STATEWIDE STANDARD OPERATING PROCEDURE FOR MET ONE BAM 1020 SEMI-CONTINUOUS $PM_{2.5}$ MONITOR AND SEMI-CONTINUOUS PM_{10} MONITOR

STATE OF FLORIDA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF AIR MONITORING

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to document the Met One Beta Attenuation Mass Monitor, Model 1020 (BAM-1020) procedures used by Florida (State and Local ambient air monitoring organizations) to measure PM 2.5 and PM10 concentrations. The goal of this SOP is to familiarize all personnel in the Florida PQAO personnel with the installation, configuration, and operation procedures of the BAM 1020 sampler for data collection. The U. S. Environmental Protection Agency (EPA) has designated the BAM 1020 Beta sampler as an equivalent method for the determination of 24-hour average PM2.5 concentrations in ambient air (Designation Number EQPM-0308-170) and for the determination of 24-hour average PM10 concentrations in ambient air (EQPM 0798-122). These procedures are intended to provide information for the BAM 1020 when used either as a PM2.5 or PM10 analyzer.

These procedures are consistent with the data management requirements specified in the Quality Assurance Project Plan for the PM2.5 Monitoring Program, DEP QAPP-001A, Rev.3, (PM2.5 QAPP). The final data are verified and submitted to the Florida Air Monitoring Assessment System (FAMAS), then uploaded by the Florida Department of Environmental Protection (FDEP) to the US EPA Air Quality System (AQS).

2.0 SCOPE AND APPLICABILITY

The purpose of this SOP is to provide a set of uniform protocols for installation, operation, maintenance, calibration, quality control (QC), and quality assurance (QA) of the Met One BAM 1020 Continuous Ambient Particulate Monitor. The procedures are based on instructions set forth in the manufacturer's manual; requirements specified in Appendix A to 40 CFR Part 58, and the FDEP Quality Assurance Project Plan. They are intended for use by the operator during routine, periodic, and unscheduled visits to the monitoring station.

2.1 PM_{10} FRM Requirements

The Met One Instruments, Inc. Model BAM-1020 is designated as an equivalent method for PM_{10} monitoring by the United States Environmental Protection Agency on August 3, 1998

Designation Number: **EQPM-0798-122**

To meet the FEM requirements for measurement of PM10 mass as described in the 40 CFR Parts 50 and 53, the BAM-1020 must be configured as follows:

- The BAM-1020 is operated to obtain a daily average of the hourly measurements, with a filter change of one hour.
- The inlet must be equipped with the standard BX-802 EPA PM10 Size-Selective Inlet.
- The unit must be used with standard glass fiber filter tape.
- The unit may be operated with or without any of the following options: BX-823 inlet tube extension, BX-825 heater kit, BX-826 230V heater kit, BX-828 roof tripod, BX-902 exterior enclosure, BX-903 exterior enclosure with temperature control, BX-961 mass flow controller, BX-67 internal span membrane system.
- The $PM_{2.5}$ FEM BAM-1020 configuration maintains the existing PM_{10} designation. To use a PM2.5 FEM BAM-1020 for PM10, simply remove the VSCC cyclone and set the CONC TYPE to STD. See Section 6.3.
- BAM-1020 units must be set to STD, and a FLOW TYPE setting to ACTUAL for PM_{10} sampling.

2.2 PM2.5 FEM Requirements

The Met One Instrument, Inc. Model 1020 is designated as an equivalent method for PM2.5 monitoring by the United States Environmental Protection Agency on March 12, 2008

Designation Number: **EQPM-0308-170**

To meet the FEM requirements for measurement of PM2.5 mas as described in the 40 CFR Parts 50 and 53, the BAM-1020 must be:

- operated for 24 1-hr average measurements;
- equipped with firmware revision 3.2.4 or later;
- operated with or without an inlet tube extension (BX-823);
- operated with or without external enclosures BX-902 or BX-903;
- operated in accordance with the BAM-1020 Particulate Monitor Operation Manual, revision F or later, and the Very Sharp Cut Cyclone (VSCC™) supplemental manual;
- equipped with a BX-596 ambient temperature and barometric pressure combination sensor;
- equipped with an internal BX-961 automatic flow controller operated in actual (volumetric) flow control mode;
- equipped with a standard BX-802 EPA PM_{10} inlet head and a BGI VSCC™ (VSCC-A);
- equipped with a BX-827 (110V) or BX-830 (230V) Smart Inlet Heater with the heater RH regulation set point at 35% and the temperature control set to "off";
- equipped with the 8470-1 revision D or later tape control transport assembly with close geometry beta source configuration;
- used with standard glass fiber filter tape;
- configured for a COUNT TIME parameter of 8 minutes and a SAMPLE TIME parameter of 42 minutes; and
- supplied with a BX-302 zero filter calibration kit. (This kit must be used to audit the BKGD (background) value upon unit deployment and periodically thereafter, as described in the BX-302 manual.)

3.0 SUMMARY OF THE METHOD

The method for the BAM-1020 configured for $PM_{2.5}$ FEM monitoring includes sampling of ambient air through a standard EPA PM_{10} inlet head and a VSCC-A at a volumetric flow rate of 16.7 LPM. A Smart Heater attached to the inlet system, and controlled by relative humidity (RH) measured at the filter tape, minimizes positive artifact from water sorption in humid environments. Particles in the air stream are collected and measured on quartz fiber filter tape. $PM_{2.5}$ concentrations and sampling attribute data are reported hourly.

The BAM-1020 employs the principle of beta ray attenuation to measure particulate mass concentration in ambient air, and reports hourly mass concentrations in user-selectable units of mg/m^3 or $\mu g/m^3$. Particles are collected by pulling a measured volume of ambient air through glass fiber filter tape. A ^{14}C element emits a constant source of high-energy electrons (beta particles) that pass through the clean filter tape before sample collection and again after the filter collects PM. The beta particles are attenuated as they collide with particles on the filter, and the beta particles are detected and counted by a sensitive scintillation detector. The attenuation through the clean filter is compared with that of the particle-laden filter. The decrease in signal detected by the BAM-1020 scintillation counter is inversely proportional to the mass loading on the filter tape, and, together with the known air volume, allows calculation of mass concentration. The spooled filter tape allows extended monitoring periods without operator intervention.

