Section I: Installation, Calibration and Maintenance Responsibilities of the Electronics and Calibration Branch (ECB) For the Met One Instruments Beta Attenuation Monitor (BAM)

Quality Assurance Plan/ Standard Operating Procedure (QAP/SOP)

Met One Instruments
BAM 1020
Continuous Ambient Particulate Matter PM2.5 Monitor

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2.37.1 BAM 1020 QAP/SOP for the ECB

The following document describes the ECB responsibilities for the Met One Instruments, Beta Attenuation Monitor (BAM) 1020 used for the continuous measurement of ambient air concentrations of particulate matter with an aerodynamic diameter equal to or less than 2.5 micrometers.

2.37.1.1 Description of the BAM 1020

The BAM 1020 automatically measures and records airborne particulate matter (PM) concentration levels in ug/m^3 at local conditions of temperature and atmospheric pressure using the principle of beta ray attenuation. A small, Carbon 14 (^{14}C) source emits a constant source of high-energy electrons known as beta particles, which are detected and counted by a sensitive scintillation detector. An external pump pulls a measured amount of PM laden air through a glass fiber filter tape. Once per hour, after the filter tape has collected some amount of ambient PM, it is automatically placed between the source and the detector thereby causing an attenuation of the beta particle signal. The degree of attenuation of the beta particles is used to determine the mass concentration of PM in the ambient air. The monitor measures a background or "zero" signal at a predetermined spot on the filter tape, which has not been exposed to the ambient air. The monitor then pulls ambient air through the same spot on the filter at a rate of 16.67 liters per minute (LPM) for a specified period of time. (See Appendix A for a diagram of the BAM 1020 system.)

The BAM is configured to operate on 1-hour cycles. During this one-hour cycle, the unit makes two 8-minute beta measurements (one for the background or blank and one for the sample) and collects one 42-minute sample for a combined total of 58 minutes. The remaining 2-minutes of each hour are used for filter tape and nozzle movements. At a preset clock time (time 00 for this discussion), the BAM advances the filter tape forward one "window" (next unused spot) where the tape is positioned between beta source and the detector. The BAM begins counting beta particles for exactly 8-minutes. At the end of minute 08, the BAM stops counting the clean spot and advances the tape exactly four windows forward, positioning that same spot under the sampling nozzle. The nozzle is lowered into position, the pump turns on and the sample is collected for exactly 42-minutes at a flow rate of 16.67 LPM. At the end of minute 50, the pump stops, the nozzle is raised and the tape moves backwards exactly four windows. The spot that was just loaded with PM is now positioned between the beta source and the detector. The BAM begins counting beta particles for exactly 8-minutes. At the end of minute 58, the BAM stops counting and calculates the PM concentration. At the end of minute 60, the BAM records the concentration to memory, provides a corresponding analog output signal to the data logger and advances the filter tape to a fresh spot and the cycle begins over at minute 00.

The calibration (or span) of the detector is performed at the factory prior to shipment and therefore requires no further calibration in the field. During each 42-minute sampling period, the BAM automatically performs a quality control check of system performance.

A "span check" is performed by automatically inserting a calibrated membrane between the source and the detector. The response is compared to the factory determined value. If this response is found to be greater than ± 5% of the factory determined value, the instrument automatically generates an error flag. A frequently occurring error flag indicates that the calibration is no longer valid and the instrument must be returned to the factory for recalibration. The BAM also checks for instrument drift caused by varying external parameters such as temperature, barometric pressure and relative humidity. If either the calibration or the drift is found to be outside of specifications, the BAM flags the data that was generated for that hour.

The small, ^{14}C element is a sealed source with a sufficiently low activity as to be below the Federal "Exempt Concentration Limit" and poses no health hazard. The source has a very long half-life (5000 + years) and should never need replacing. However, under no circumstances should anyone but factory technicians attempt to remove or access the beta source.

The sample inlet system is equipped with a PM10 head which is used to separate out PM that is equal to or larger than 10 micrometers in diameter and a PM2.5 very sharp cut cyclone (VSCC) which is used to further separate out PM larger than 2.5 micrometers in diameter**. The BAM 1020 received the designation as a Federal Equivalent Method (FEM) for measuring PM2.5 in the ambient air from the EPA on March 12, 2008. To maintain this status, the instrument must be operated as detailed in the instruction manual and as outlined in the procedures provided in this QAP/SOP.**

The "Main Menu" and keyboard are shown in Figure 1 below, followed by a description of the keyboard functions.

