SELECT key.



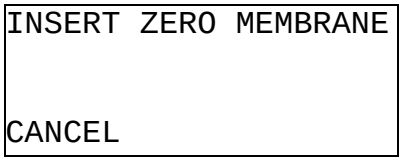
3. Press the START key once you are ready to start the calibration.



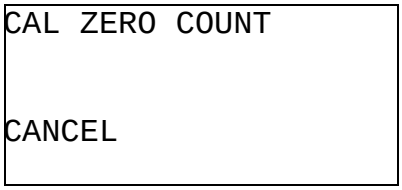
4. The filter tape will advance, the nozzle will lower, and the E-BAM will take a 4-minute blank ZERO count. Press CANCEL to re-start the test.



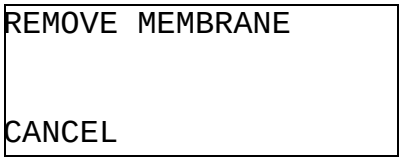
5. After the 4-minute count, the nozzle will move up and wait for you to insert the ZERO membrane.



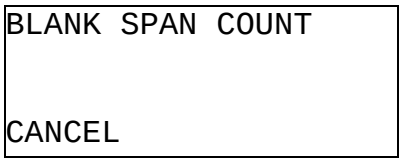
6. Insert the ZERO Membrane; the nozzle will lower and the E-BAM will take a 4-minute ZERO count.



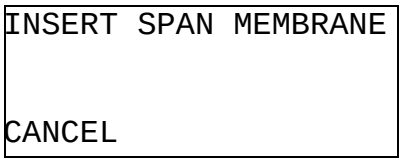
7. After the 4-minute sample, the nozzle will move up and ask you to remove the ZERO membrane.



8. When the ZERO membrane is removed, the nozzle will lower and the E-BAM will take a 4-minute blank SPAN count.



9. After the 4-minute blank SPAN count, the nozzle will move up and wait for you to insert the SPAN membrane.



10. After you insert the SPAN membrane, the nozzle will lower and the E-BAM will take a 4-minute SPAN count.

```
CAL SPAN COUNT


CANCEL
```

11. Note the test results and take out the SPAN membrane.

```
MEMBRANE TEST RESULT
ZERO MEMBRANE:  PASS
SPAN MEMBRANE:  PASS
                 OK
```

If the ZERO or SPAN test failed, rerun the test. If the failure continues, clean the detector and re-run the test. If the failure persists, contact the factory service center. Press OK to return to the FIELD CALIBRATION MENU.

NOTE: The measuring system performance is checked and verified by completion of the Zero and Span tests.

6.2.4 Inlet Heater Maintenance

The inlet heater needs periodic maintenance for the Filter RH and Filter Temperature sensors. Both sensors can be audited and calibrated from the E-BAM display.

6.2.4.1 Filter RH

The filter RH sensor is used to control the heater during periods when the sample air has an RH value that exceeds the set point. The Filter RH audit display is located in the MAIN MENU/FIELD CALIBRATION/FILTER RH screen.

```
FILTER RH
E-BAM: 57 %
REF: xxx %
CALIBRATE      DEFAULT
```

E-BAM: This is the measurement that the E-BAM is calculating for the selected sensor.

REF: This is the value that the Reference sensor is calculating. By entering the reference value into this entry and pressing CALIBRATE, the E-BAM measurement will be calibrated to the entered value.

CALIBRATE: Press this key to recalibrate the E-BAM sensor to the inputted REF value.

DEFAULT: Press this key to restore factory default values.

6.2.4.2 Filter Temperature

The filter temperature sensor is used to limit the heat added during periods when the sample air has an RH value that exceeds the set point. The filter temperature audit display is located in the MAIN MENU/FIELD CALIBRATION/FILTER TEMPERATURE screen.

```
FILTER TEMPERATURE
E-BAM:  xx.x C
REF:  -xx.x C
CALIBRATE      DEFAULT
```

E-BAM: This is the measurement that the E-BAM is calculating for the selected sensor.

REF: This is the value that the Reference sensor is calculating. By entering the reference value into this entry and pressing CALIBRATE, the E-BAM measurement will be calibrated to the entered value.

CALIBRATE: Press this key to recalibrate the E-BAM sensor to the inputted REF value.

DEFAULT: Press this key to restore factory default values.