4.0 DEFINITIONS AND CONVERSION FACTORS

Most technical terms in this SOP are defined as they are introduced so that their meaning is made clear in context.

Audit - is often used in a generic way to mean check, inspect, examine, or assess, and many SOPs use the term to refer to QC procedures, such as flow checks or leak checks, that are carried out by field operators during the course of normal operations and maintenance.

Quality Control (QC) - refers to the operational techniques and activities used to fulfill the requirements for quality.

Quality Assurance (QA) - refers to the planned or systematic activities used to provide confidence that the requirements for quality are fulfilled. An independent audit is an example of a QA activity. QA protocols determine whether the QC procedures are adequate.

Verification - review of interim work steps to ensure they are acceptable and to determine whether the system is consistent, adheres to standards, uses reliable techniques, and performs the selected functions in the correct manner.

Validation - determining whether the system complies with requirements, performs the functions for which it is intended, and meets the organization's goals and user needs. It is a determination of correctness of the data and is usually performed only periodically (e.g., quarterly) or at the end of a project.

5.0 HEALTH AND SAFETY PRECAUTIONS

Safety precautions should be heeded during the setup and operation of the BAM-1020. General safety rules regarding electricity and power tools should be observed. Working at above-ground elevations and on ladders is frequently required and precautions should be taken to avoid falls and personal injury. Users of the BAM-1020 need to be aware that it contains a radioactive component. The following paragraph is a direct quote from the BAM-1020 Operation Manual (Rev H):

> "The Met One Instruments BAM-1020 contains a small ^{14}C (Carbon 14) beta radiation-emitting source. The activity of the source is **60 µCi** ±15µCi (micro curies), which is below the "Exempt Concentration Limit" as defined in 10 CFR Section 30.70–Schedule A. The owner of a BAM-1020 is not required to obtain any license in the United States to own or operate the unit. The owner of a BAM-1020 may elect to return the entire unit to Met One Instruments for recycling of the ^{14}C source when the unit has reached the end of its service life, although the owner is under no obligation to do so. Under no circumstances should anyone but factory technicians attempt to remove or access the beta source. The beta source has a half-life of about 5730 years, and should never need to be replaced. Neither the ^{14}C source nor the beta particle detectors are serviceable in the field. Should these components require repair or replacement, the BAM-1020 must be returned to the factory for service and recalibration."

6.0 INTERFERENCES

The BAM-1020 is a robust instrument that has minimal potential interferences. Poor siting, inadequate electrical grounding, and poor control of the RH of the sampled air in humid environments are known sources of interference. Interferences arising from improper siting can be avoided by exercising care during site selection (Section 9.3), and grounding and RH issues should be addressed during the setup process (Sections 9.5.1 and 9.5.10).

Contaminated or dirty quartz filter tape can also interfere with measurements. Proper storage and handling of the filter tape will minimize this interference (Section 9.6.3).

7.0 PERSONNEL QUALIFICATIONS

While no special qualifications or training are necessary to operate the BAM-1020, a basic understanding of the principles governing ambient air sampling is assumed. The QA procedures detailed herein require an understanding of the BAM-1020 flow system, calibration protocol, and recognition that out-of-the-ordinary protocols, such as the bi-annual background zero test, must be followed to satisfy $PM_{2.5}$ FEM requirements.

EPA Quality Assurance Guidance Document 2.12 Monitoring PM2.5 in Ambient Air Using Designated Reference of Class 1 Equivalent Methods, (Quality Assurance Guidance Document 2.12, Monitoring PM2.5 in the Ambient Air Using Designated Reference or Class 1 Equivalent Method, U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Assessment Division RTP, NC 27711, January 2016) covers the specifics of field personnel qualifications, and provides the following general guidelines. All field operations personnel should be familiar with environmental field measurement techniques. Those who service the PM sampler in the field must be very conscientious and attentive to detail in order to report complete and high-quality $PM_{2.5}$ data. Persons qualified to perform $PM_{2.5}$ field operations should be able to

- Operate the $PM_{2.5}$ sampler;
- Calibrate, audit, and troubleshoot the $PM_{2.5}$ sampler; and use common methods to determine temperature, pressure, and flow rate.
- Understand the operation and use of temperature, pressure and humidity calibration instruments. The operator must be trained to follow and use the ancillary SOP documents such as the temperature, pressure and humidity operations.

Operators are required to read the manufacturer's instruction manual supplied with the monitor to become familiar with the various controls and components prior to attempting any operation described in this procedure. The manufacturer's manual contains useful operation, maintenance, and diagnostic information that may not be contained in this SOP.

8.0 EQUIPMENT AND SUPPLIES

The following equipment and supplies are necessary for ambient air monitoring of PM2.5 and PM10 with the BAM 1020 particulate monitor.

1. BAM 1020 Monitor – The BAM 1020 monitor that is designated by the EPA as an official reference or equivalent method and bears the designation sticker on the instrument. The instrument must be setup as described in the manufacturer's manual for EPA designation Number: EQPM-0308-170 for PM2.5 and Designation Number: EQPM-0798-122 for PM10.
2. Flow Meter - Used to verify sample flow rate during flow verification and calibrations.
3. Sample filter tape as specified in the EPA designation for the BAM 1020.
4. Thermometer – Used to verify or calibrate the temperature of the BAM 1020 monitor.
5. Barometer – Used to verify or calibrate the pressure of the BAM 1020 monitor.
6. Sample Shelter – Of adequate size to house the equipment. The shelter temperature must be maintained at ≥ to 0°C to ≤ 50°C. Typically, the monitor is housed in a shelter that operate at ≥ to 20°C and ≤ 30°C.
7. Sample Shelter Temperature Probe – Used to document the internal sample shelter temperature stays within specification. Calibrated initially and then annually against a NIST traceable primary or secondary temperature standard, resettable with accuracy to ± 1°C.
8. Minimum/Maximum Thermometer – Used as a backup to the temperature probe. Calibrated initially and then annually against a NIST traceable primary or secondary temperature standard, resettable with accuracy to ± 1°C.
9. Data Logger or alternate data acquisition instrument – Used to electronically record the BAM 1020 monitor outputs. Calibrated against a NIST traceable voltage standard initially and then annually.
10. Computer – Capable of communicating with the data logger. The computer is used for electronic documentation of calibrations, checks, maintenance, and other operations using MS-Excel, data acquisition or other software.
11. Logbooks, Log Forms, etc. – Must be designated to accommodate all pertinent information in an organized manner. These are typically on Excel spreadsheets, but other software products capable of recording the documentation per this SOP are acceptable.