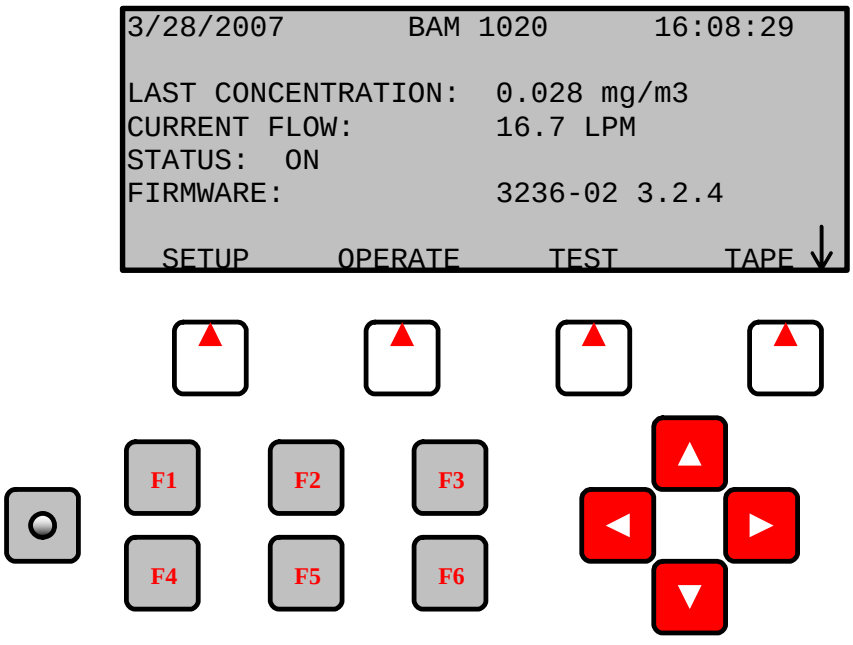


Figure 1. The BAM-1020 Main Menu and Keyboard

Soft Keys:
Directly beneath the display are four white buttons called “soft-keys” or “hot-keys”. These are dynamic keys whose function changes in response to a menu option displayed directly above each key on the bottom row of the display. Whatever menu option is displayed above one of these keys is the function which that key will perform in that particular menu. These are used throughout the entire menu system for a wide variety of functions. For example, changes/updates made within a menu are usually not saved unless a SAVE soft-key is pressed. EXIT is also another common soft-key function.

Arrow (Cursor) Keys:
The four red arrow 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.

Contrast Key:
The key with a circular symbol on it is for adjusting the light/dark contrast on the LCD display. Press and hold the key until the desired contrast is achieved. It is possible to over-adjust the contrast and make the entire display completely blank or completely dark, so be careful to set it to a visible level or it may appear that the unit is not operating.

Function Keys F1 to F6:
The function keys serve as shortcuts to commonly used menu screens, and can be safely pressed at almost any time without interrupting the sample cycle. The **F** keys are only functional from the main menu screen or for entering passwords. The factory default password is F1, F2, F3, F4.

F1 **Current:** This key is a shortcut to the OPERATE > INST screen, used to display the instantaneous data values that are being measured by the BAM-1020. The F1 key can be used without interrupting a sample cycle.
F2 **Average:** This key is a shortcut to the OPERATE > AVERAGE screen, used to display the latest average of the data recorded by the BAM-1020. The F2 key can be used without interrupting a sample cycle.
F3 **Error Recall:** This key allows the user to view the errors logged by the BAM-1020. The errors are sorted by date. The last 12 days which contain error records are available, and up to the last 100 errors can be viewed. The F3 key can be used without interrupting a sample cycle.
F4 **Data Recall:** This key allows the user to view the data stored in the BAM-1020, including concentrations, flow, and all six external channels. The data is sorted by date, and the user can scroll through the data hour-by-hour using the soft-keys. Only the last 12 days which contain data records are available in this menu. The F4 key can be used without interrupting a sample cycle.

F5 Transfer Module: This key is used to copy the memory contents to an optional transfer storage module to retrieve the digital data without a computer. This function is rarely used. Met One recommends downloading the data with a laptop, computer or modem connection.

F6 (Blank): This key is not assigned a data function.

2.37.1.2 BAM 1020 Set-Up, Maintenance and Calibration Responsibilities

The ECB will have the responsibility for the set-up, routine calibration and maintenance/trouble shooting of the BAM. The BAM automatically performs a zero and span calibration check every hour. Calibration activities associated with several components of the instrument are discussed separately in subsequent sections. **All activities performed during each site visit must be accurately and completely documented on the ECB electronic field data form(s) (prepared by the ECB) and in the site logbook.** Any BAM malfunctions, problems or questionable operations must be reported to the regional chemist, the ECB supervisor and the Headquarters BAM leader. The following is a list of the tasks, task frequency and responsibilities regarding the BAM set-up, maintenance, and calibration that are to be performed by ECB personnel. Each topic is discussed in detail in subsequent sections of this document. (See Section 2.37.1.4, Table 1, for an Activity Summary.)

2.37.1.3 Set-Up of BAM 1020

In order for the BAM 1020 to operate as a FEM to the FRM 2.5 monitor, certain hardware and firmware parameters must be utilized and are listed below:

2.37.1.3.1 Hardware

- The inlet must be equipped with an EPA-designated $PM_{2.5}$ Very Sharp Cut Cyclone (VSCC™-A by BGI, Inc.). The Met One stock number for the VSCC™ is BX-808.
- The inlet must be equipped with a standard EPA PM_{10} inlet head. Met One BX-802.
- The unit must be equipped with a BX-596 ambient temperature and barometric pressure combination sensor. This is used for flow control and flow statistics.
- The unit must be equipped with the internal BX-961 automatic flow controller, and must be operated in Actual (volumetric) flow control mode.
- The unit must be equipped with a BX-827 (110V) Smart Inlet Heater, with the heater RH regulation set-point set to 35%, and Delta-T control disabled.
- The unit must be equipped with the 8470-1 rev D or later tape control transport assembly with close geometry beta source configuration. All BAM-1020 units manufactured after March 2007 have these features standard. The unit must be operated with standard glass fiber filter tape.
- The BX-302 zero filter calibration kit is a required accessory. This kit must be used to verify or update the BKGD (background) value upon unit deployment and periodically thereafter, as described in the BX-302 manual.