6.2.5 Pump Test

The dual diaphragm pump in the E-BAM has an 8,000-hour estimated lifetime. Under normal use, it should be serviced once a year. The pump cannot be rebuilt. A replacement pump must be purchased and installed.

6.2.5.1 Testing the Pump

A flow test inlet valve (BX-305) will be needed to test the pump.

This test is found in the **PUMP TEST** screen. This display is located in the MAIN MENU/FIELD CALIBRATION/PUMP TEST screen. There are two modes in this screen, which are LEAK TEST and PUMP TEST. Select **PUMP TEST** mode.

```
MODE: PUMP TEST
FLOW: 16.7 LPM
PRES: 999999 PA
EXIT
```

1. Remove the inlet head(s).

2. Place the flow test inlet valve over the inlet tube on the top of the E-BAM.

3. Turn the E-BAM on and allow the pump to equilibrate at 16.7 LPM. Slowly close the valve on the BX-305 until the flow is one of the values in Table 6.1. Let the pump run at that flow rate for at least 1 minute. Readjust as necessary.

Table 6.1. Vacuum Test for Pump Condition.

Flow Rate, LPM	Pump Condition Pressure Reading		
	Good	OK	Replace
14.0	52056	54138	57262
14.1	52212	54300	57433
14.2	52505	54605	57756
14.3	52662	54768	57928
14.4	52857	54971	58143
14.5	53131	55256	58444
14.6	53267	55398	58594
14.7	53482	55621	58830
14.8	53756	55906	59132
14.9	53932	56089	59325
15.0	54127	56292	59540

Compare the pressure reading to the acceptable pressure readings in Table 6.1. If the pressure is within tolerances, the pump does not need to be replaced. If it is out of tolerance, replace the pump.

6.2.5.2 Replacing the Pump

In addition to the steps listed below, Figure 6.2 illustrates how to remove the pump for replacement.

1. Turn off the power to the E-BAM.

2. Open the cabinet door and remove the two 8-32 Phillips-head screws holding the pump cover plate on.

3. Disconnect the pump power connector from the printed circuit board.

4. Take out the four 6-32 Phillips-head screws holding the inlet tube to the pump.

5. Slide the upper sealing collar upward. There are no threads on the collar and it should move up with a slight twist and firm push.

6. Slide the lower sealing cover upward.

7. Take out the inlet tube.

8. Take out the three 6-32 Phillips-head screws holding the pump mount to the front panel.

9. Pull off the four 3/8-inch Tygon tubes from the pump ports. Be sure to mark the tubes so they go back on the same pump ports later.

10. The pump can now be taken out of the cabinet.

11. Re-install the pump in the reverse order.

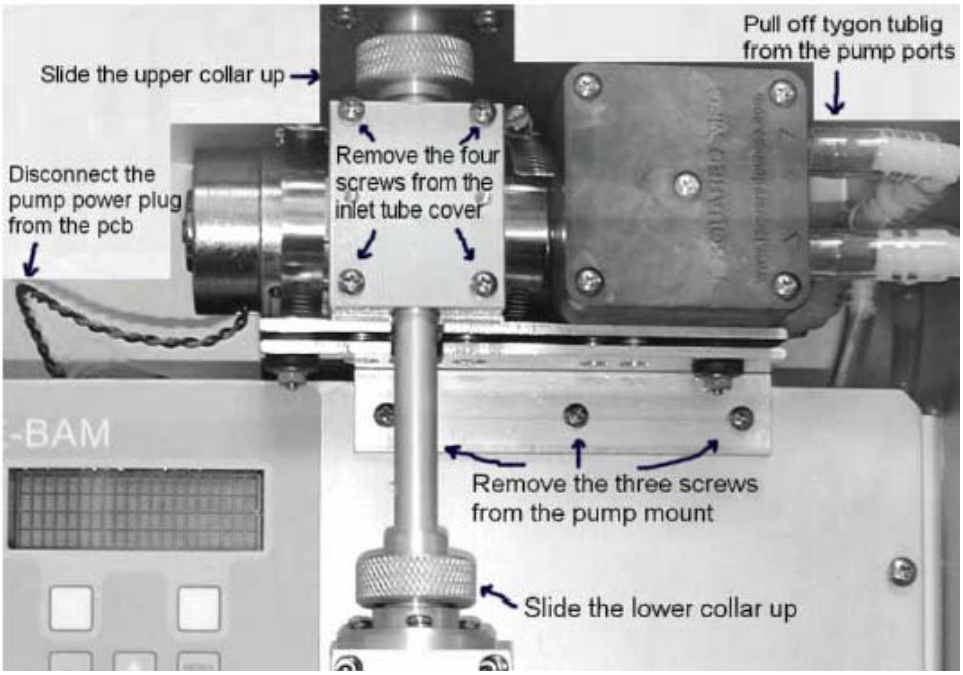


Figure 6.2. Removing the Pump for Replacement.