9.0 INSTALLATION AND STARTUP

9.1 Installation

Installation of the BAM 1020 monitor involves modifying the roof of the shelter to permit the BAM 1020 sample tube to extend from inside the shelter to the outside with a straight supplied 9 feet metal tube. The following modification are required for proper installation.

CAUTION: *When lifting the instrument, use a procedure appropriate to lifting a heavy object, such as, bending at the knees while keeping your back straight and upright. Do not attempt to lift the instrument by the cover or other external fittings.*

WARNING *The BAM 1020 is supplied with a three-wire grounding cord. Under no circumstances should this grounding system be defeated.*

9.1.1 Roof Modification

Determine the location where the BAM inlet will pass through the roof of the enclosure and drill a 2 ¼ or 2/ ½ diameter hole through the roof. Make sure the hole is directly above where the BAM inlet receiver is to be located as the inlet tube must be perfectly vertical. Ensure that there is adequate clearance between the shelter wall and the BAM 1020 for accessing the rear or side of the instrument. The diagrams shown in Figure 9-1 and Figure 9-2 below, taken from the BAM 1020 manual directly, show how the monitor is installed and clearances for the monitor. The roof inlet and waterproof flange can be ordered to be installed during manufacturer of a new shelter.

9.1.2 Waterproof Flange

Install the waterproof flange with all-weather caulking. The flange is available for purchase from Met One, model number BX-801. Secure the flange with four lag bolts. Apply Teflon tape to the thread of the gray plastic watertight fitting, and screw it into the roof flange.

9.1.3 Inlet Tube

Remove the cap and rubber seal from the flange assembly. Lower the inlet tube through the flange assembly in the roof and into the inlet receiver on the BAM 1020 monitor. Make sure the tube is firmly seated.

9.1.4 Inlet Alignment

It is very important for the inlet tube to be perpendicular to the top of the BAM. The nozzle may not close properly if there is binding caused by misalignment. A simple check is to rotate the inlet tube back and forth by hand (before tightening the roof flange seal or the BAM inlet set screws). If the inlet tube is installed straight, then the tube should rotate fairly easily while inserted into the BAM. If it does not rotate, check the inlet tube for vertical alignment or move the BAM slightly.