2.37.1.3.2 Firmware

- The unit generates hourly average measurements. The $PM_{2.5}$ concentration is calculated (external to the BAM through a datalogger) as a daily average of the 24 one hour concentration measurements made by the BAM-1020.
- The unit must be equipped with firmware revision 3.2.4 or later.
- The BAM-1020 must be operated in proper accordance with the operation manual, revision F or later. A supplemental BGI Inc. manual is also supplied with the VSCC™.
- The COUNT TIME parameter must be set for 8 minutes.
- The SAMPLE TIME parameter must be set for 42 minutes.

2.37.1.3.3 Set-Up Parameters

The instrument parameters must be set-up initially as follows:

```
        Station ID, 1             (user set)
          Firmware, 3236-02 3.2.5
                 K, 01.000        (factory set)
              BKGD, 00.000        (factory set)
               usw, 00.301        (factory set)
               ABS, 00.823        (factory set, value near 0.800)
             Range, 1.000         (mg/m3)
            Offset, -0.005
             Clamp, -0.005
        Conc Units, ug/m3
         Conc Type, ACTUAL
        Count Time, 8

                cv, 01.000          (factory set)
                Qo, 00.000          (factory set)
         Flow Type, ACTUAL
        Flow Setpt, 0016.7
          Std Temp, 25
         Temp Mult, 1.0000
         Pres Mult, 1.0000
         Flow Mult, 1.0000
  High Flow Alarm, 20
   Low Flow Alarm, 10

         Heat Mode, AUTO
          Heat OFF, 20
           RH Ctrl, YES
          RH SetPt, 35
            RH Log, YES             (monitored on channel 4)
           DT Ctrl, NO
          DT SetPt, 10
            DT Log, yes             (monitored on channel 5)

        BAM Sample, 42
        MET Sample, 60
        Cycle Mode, Early cycle
```

```
    Fault Polarity, NORM
    Reset Polarity, NORM
       Maintenance, OFF
      EUMILRNFPDCT
      111111111111
                AP, 000150
          Baud Rate, 9600
    Printer Report, 2
                e3, 00.000          (factory set)
                e4, 15.000          (factory set)

Channel,         1,       2,       3,       4,       5,       6,
Sensor ID,     255,     255,     255,     255,     255,     255,
Channel ID,    255,     254,     254,     255,     255,     254,
Name,           BP, Shelter T. notused,    RH,   Delta,      AT,
Units,        mmHg,       C,   nothing,     %,       C,       C,
Prec,            1,       1,       0,       0,       1,       1,
F Volts,     2.500,   2.500,   0.000,   0.500,   2.500,   2.500,
Mult,        1.000,   1.000,   1.000,   1.000,   1.000,   1.000,
Offset,     0525.0,   0.000,   0.000,  -25.81,  0095.8,  -040.0
Vect/Scalar,     S,       S,       S,       S,       S,       S,
Inv Slope,       N,       N,       N,       N,       N,       N,

Calibration       Offset            Slope
      Flow        -0.253            0.977
      AT          0.600
      BP          -1.146
      RH          0.000
      FT          0.000
```

2.37.1.3.4 Siting Requirements

Selection of a proper site for the BAM-1020 is critical for accurate and representative measurements. In many cases, these items must be correctly addressed in order for the collected data to be acceptable for regulatory requirements, such as EPA PM_{10} and $PM_{2.5}$ equivalent methods. Specifications for the site selection can be found in EPA documents EPA-450/4-87-007 May 1987 “Ambient Monitoring Guidelines for Prevention of Significant Deterioration”, EPA-454R-99-022 December 1997 “Guidance for Network Design and Optimum Site Exposure for PM2.5 and PM10” as well as 40 CFR, Part 58. In any case, the Code of Federal Regulations takes precedence.

The final siting of the monitor must be approved by the Central Office, Project and Procedures Branch supervisor.

A) Inlet Height:

- **The inlet should be located in the “breathing zone”, between 2 and 15 meters above ground level.** If the BAM is to be installed in an enclosure at ground level, then the inlet height must be two meters or greater above the ground.
- If the inlet is located on (or through) a rooftop, the total height must be no more than 15 meters from the ground level. The inlet height must be two meters above roof surface of the building that the unit is installed in. This matches the specified

inlet height of most FRM samplers.

- **If the BAM-1020 is to be co-located with other particulate instruments, such as FRM filter-based samplers or other BAM units, then the air inlet must be the same height as the inlet of the other samplers.**
- The maximum allowable total inlet tube length is 16 feet between the BAM-1020 and the bottom of the inlet head. Interconnecting tubes up to 8 feet long each are available for custom installation if needed.

B) Inlet Radius Clearance:

- The BAM-1020 inlet must have a one-meter radius free of any objects that may influence airflow characteristics, including the inlet of another instrument.
- **If the BAM-1020 is to be collocated with other BAM or FRM samplers, then the monitors must be spaced such that the inlets are no closer than one (1) meter and no more than four (4) meters apart.**
- If installing near a PM_{10} SSI Hi-Volume sampler, then the distance between the inlet of the BAM-1020 and the Hi-Vol should be no less than two (2) meters.
- The BAM-1020 inlet must be located at least two meters from obstructions such as short walls, fences, and penthouses.
- If located beside a major obstruction (such as a building) then the distance between the unit and the building must be equal to twice the height that the building extends above the inlet.
- The inlet must be at least 10 meters from the drip line of any overhanging trees.
- The inlet must have at least 90% of the monitoring path exposed to unrestricted airflow. The predominant direction of concentration movement during the highest concentration season must be included in the 90 % unrestricted airflow path.