7.0 ROUTINE SERVICE CHECKS AND MISCELLANEOUS MAINTENANCE

7.1 ROUTINE SERVICE CHECKS

Normal E-BAM maintenance requires keeping the E-BAM central unit and inlet dust free. Every year of operation, the accumulated dust on the detector-sensing region should be cleaned off as well. Table 7.1 lists the various items that require calibration or replacement over various time periods.

Table 7.1. Maintenance Schedule.

Time Period	Item
Monthly	Leak Check
Monthly	Flow Audit
Monthly	Tape Check
Monthly	Alarm Check
Every 2 Months	Pump Test
Every 6 Months	Flow Calibration
Every 6 Months	Analog Check for External Datalogger
Every 6 Months	Inlet Cleaning
Every 12 Months	Zero and Span Verification
Every 12-24 Months	Pump replacement
Every 12-24 Months	PMT Cleaning
Every 5 Years	Internal Filter
NOTE: Depending on site, maintenance may need to occur at higher intervals.	

7.2 MISCELLANEOUS MAINTENANCE

1. Alarm Log. Check this log to see if certain errors are occurring regularly. This log can be checked in the MAIN MENU under the heading of **View Error Log**. Note the errors and correct if necessary. For a troubleshooting guide, see Chapter 8.

2. Clean the PM_{10} Inlet Head. Under continuous use, the PM_{10} inlet head should be removed and cleaned every six months. The PM_{10} inlet requires removal from the inlet tube, disassembly, and cleaning. Disassemble the PM_{10} inlet and wipe clean with a lint-free cloth. Ensure that all O-ring surfaces are in excellent shape and are re-installed correctly. If O-rings are damaged, contact Met One for replacement parts.

3. Clean the $PM_{2.5}$ SCC. The $PM_{2.5}$ SCC inlet requires removal from the inlet tube, disassembly, and cleaning. Disassemble the SCC and wipe clean with a lint-free cloth. Ensure that all O-ring surfaces are in excellent shape and are re-installed correctly. If O-rings are damaged, contact Met One for replacement parts.

4. Filter Tape. Depending on Filter Tape Advance settings and concentration, the filter tape will need to be replaced. A simple check each month will prevent the E-BAM from running out of filter tape.

5. Clean the PMT: All E-BAMs manufactured after June 2003 have a new style of PMT installed and cannot be cleaned with a Q-tip and alcohol like the older style of PMT. The new style PMT should only be cleaned with low-pressure clean air. Care must be taken that the PMT surface does not come into contact with any other surface.

8.0 TROUBLESHOOTING

A basic troubleshooting guide is provided in Table 8.1

Table 8.1. Troubleshooting Guide for E-BAM Mass Monitor.

SYMPTOM	PROBABLE CAUSE	REMEDY
Low or no 12 Volt DC power	Bad battery, discharged battery, bad connection	Test battery, charge or replace if necessary, clean battery connections, replace power cable.
Pump will not start	Bad pump	Check pump and replace if bad. Lift nozzle and check for obstruction in flow path.
Flow rate is too low	Air leak, bad pump, obstruction in air path	Check for an air leak. Check pump and replace if bad.
No filter tape movement	Bad motor/drive	Replace the motor/drive unit.
Filter tape slips	End of tape is slipping on take up spool	Tape end of filter tape to the take up spool.
Filter tape is being cut by the nozzle	Debris under nozzle	Lift nozzle and clean off debris.
Nozzle does not move	Bad motor or limit switch	Replace the motor or limit switch.

9.0 DATA RETRIEVAL

The E-BAM data system stores and retrieves information. Once the data are stored, retrieval of the data can be done a number of ways. The E-BAM allows front screen viewing of the stored data (refer to Chapter 3 for additional information on this procedure). The data can also be downloaded from the E-BAM by a number of methods. The E-BAM will utilize the AIRSIS remote satellite telemetry system to transmit data from the E-BAM using the AQEB-2000 satellite modem to the AIRNow Website, where data will be accessible with a username and password.