Figure 9-1. Typical BAM 1020 installation in a walk-in trailer

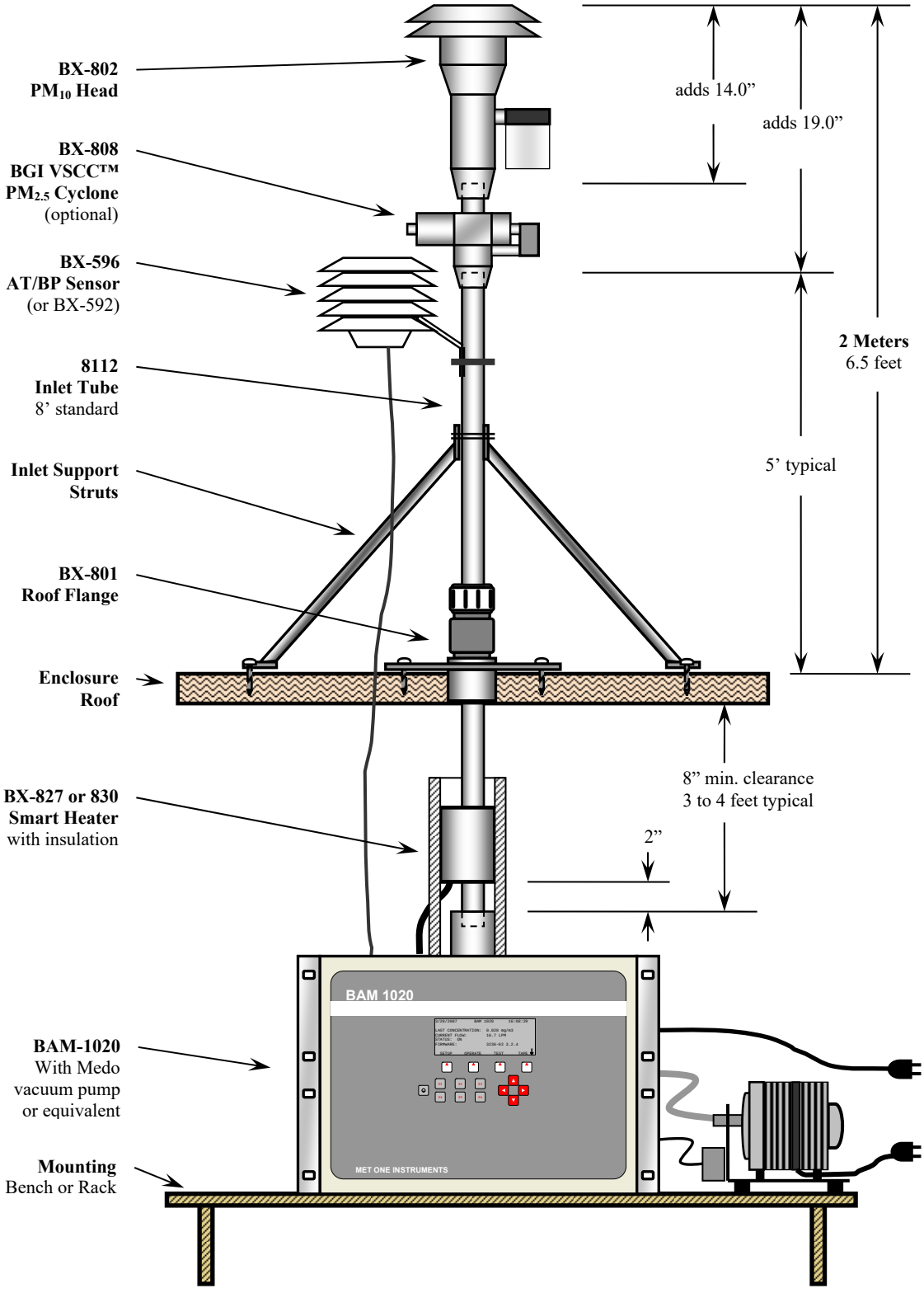
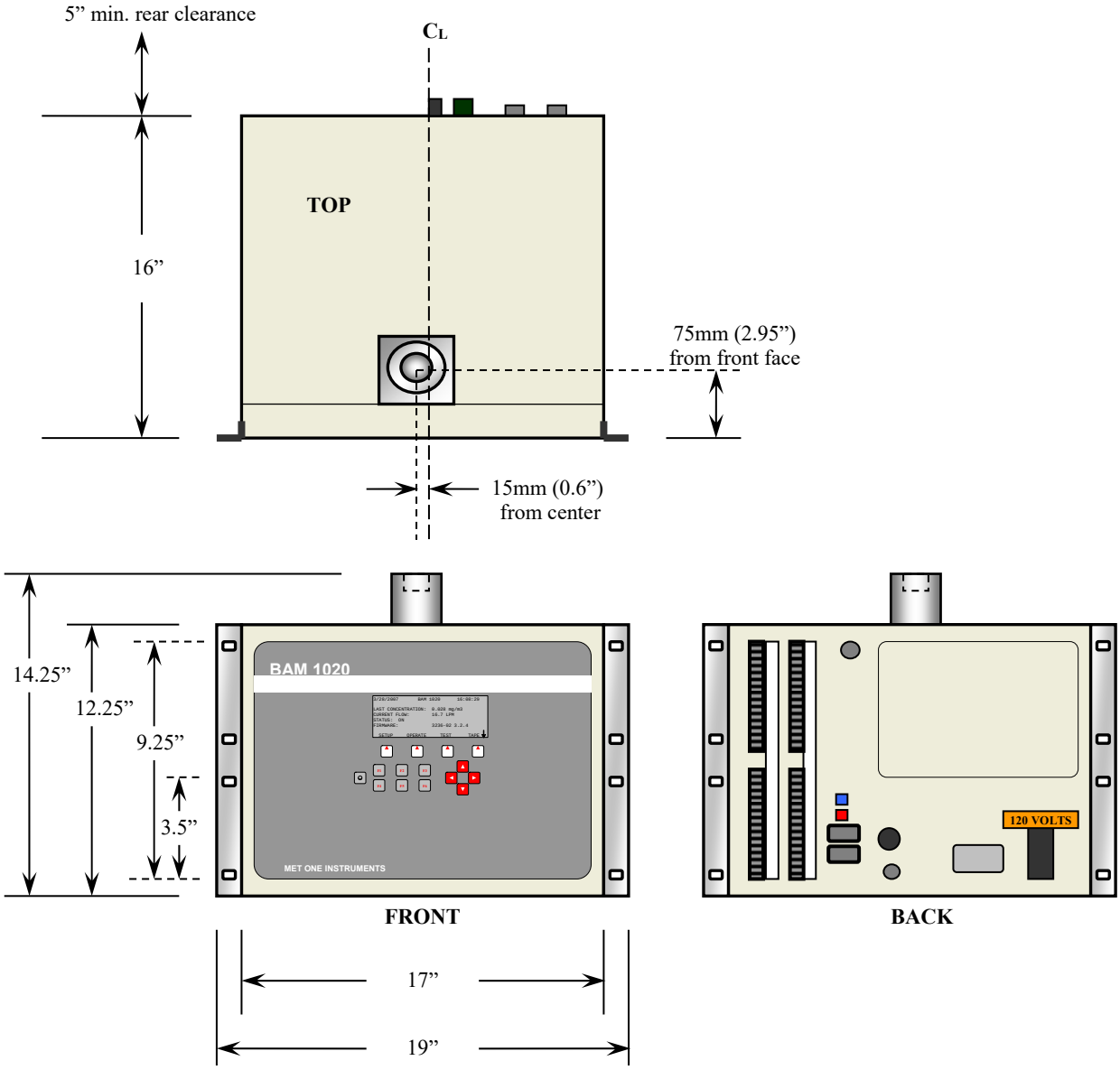


Figure 9-2. BAM 1020 Mounting Directions



9.1.5 Smart Heater

Before tightening the inlet tube in place, the BX-827 or BX-830 smart inlet heater (used on most BAM-1020 units) must be installed on the tube. Pull the inlet tube up out of the inlet receiver, and pass the tube through the hole in the heater body (the cable end is the bottom). Then re-insert the inlet tube into the BAM. Position the bottom of the heater unit **two inches** above the top of the inlet receiver on the BAM, and securely tighten the two set screws in the heater to fasten it to the tube. Included with the smart heater is a 12" tube of insulation. The tube is split down its length for easy application. Wrap the insulation around the heater body and peel back the adhesive cover strip to secure in place. The insulation may be cut to fit if needed.

9.1.6 Inlet Tightening

Slide the black rubber seal and white cap down over the top of the inlet tube and into the roof flange. It is easier if you wet the rubber seal with water or alcohol first. Tighten the white plastic cap.

9.1.7 Support Struts

The BX-801 inlet kit usually comes with two angled aluminum struts to support the inlet tube above the roof and prevent the inlet from moving in the wind. These struts are typically fastened (about 90 degrees apart) to the inlet tube with a supplied hose clamp. The bottom ends of the struts should be fastened to the roof with lag bolts. Note: Some installations may require different methods or hardware for supporting the inlet tube. Support the tube in the best manner available.

9.1.8 Temperature Sensor

Most BAM-1020 units are supplied with a BX-592 (temperature) or BX-596 (temperature and pressure) sensor, which is attached to the inlet tube above the roof. The sensor cable must feed into the shelter to be attached to the BAM. In some cases it is easiest to simply drill a 3/8" hole through the roof about six inches away from the inlet tube, then feed the cable through the hole and caulk around it to prevent leaks. In some applications there may be a better place to feed the cable into the shelter. Route the cable into the shelter in the best manner. The BX-596 attaches directly to the inlet tube with a supplied U-bolt. If using a BX-592, fasten the aluminum cross-arm to the inlet tube, and clip the temperature probe to the cross-arm.