C) 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 BAM-1020. Even sources of filtered air must not blow across the inlet.

D) Spacing from Roadways: The BAM-1020 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 BAM inlet.

- The actual distance from major roads is based on average daily traffic count and this distance is determined from a diagram provided in Appendix E to Part 58 of 40 CFR. The minimum distance for a traffic count of approximately 17,000 would be 17 meters. This is the case for DAQ sites at this time.
- The 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 affects of re-entrained fugitive dust.

2.37.1.3.5 Enclosure Selection

The BAM-1020 unit is designed to be mounted in a weatherproof, level, vibration free, dust free, and temperature controlled environment where the operating temperature is between 0^{o} C and $+50^{o}$ C, and where the relative humidity is non-condensing and does not exceed 90%. There are two standard configurations described below for providing a weatherproof location in which to install the unit.

A) A walk-in building or mobile shelter with a flat roof: This is often a pre-fabricated shelter, a trailer shelter, or a room in an existing permanent building. The BAM is mounted on a bench-top or in an equipment rack, often with a variety of other instruments installed in the same shelter. The inlet tube of the BAM must extend up through the roof with appropriate hardware. AC power must be available. Instructions for this type of installation are included in this section of the manual.

B) BX-903 environmentally controlled mini enclosure: Sometimes nicknamed "dog house" enclosures, these small pre-fabricated enclosure are just big enough for the BAM and related accessories, and are installed on the ground or on the roof of a larger building. The BX-903 is supplied with a heater and air conditioner. These enclosures are custom designed by Met One to accept the BAM-1020, and are supplied with a supplemental setup and installation manual.

NOTE: The air temperature inside any enclosure in which a BAM-1020 is installed must be held as constant as possible over the course of each sampling hour. This is important because the unit measures the beta particles through a small gap of air around the filter tape at the beginning and the end of each hour. If the air temperature inside the enclosure has changed by more than about 2 degrees C during this time, the concentration measurement can be affected on the order of several micrograms. **Met One recommends logging the air temperature inside the enclosure to monitor this effect. The exact temperature is not critical as long as it fluctuates by no more than ± 2 ºC during any one- hour sampling period. The BAM will be configured with a temperature sensor inside of the shelter, which will be monitored through Channel 2 on the BAM 1020 instrument.**

2.37.1.3.6 Electrical Connections

All electrical connections will be made following the instructions provided in the BAM 1020 manual in Section 2.6 (Electrical Connections), Section 8.1 (Analog Concentration Output Signal), Section 8.3 (Telemetry and Error Relays) and Section 9.1 (Serial Port Connections and Setting). These connections will be used for: synchronizing the BAM clock with the ESC 8832 data logger; daily polling of alarm errors; recording the internal temperature of the shelter; recording the analog concentration signal; recording the hourly ambient temperature and barometric pressure and downloading data from the instrument memory.

2.37.1.4 BAM 1020 Maintenance and Calibration Activities

All maintenance and calibrations activities will be documented in an instrument specific bound logbook that resides at the ECB facility. Each activity that is performed will be manually recorded in the logbook as to date performed and what activity was performed (i.e., "zero background test", "volumetric flow check/calibration" etc.). The actual results of each activity will be recorded on a separate "Calibration and Maintenance" spread sheet form that will be developed by the ECB person responsible for the BAM. This form will be similar to that previously developed for the TEOM, but specific to the BAM. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". Scheduled Activities are summarized in Table 1.

2.37.1.4.1 Semi-Annual Activities

The following procedures will be performed at least once every 6 months by ECB staff:

2.37.1.4.1.1 Field "BKGD" (Zero Background Tests)

The BACKGROUND value is the factory-set zero correction (slope offset) for the BAM-1020 concentration. **BAM-1020 units set up to monitor $PM_{2.5}$ must have this value "field" verified (and adjusted if necessary) upon deployment, and at least twice per year afterwards using the BX-302 Zero Filter Calibration Kit.** The test corrects the BKGD value to compensate for minor variations caused by local conditions such as grounding and shelter characteristics. This results in optimum accuracy at lower concentrations typical of $PM_{2.5}$ levels. The test also provides information about the zero noise levels of the unit being tested.

This "zero-correction" is determined by running the unit for at least 72 hours with a 0.2 micron zero filter on the inlet (Part No.BX-302 with instructions). The concentration values over this time are averaged (using an Excel spread sheet), and the **BKGD is the negative** of this average. All of the stored and displayed data contains this correction. The BKGD value is typically between 0.000 and -0.005 mg/m^3 (-5 ug/m^3). **Warning: This is a unit-specific calibration value, which may significantly affect the accuracy of the data.** Note: The BKGD value is not to be confused with the OFFSET (range offset) value in the SETUP > SAMPLE menu.