SATELLITE MODEM SETUP

1. Place E-BAM tripod in the highest location available with a clear view of the sky. Buildings or large natural barriers will obstruct the AQEB-2000 modem's ability to obtain satellite communications.

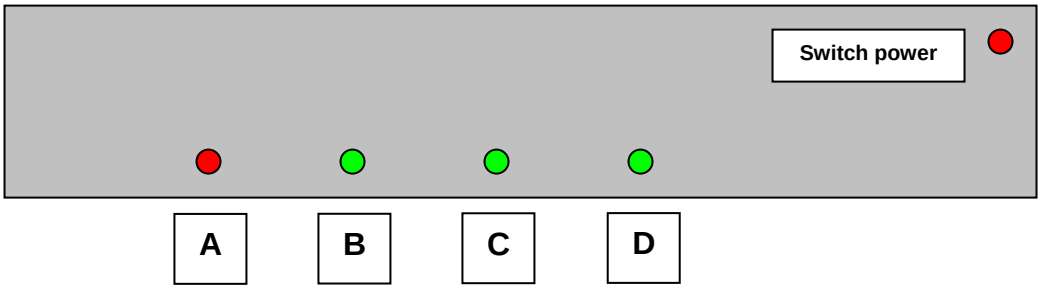
2. Assemble brackets and hang the unit on the E-BAM tripod.

3. Screw the satellite antenna to the top of the AQEB box making sure it is firmly seated.

4. To maintain backup battery charge, plug the power cord into a 110-Volt power outlet.

5. Plug in 7-pin data cable to Serial Communication Port on the bottom of E-BAM.

   The following diagram shows the various states of the satellite modem and corresponds to the LED indicators located on the monitor. LED indicators verify that the satellite modem has power, the modem is receiving information from the E-BAM, and the antenna is properly placed for the modem to "see" the satellites.



A. Modem initialized light is on.
B. Serial Data measurement Digital 0 from E-BAM light is on.
C. Serial Data measurement Digital 1 from E-BAM light is on.
D. Light is ON when satellite is in view and OFF between satellite passes. (If this green LED light does not illuminate within 30 minutes, reposition the antenna to a higher and unobstructed position.)

6. After the E-BAM battery is fully charged, turn on the AQEB-2000 and confirm the light is on above the power switch. The first red LED should illuminate after a few seconds. This indicates the modem has power.

7. Lights A+B+C will be on when the modem is functioning and data are being sampled. Light D will be on when the satellite is in view.

NOTES:

1. **This unit is equipped with an internal battery and should be charged for a full day before the unit is connected for use.**
2. **The door of E-BAM must be completely closed during unit operation.**
3. **The E-BAM unit must be set to Greenwich Mean Time (GMT) *not* local time. Website time postings will be converted and accurate for local time.**

10.0 REFERENCES

[1] Met One Instruments, Inc. (2004). "Operation Manual," E-BAM-9800 Rev D. December.

[2] Personal Communication from Rachel Sell (Battelle) to Mike Putnam (Met One) (2004). "Operation Manual," Met One Instruments, Inc., E-BAM-9800 Rev D, December.

[3] Personal Communication from Rachel Sell (Battelle) to Dean Rosenberg (AIRSIS) (2004). "AIRSIS," remote satellite telemetry system, December.

APPENDIX A:

INSTRUCTION SHEET FOR THE FIRMWARE UPDATE UTILITY

Appendix A: Instruction Sheet for the Firmware Update Utility

Firmware Update Utility

This PC-based utility program is used to update firmware in Met One products equipped with FLASH memory technology.

Warning!

This firmware upgrade process will over-write the datalogger memory. Save your datalogger memory before proceeding.

Setting Up Your System

Locate a PC with an available RS-232 COMM port and install the firmware update utility.

Connect the serial cable that came with the Met One product to the product itself and the other end to the available RS-232 port on the PC.

Configure the PC and the Met One product to 9600 baud.

Warning!

Take great effort to ensure that the power source to the Met One product will not be interrupted during the update process! A power interruption may cause the product's firmware to become inoperative! If this happens, the product will have to be returned to the factory.

Running the Update Utility

From the **Start** menu, go to `Programs/Met One/E-BAM/E-BAM Master Program Installer.`

The program will prompt you for the COMM port number. Enter the number and press the **Enter** key to begin the update process.

A **'Done**!' message will be displayed at the end of the update process. Execution time is approximately five (5) to fifteen (15) minutes.

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