9.1.9 Inlet Separator Heads

If the BAM-1020 is to be configured for FEM $PM_{2.5}$ monitoring, then install the $PM_{2.5}$ Very Sharp Cut Cyclone (BGI VSCC™) onto the top of the inlet tube beneath the BX-802 PM_{10} head. For PM_{10} monitoring, the BX-802 is installed on the inlet tube with no cyclone. Use O-ring lubricant as needed.

9.1.10 Inlet Tube Grounding

Tighten the two ¼"-20 set screws located in the inlet receiver of the BAM to secure the inlet tube. This also creates a ground connection for the inlet tube, as static electricity can build up on the inlet under certain atmospheric conditions and cause errors. This is very important in areas near electromagnetic fields, high voltage power lines, or RF antennas. Check the connection by scraping away a small spot of the clear anodizing near the bottom of the inlet tube, and use a multi-meter to measure the resistance between this spot and the "CHASSIS" ground connection on the back of the BAM. It should measure just a couple of Ohms or less if a good connection is made with the set screws. If not, remove the set screws and run a ¼-20 tap through the holes. Then reinstall the screws and check the electrical resistance again. **Note:** Anodized aluminum surfaces are non-conductive.

9.2 Electrical Connections

Each BAM-1020 is factory configured to run on either 120 or 230 volt AC power. Your shelter must be wired for power to run the BAM, the pump, and any other AC powered devices such as computers, data loggers, other instruments, etc. A good earth-ground connection point near the BAM unit is highly recommended. Have a qualified electrical contractor provide power according to all local codes. After the BAM unit is installed and power is provided, connect the electrical accessories as follows. Refer to the diagram below.

9.2.1 BAM-1020 Power

Plug the BAM-1020 into the AC power mains with the provided power cord. Note: There are two fuses located inside the BAM power switch module, which can be accessed by prying open the small cover surrounding the switch.

9.2.2 Battery Back-up Supply

Met One recommends plugging the BAM-1020 unit into a battery back-up UPS (uninterruptible power supply) since even a momentary power outage will reset the BAM and stop an entire hour's worth of data collection. A small computer-style UPS of 300 Watts or greater is usually sufficient. The vacuum pump usually does not need to be connected to the UPS as the BAM can compensate for short pump power outages. If the pump is to be backed up as well, then a much larger UPS is required.

9.2.3 Chassis Ground

Connect one of the terminals marked "CHASSIS" on the back of the BAM to a ground point as close as possible to the instrument. Use the green/yellow ground wire supplied with the unit. A ground rod is recommended, but a cold water pipe, or junction box safety ground are other possible connection points. Note: the BAM-1020 also uses the standard safety ground line inside the power cord.

9.2.4 Pump Connection

Decide on a location to place the air pump. The best location is often on the floor under the rack or bench, but it may be up to 25 feet away if desired. Route the air tubing from the pump to the back of the BAM unit, inserting it firmly into the compression fittings on both ends. The tubing should be cut to the proper length and the excess saved for replacements. The pump is supplied with a 2-wire signal cable which the BAM uses to turn the pump on and off. Connect this cable to the terminals on the back of the BAM marked "PUMP CONTROL" The end of the cable with the square black ferrite filter goes to the BAM, but the polarity of the wires is not important. Either the red or black wire can go to either terminal. Connect the other end of the cable to the two terminals on the pump.

9.2.5 Temperature/Pressure Sensor

The BX-596 or BX-592 temperature sensor should already be installed onto the inlet tube, and the sensor cable routed to the BAM-1020. Connect the cable to the terminals on the back of the BAM as follows:

Table 9-1. Temperature/Pressure Terminal Connection

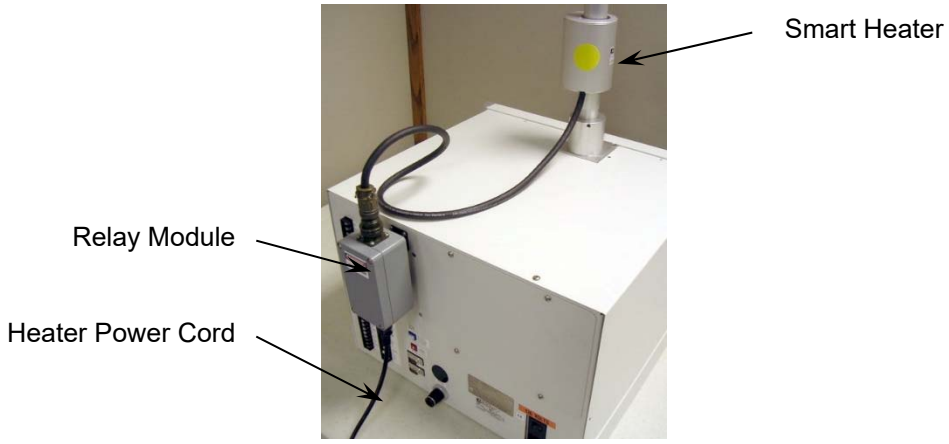
BX-596 AT/BP Sensor	
Wire Color	**Terminal Name**
Yellow	Channel 6 SIG
Black/Shield	Channel 6 COM
Red	Channel 6 POWER
Green	Channel 6 ID
White	Channel 7 SIG

BX-592 AT Sensor	
Wire Color	**Terminal Name**
Yellow or White	Channel 6 SIG
Black/Shield	Channel 6 COM
Red	Channel 6 POWER
Green	Channel 6 ID

9.2.6 Smart Heater

There are two possible versions of the BX-827/830 Smart Heater electrical connection. If the Smart Heater kit was supplied with a gray relay module (units built after May, 2008 as shown below), then plug the relay module into the mating control connector on the back of the BAM, and connect the Smart Heater to the green connector on the top of the relay module. The relay module has its own power cord to supply power to the heater. **Note:** The connector on the back of the BAM has been changed to prevent connecting the heater directly to the BAM.

On previous versions of the kit, the Smart Heater assembly simply plugs directly into the back of the BAM-1020, and power is supplied internally by the BAM. If the BAM is configured like this, then simply plug the heater cable directly into the mating green metal connector on the back of the BAM-1020.