The test involves running the BAM in its normal operating environment with a zero filter on the inlet for at least 72 hours. If the newly determined value is within ± 1 ug/m^3 of the current value, then no update is required. If not, the new value is to be entered into the BAM. To assist the ECB with this procedure, the site operator will be required to place the "background filter" test device on the inlet and after a 72 hour period, download the data and send the file to the ECB. The test should not be performed during a period of rapidly changing weather. A complete set of instructions for the test is included with the BX-302 kit. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record

(file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.1.2 Volumetric Flow and Ambient Temperature/Pressure Sensor Calibration

Actual (volumetric) flow calibration is very fast and easy. This type of calibration can only be performed on BAM units which have an automatic flow controller and a BX-592 or BX-596 ambient temperature sensor on channel 6. The unit must also have the "Flow Type" set to ACTUAL in the SETUP > CALIBRATE menu or the flow calibration screen will not be visible. These calibrations are performed as described below:

```
MULTIPOINT FLOW CALIBRATION
             TARGET    BAM      STD
          AT:          23.8    23.8 C
          BP:           760     760 mmHg
<CAL> FLOW 1: 15.0     15.0    15.0 LPM
      FLOW 2: 18.3     18.3    18.3 LPM
      FLOW 3: 16.7     16.7    16.7 LPM
  CAL       NEXT      DEFAULT    EXIT
```

"Actual" Flow Calibration Screen

1. From the MAIN menu, enter the TEST > FLOW menu as shown above. The nozzle will lower automatically when this screen is entered. The "BAM" column is what the BAM-1020 measures for each parameter, and the "STD" column is where you will enter the correct values from your reference standard. The <CAL> symbol will appear next to the parameter selected for calibration. **The ambient temperature (AT) and pressure (BP) must be calibrated first**, as the BAM uses these to calculate the air flow rate in the actual (volumetric) mode.
2. Measure the ambient temperature with a certified reference standard positioned near the BX-596 ambient temperature probe. Enter the value from a certified reference standard into the STD field using the arrow keys. Press the CAL hot key to correct the BAM reading. The BAM and STD values should now be the same.
3. Press the NEXT hot key to move the <CAL> indicator to the BP field, and repeat the same steps for barometric pressure.
4. After the temperature and pressure readings are correct, remove the PM_{10} and $PM_{2.5}$ heads from the inlet tube and install a certified reference flow meter onto the inlet. Press the NEXT hot key to move the <CAL> indicator to the first flow point of 15.0 LPM. The pump will turn on automatically. Allow the unit to regulate the flow until the BAM reading stabilizes at the target flow rate. Enter the flow value from your standard into the STD field using the arrow keys. Press the CAL hot key to correct the BAM reading. **NOTE: The BAM reading will not change to match the STD**

until after you have entered all three calibration points.

5. Press the NEXT hot key to move the <CAL> indicator to the second flow point of 18.3 LPM and repeat the process.
6. Press the NEXT hot key to move the <CAL> indicator to the third flow point of 16.7 LPM and repeat the process. Enter the flow value and press <CAL>.
7. **When all of the calibrations are complete, the BAM-1020 flow readings should match the traceable flow standard reading at 16.7 LPM, +/- 0.1 LPM. Exit the calibration menu.**

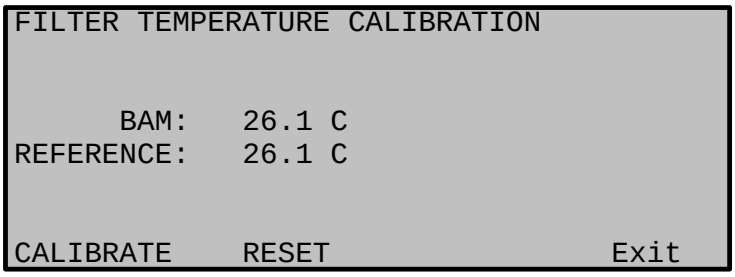
The DEFAULT hot key can be pressed to reset the user calibration from the selected parameter and replace it with a factory setting. If any of the FLOW parameters are selected, the DEFAULT key will reset the calibrations of all three flow points. This feature can be used to start over with a calibration if difficulty is encountered. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.1.3 Filter Temperature and Filter Humidity Sensor Calibration

These sensors are located downstream of the filter tape and are calibrated as follows:

Temperature Sensor: From the MAIN menu, select the TEST > FILTER-T screen which is used to calibrate the filter temperature sensor located in the air stream beneath the filter tape. When this screen is entered, the BAM will automatically raise the nozzle and turn the pump on. This allows ambient air to enter through the narrow slot between the nozzle tip and the filter support vane to equilibrate the filter temperature sensor. **Some amount of air may also be inadvertently drawn in through the sample inlet tube. To eliminate the possibility of any heating effects from the Smart Heater, any air flow from the sample tube is eliminated by sealing the inlet with the leak check flow shut off adapter.** Obtain a stable temperature reading of the air that would be representative of the air being drawn into the instrument. Allow the pump to run for at least 5 minutes to allow the sensor to equilibrate. Press the RESET hot key to clear out any past calibration values, then enter the ambient temperature from your reference (NIST traceable) standard into the REFERENCE field and press the CALIBRATE hot key. The BAM reading should change to match within **+/- 1 deg C**. The RESET hot key can be used to revert to default calibrations and start over if difficulty is encountered. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity

and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.