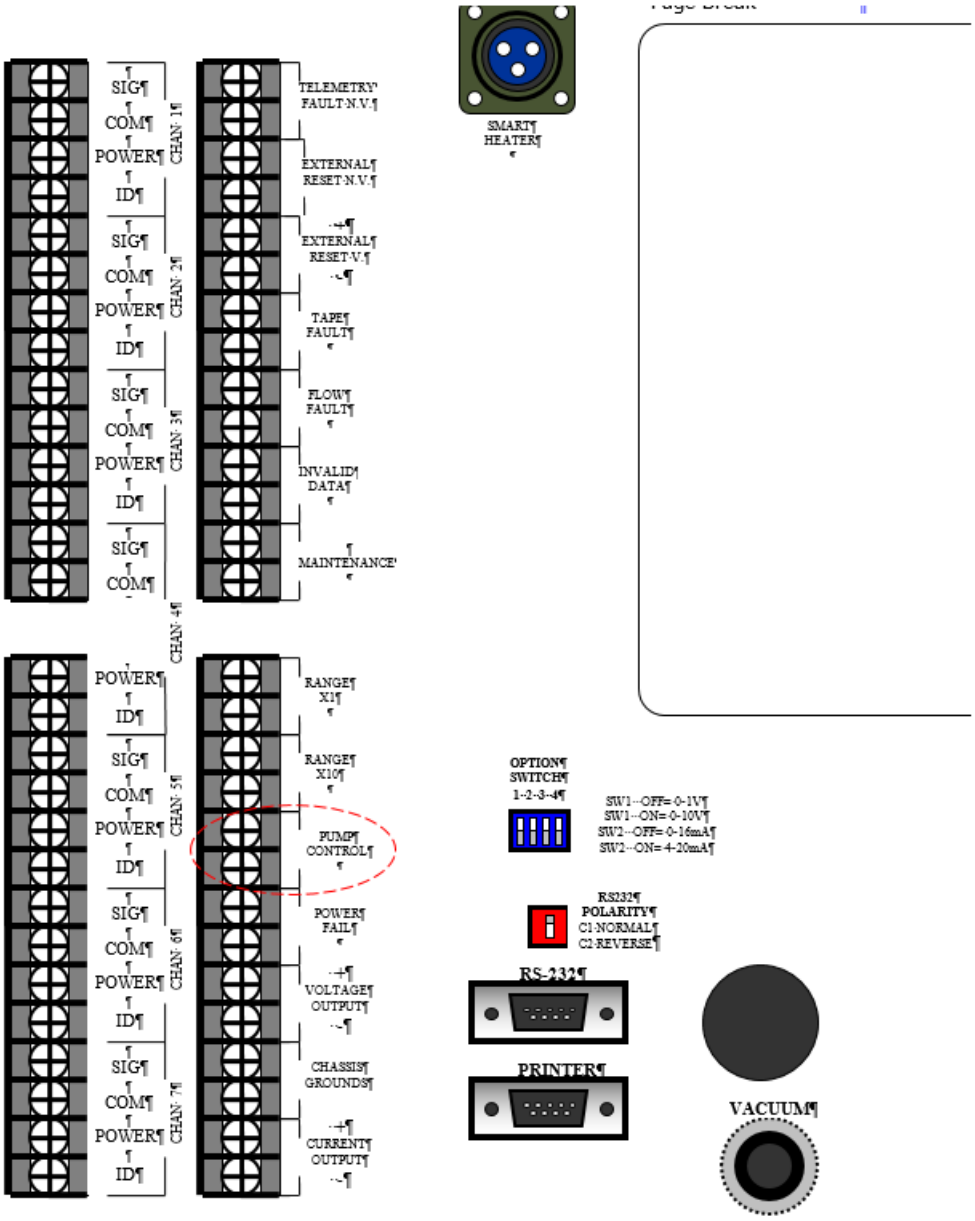
9.2.7 Optional Data Logger Connection

The BAM-1020 has an analog output which may be recorded by a separate data logger if required. Connect the terminals on the back of the BAM marked "VOLT OUT +, -" to the data logger with 2-conductor shielded cable. Polarity must be observed. Information on configuring this analog output is provided in of the manual. A current loop output is also available.

9.2.8 Other Connections

The BAM-1020 has a variety of telemetry I/O relays and error relays located on the back of the unit. There are also RS-232 data connections. These items are described in Section 8 and Section 9 of this manual.

Figure 9-3. BAM-1020 back panel connections



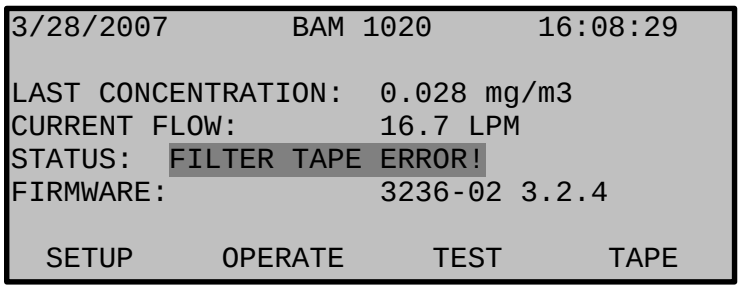
9.3 Startup

This section describes the process for setting up and configuring your BAM-1020, as well as the basic steps required to put the unit into operation

9.3.1 Power On

The BAM-1020 has a power switch located on the back of the unit directly above the power cord. Verify that the unit is plugged in to the correct AC voltage, and that any electrical accessories are correctly wired before turn the unit on. (Section 2.6) When power is switched on the main menu screen should appear after a few seconds as shown below. The unit will probably flash an error indicating that there is no filter tape installed. Note: Units running revision 3.1 or earlier firmware will display a slightly different main menu screen.