The FILTER-T Test Screen

Relative Humidity Sensor: From the MAIN menu, select the TEST > RH screen to calibrate the filter relative humidity sensor located in the air stream beneath the filter tape. This screen works just like the FILTER-T screen described above. Allow the pump to run for at least 5 minutes to allow the sensor to equilibrate. Press the RESET hot key to clear out any past calibration values, then enter the ambient room relative humidity from your reference (NIST traceable) standard into the REFERENCE field and press the CALIBRATE hot key. The BAM reading should change to match within **+/- 4% RH**. The RESET hot key can be used to revert to default calibrations and start over if difficulty is encountered. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.1.4 Leak Check

Leak checks must be performed at least monthly by the operators, whenever the filter tape is changed and during semi annual calibration/maintenance activities performed by the ECB. Almost all air leaks in the BAM system occur at the nozzle where it contacts the filter tape. **The BAM-1020 has no way of automatically detecting a leak at this interface**, because the airflow sensor is located downstream of the filter tape. There will normally be a very 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 total air volume calculation (and the concentration) to be incorrect. **Allowing a leak to persist may cause an unknown amount of data to be invalidated!** Perform the following steps to check for leaks:

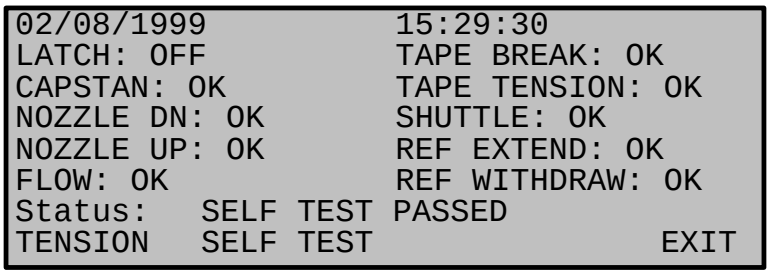
1. **Remove only the PM_{10} head** from the inlet tube. Install a leak test valve onto the **inlet of the VSCC**. Turn the valve to the OFF position to prevent any air from entering the inlet tube.

2. In the TEST > TAPE menu, advance the tape to a fresh, unused spot.
3. In the TEST > PUMP menu, turn the pump on. The flow rate should drop below 1.0 LPM. If the leak flow value is 0.75 LPM or greater, then the nozzle and vane need cleaning, or there may be another small leak in the system.
4. Resolve the leak and perform the check again. A properly functioning BAM with a clean nozzle and vane will usually have a leak value of about 0.5 LPM or less using this method, depending on the type of pump used. **The acceptance criteria, for the DAQ, is currently set at a flow of 0.75 LPM or less.**
5. Turn the pump off, remove the leak test valve, and re-install the inlet heads.
6. If a flow rate greater than 0.75 LPM is observed, leaks can be further isolated using a soft rubber sheet with a ¼" hole in it, such as Met One Part No. 7440. The filter tape is removed and the rubber seal inserted with the hole centered under the nozzle. The seal allows the leak check to be performed as usual (from the VSCC through the entire system), but without any leakage through the filter tape. The leak value should drop to 0.2 LPM or less with this method. A leak can be further isolated by using the part of the seal without the hole. This allows a leak test to be performed only on the system below the filter tape junction. If the nozzle and vane are thoroughly clean, but a leak persists, then refer to the trouble shooting section of the BAM manual (Section 7.0) for some troubleshooting steps for leaks in other parts of the flow system. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.1.5 Self Test

The BAM-1020 has a built-in self-test function which automatically tests most of the tape control and flow systems of the unit. The self-test should be run right after each time the filter tape is changed, if the operator suspects a problem with the unit and after all semi annual maintenance/calibration activities have been completed. More detailed diagnostic menus are also available in the BAM, and those are described in the troubleshooting section (Section 7 of the manual).

The self-test feature is located in the TAPE menu. Press the SELF TEST soft-key to start the test. The tests will take a couple of minutes, and the BAM-1020 will display the results of each tested item with an **OK** or a **FAIL** tag. If all of the test items are OK, the status will show SELF TEST PASSED as shown in the drawing below. If any item fails, the status will show ERROR OCCURRED. The parameters that are automatically tested are described below.



Self-Test Status Screen

LATCH: This will show OFF if the photo interrupter senses that the pinch rollers are unlatched as in normal operation. It will show ON if the roller assembly is latched in the up position. The tape cannot move if the rollers are up!

CAPSTAN: The unit will rotate the capstan shaft forward and backwards and will check if the photo interrupter sees the shaft rotating. The Capstan shaft is what moves the filter tape back and forth.

NOZZLE DN: The unit will attempt to lower the nozzle, and will check if the nozzle motor has moved to the down position with a photo interrupter. It is possible for the nozzle to become stuck in the UP position, even if the nozzle motor has successfully moved to the DOWN position. For this reason, proper inlet alignment and maintenance is necessary.

NOZZLE UP: The unit will attempt to raise the nozzle, and will check if the nozzle motor has moved to the up position with a photo interrupter.

FLOW: The unit will attempt to turn the pump on, and will then look for output on the flow sensor. This test takes about a minute and will fail if the pump is not connected.

TAPE BREAK: The unit will move the supply and take-up motors to create slack in the filter tape, and look for proper operation of the tensioner photo interrupters.

TAPE TENSION: The unit will tension the filter tape, and then check the condition of the tensioner photo interrupters.

SHUTTLE: The unit will attempt to move the shuttle beam left and right, and will check the motion with a photo interrupter.

REF EXTEND: The unit will attempt to extend the reference membrane, and will check the motion with a photo interrupter.

REF WITHDRAW: The unit will attempt to withdraw the reference membrane, and will check the motion with a photo interrupter.

The responsible ECB personnel will document the actual results on the “BAM Calibration and Maintenance” electronic form. The resulting electronic record (file) will reside on the technician’s laptop computer. All files generated will be electronically “backed-up” on a monthly basis by copying to a BAM “folder” on a DAQ network server. Each file will have a unique name such as “MIL_093008_semiannual”. A description of the activity and date performed will be

manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.1.6 Replace/Clean Pump Muffler

The pump muffler is a filter device that screws onto the pump exit and is used to reduce pump noise. If it becomes clogged with debris, the pump will have difficulty providing the necessary vacuum to maintain the correct flow and will shorten the pump life. This device must be removed, inspected and cleaned if necessary or replaced. The pump will operate adequately without the device, but will be noisier. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.2 Annual Activities

The following activities will be performed at least once every twelve months:

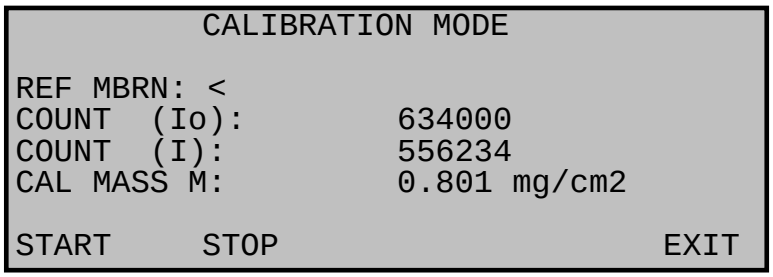
2.37.1.4.2.1 Clean Internal Debris Filter

The internal debris filter is located inside of the instrument, just upstream of the mass flow controller (MFC), and is used to prevent any particulate matter, mainly filter tape fibers from entering the MFC. Remove the instrument cover, locate and remove the filter and using a can of compressed air (or equivalent) remove any accumulated particulate. Reinstall the filter and replace the instrument cover. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.2.2 Clean Membrane Span Foil

This maintenance activity is recommended by the manufacturer to be performed on an annual basis, but is ***optional*** as long as "D" errors (Deviant Membrane Density) are not reported on a reoccurring basis. Tests of the "Reference Membrane Span Check" occurs automatically every sample cycle, but an independent test can be performed through the TEST > CALIBRATE screen. This test must be run if the BAM-1020 has been logging "**D"** errors. Each BAM-1020 has an individually weighed membrane, and this mass **(m)** is measured and displayed during this test. Compare the value from this test with the ABS value on the calibration sheet for your unit. (The ABS value will be different for each instrument, but will be nominally 0.800.) The values must match within 5%. If not, the most common cause is a dirty membrane (dust or lubricant on the foil). The membrane

can be carefully cleaned with canned air or a clean water rinse. **Alcohol is not used because it leaves a film.** CD cleaner works well for badly soiled membranes. **Caution: The membrane foil is a thin sheet of polyester and is extremely fragile!** It must be replaced if damaged. **Contact the Service department for cleaning/replacement instructions.**



The CALIBRATE Test Screen

To perform this independent test, enter the TEST>CALIBRATE screen from the MAIN menu and press the START soft key.

START: This soft-key starts the test cycle. Counting will immediately begin. After 4-minutes the **I_0 count** will stop, the membrane will extend, and the **I count** will begin. At the completion of the test the counting will stop and the mass of the membrane will be calculated. The total elapsed time is about 8.1 minutes per test.

REF MBRN: This indicates if the reference membrane is extended **(>)** or withdrawn **(<)** from the beta particle path.

COUNT (I_0): The total 4-minute beta count through the filter tape only, no membrane.

COUNT (I): The total 4-minute beta count through both the filter and the membrane.

CAL MASS M: This is the calculated calibration mass **(m)** derived from the two count values, the mass which the unit has just measured for the membrane. An average of several of these values should match the **ABS** value within 5%.

The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.2.3 Analog Output

From the MAIN menu, the TEST > DAC screen is used to test the function of the analog concentration output voltage and the DAC (digital-to-analog-converter) electronics. Use the up/down arrow keys to set the voltage anywhere from **0.000 to 1.000 volts** in 0.100 increments. Measure the VOLT OUT +/- terminals on the back of the BAM-1020 with a high quality voltmeter and verify that the actual voltage matches the BAM display value within ±0.001 volts at each point. Then attach the voltmeter to the input of your datalogger and repeat the test to verify that the correct voltages get to the input. If the analog output does not match the value on the TEST > DAC screen, contact the Service department for instructions. Note: 1 millivolt = 1 microgram of concentration in most applications. The DAC output cannot go negative. Perform the test at four (4) output voltages: 10% FS, 25% FS, 50% FS and 80% FS. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.2.4 Smart Heater

From the MAIN menu, the TEST > HEATER screen is used to force the Smart Heater ON or OFF for testing purposes. The heater takes several minutes to heat up or cool down noticeably. The heater automatically turns off upon exit from the screen.
The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.3 Other Activities (Every 2-Years)

The following activities will be performed at least once every 24 months. The responsible ECB personnel will document the actual results on the "BAM Calibration and Maintenance" electronic form. The resulting electronic record (file) will reside on the technician's laptop computer. All files generated will be electronically "backed-up" on a monthly basis by copying to a BAM "folder" on a DAQ network server. Each file will have a unique name such as "MIL_093008_semiannual". A description of the activity and date performed will be manually entered into a bound logbook that is specific for each instrument and resides at the ECB facility.