Figure 9-4. BAM 1020 Main Menu Screen



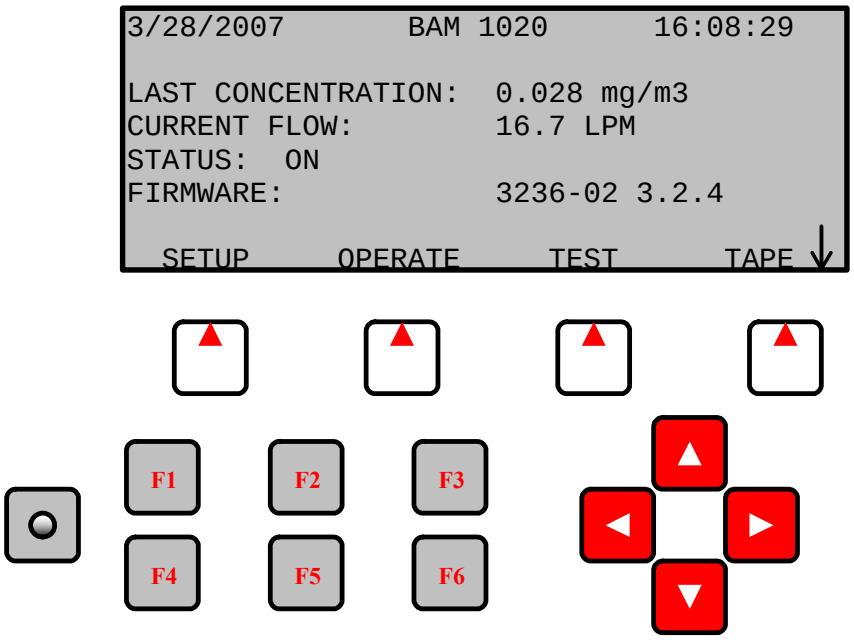
9.3.2 Warm-up

The BAM-1020 must warm up for **at least one hour** before an operation cycle is started. This is because the beta detector contains a vacuum tube which must stabilize every time the unit is powered up. This also allows the electronics to stabilize for optimal operation. This applies any time the unit is powered up after being off for more than a moment. Instrument setups and filter tape installation can be performed during this warm up time. Most agencies choose to discard the first few hours of concentration data after the BAM is powered up.

9.3.3 Using the Keypad and Display

When the BAM-1020 is powered up it will display the main (top level) menu on the LCD display. This menu is the starting point for all functions of the BAM-1020 user interface.

Figure 9-5. BAM 1020 User Interface



A. *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, modifications made within a menu are usually not saved unless a SAVE soft-key is pressed. EXIT is also another common soft-key function.

B. *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.

C. *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.

D. *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. See section 3.12. 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. See Section 3.13. 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.

9.3.3 Filter Tape Loading

A roll of filter tape must be loaded into the BAM-1020 for sampling. One roll of tape should last more than 60 days under normal operation. It is important to have several spare rolls of tape available to avoid data interruptions. Met One recommends wearing lint-free cotton gloves when handling the tape. Some agencies save the used rolls of tape for post-sampling analysis, although there is no guarantee that the sampled spots have not been contaminated. Used filter tape should never be "flipped over" or re-used! This will result in measurement problems. Loading a roll of filter tape is a simple matter using the following steps:

A. Turn the BAM-1020 on and enter the TAPE menu (Note: This is not the same as the TEST > TAPE menu). If the nozzle is not in the UP position, press the TENSION soft-key to raise the nozzle.

B. Lift the rubber pinch roller assembly and latch it in the UP position. Unscrew and remove the clear plastic spool covers.

C. An empty core tube **MUST** be installed on the left (take-up) reel hub. This provides a surface for the used tape to spool-up on. Met One supplies a plastic core tube to use with the first roll of tape. After that, you can use the empty core tube left over from your last roll to spool-up the new roll. Never fasten the filter tape to the aluminum hub.

D. Load the new roll of filter tape onto the right (supply) reel, and route the tape through the transport assembly as shown in the drawing. Attach the loose end of the filter tape to the empty core tube with cellophane tape or equivalent.

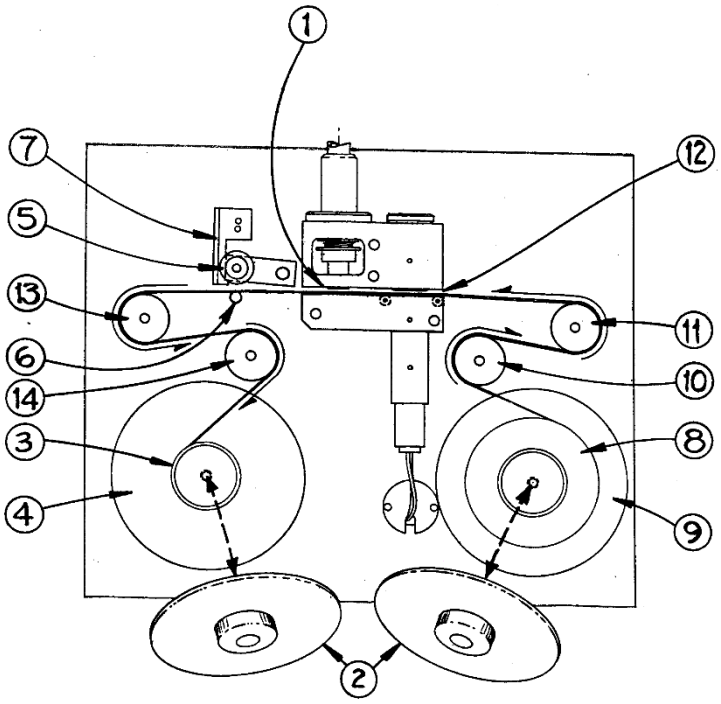
E. Rotate the tape roll by hand to remove excess slack, then install the clear plastic spool covers. The covers will clamp the rolls to the hubs to prevent slipping.

F. Align the filter tape so that it is centered on all of the rollers. Newer units have score marks on the rollers to aide in visually centering the tape.

G. Unlatch and lower the pinch roller assembly onto the tape. **The BAM will not function if the pinch rollers are latched up, and it has no way of automatically lowering the roller assembly!**

H. Press the TENSION soft-key in the TAPE menu. The BAM-1020 will set the tape to the correct tension and alert you if there was an error with the process. Exit the menu.

Figure 9-6. Filter Tape Loading Diagram



9.3.4 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, and it can also be used if the operator suspects a problem with the unit. More detailed diagnostic menus are also available in the BAM, and those are described in the troubleshooting section.

The self-test feature is located in the TAPE menu. Press the SELF TEST soft-key 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.