2.37.1.4.3.1 Rebuild vacuum pump (refer to manual for instructions and parts);
2.37.1.4.3.2 Clean sample inlet tube;

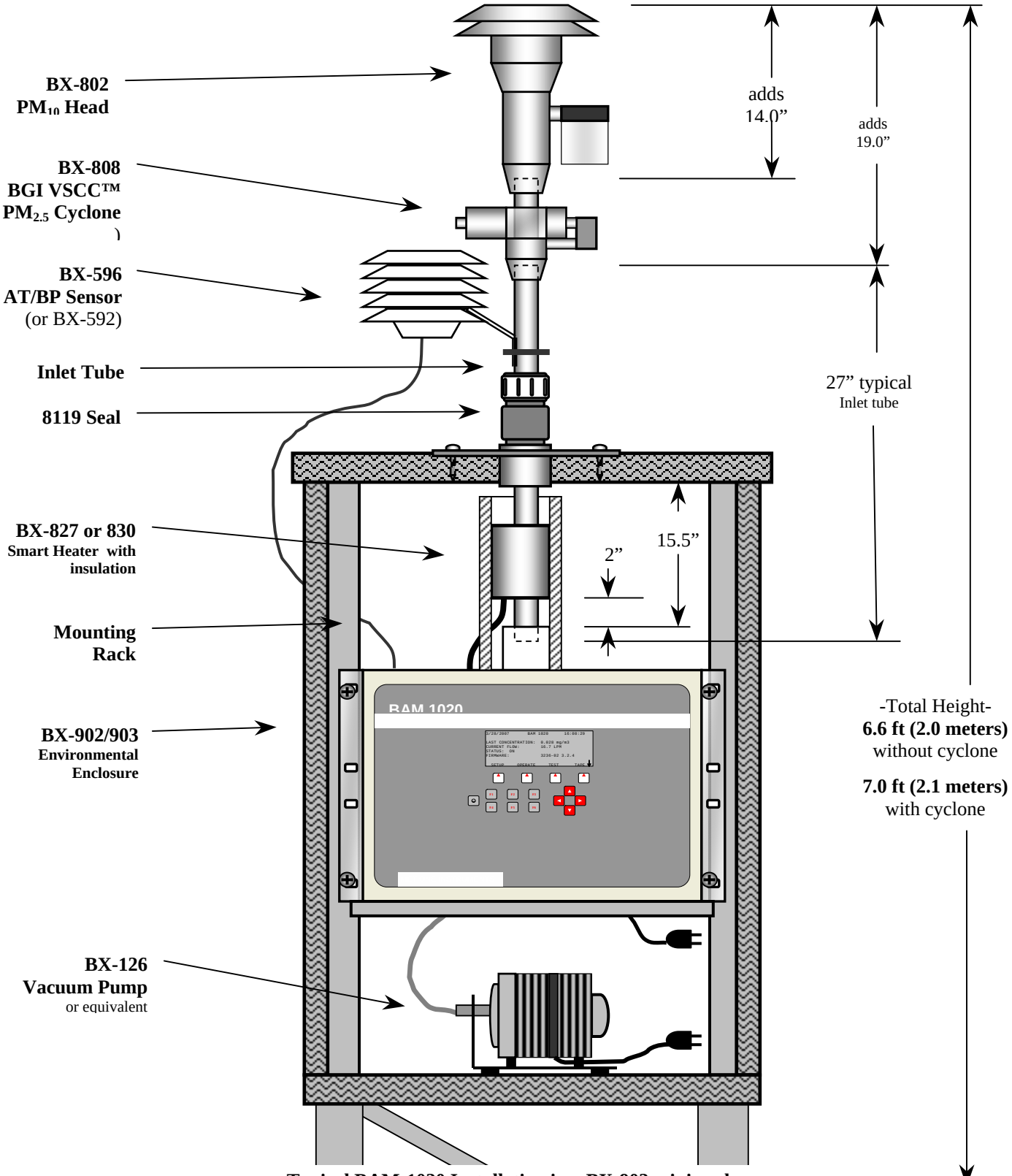
2.37.1.4.3.3 Replace nozzle "O" rings (refer to manual for instructions and parts);
2.37.1.4.3.4 Replace pump tubing.

Table 1 Scheduled Activities

Item #	Activity	Frequency	Details found in Section…
1	Verify Set-up Parameters	At Deployment and every six months	2.37.1.3.3
2	Zero Background Test	At Deployment and every six months	2.37.1.4.1.1
3	Flow Calibration	At Deployment and every six months	2.37.1.4.1.2
4	Filter RH and Temperature Calibration	At Deployment and every six months	2.37.1.4.1.3
5	Leak Check	Every six months	2.37.1.4.1.4
6	Perform Self Test Procedure	Every six months	2.37.1.4.1.5
7	Replace/Clean Pump Muffler	Every six months	2.37.1.4.1.6
8	Clean/replace Internal Filter	Annually	2.37.1.4.2.1
9	Clean Membrane Span Foil	As Needed	2.37.1.4.2.2
10	Check Analog Output	Annually	2.37.1.4.2.3
11	Check Smart Heater Operation	Annually	2.37.1.4.2.4
12	Rebuild Vacuum Pump	Every 2 Years or as needed	2.37.1.4.3.1
13	Replace Nozzle "O" Rings	Every 2 Years or as needed	2.37.1.4.3.3
14	Clean Inlet Tubing	Every 2 Years or as needed	2.37.1.43.2
15	Replace Pump Tubing	Every 2 Years or as needed	2.37.1.4.3.4

Appendix A

Diagram of BAM 1020 System



Typical BAM-1020 Installation in a BX-902 mini enclosure