Table 9-2. Self-Test Status Screen

```
02/08/1999          15:29:30
LATCH: OFF          TAPE BREAK: OK
CAPSTAN: OK         TAPE TENSION: OK
NOZZLE DN: OK       SHUTTLE: OK
NOZZLE UP: OK       REF EXTEND: OK
FLOW: OK            REF WITHDRAW: OK
Status:   SELF TEST PASSED
TENSION   SELF TEST              EXIT
```

A. 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!

B. 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.

C. 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.

D. 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.

E. 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.

F. 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.

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

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

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

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

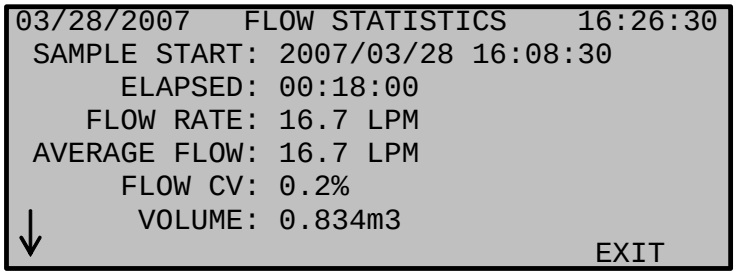
9.3.5 Starting a Measurement Cycle

When the preceding steps of Section 3 have been completed, exit out to the main top level menu. The "Status" line should display "ON" (no errors). If so, the unit will start at the top (beginning) of the next hour, and will continuously operate until it is commanded to stop. The unit will stop if the operator sets the Operation Mode to OFF or enters any of the SETUP or TEST menus. The BAM-1020 will also stop itself if a non-correctable error is encountered, such as broken filter tape or failed air flow.

9.3.6 The Flow Statistics Screen

In the main BAM-1020 menu screen a small arrow has been added to the bottom right corner. When the DOWN ARROW button is pressed the BAM will display the FLOW STATISTICS screen as shown below. This screen displays the flow, temperature and pressure statistics for the current measurement cycle. Pressing the ARROW DOWN key while in this screen will further scroll down to the remaining parameters below the viewable area of the display. This screen will not interrupt the sample. This function is only available with revision 3.2 firmware or later.

Figure 9-7. Flow Statistics Screen

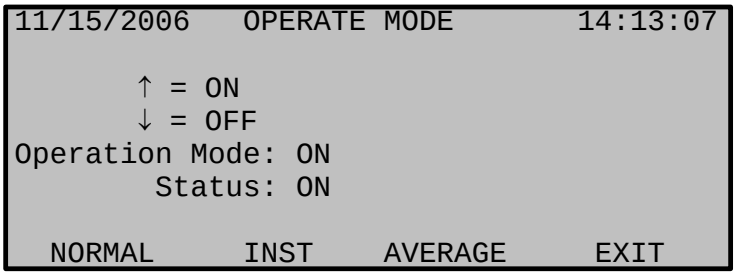



```
    FLOW FLAG: OFF
           AT: 23.0
       MAX AT: 23.5
   AVERAGE AT: 23.0
       MIN AT: 22.5
           BP: 760
       MAX BP: 765
   AVERAGE BP: 760
       MIN BP: 755
```

9.3.7 The OPERATE Screen

Press OPERATE soft-key at the main menu to enter operate menu as shown below. This will not interrupt the sample if already running.

Figure 9-8. The OPERATE Screen

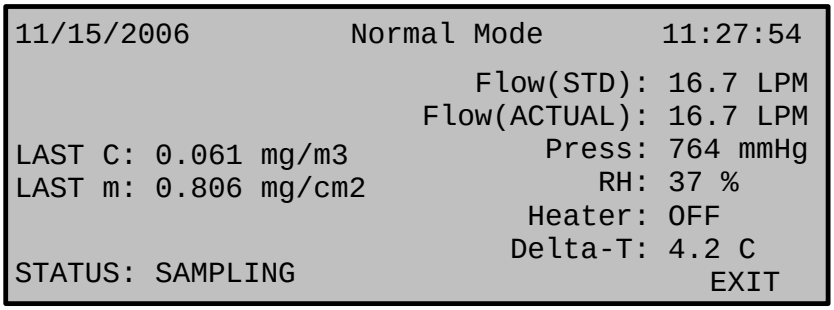


The DOWN arrow can be used to set the Operation Mode from ON to OFF. This will stop the measurement cycle, but will not power-down the BAM-1020. NOTE: If the operator sets the Operation Mode to OFF, or the unit stops itself due to an error, it will still automatically set the mode back to ON at the top of the hour, and try to run a new cycle! The only ways to prevent the unit from automatically starting a cycle are to power off the unit, leave the unit in a TEST or SETUP menu, or leave the pinch rollers latched in the UP position. The OPERATE menu has three soft-key options for viewing the operating status and sensor measurements while the unit is operating: NORMAL, INST, and AVERAGE.

9.3.8 The NORMAL Screen

Normal Mode is the primary operation screen which displays most of the important parameters of the sample progress in one place, as shown below. Many operators leave their BAM-1020 in the NORMAL screen whenever the unit is operating, instead of the Main menu.

Figure 9-9. Normal Screen Mode



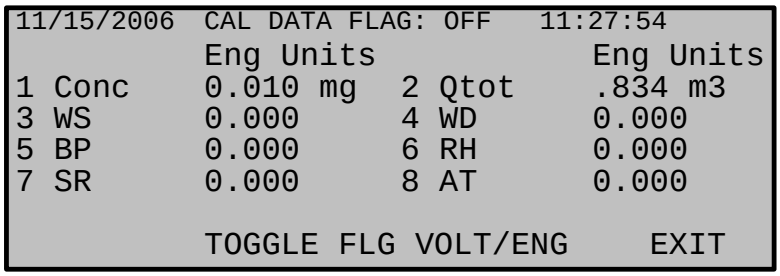
9.3.9 The NORMAL Menu

The **LAST C** value indicates the last concentration record, updated at the end of the cycle. The **LAST m** value indicates the last measured value of the reference span membrane. The value should be very close or equal to the expected value (**ABS**). The other values are instantaneous measurements.

9.3.10 The INSTANTANEOUS Screen

The INST (Instantaneous) screen displays the instantaneous data values that are being measured by the BAM-1020. This screen is useful for monitoring the current reading of any optional sensors that may be connected to the BAM-1020. All values except **Conc.** (concentration) and **Qtot** (total flow volume) are current. The Conc. represents the concentration of the last period. Qtot represents total flow volume during the last period.

Figure 9-10. Instantaneous Screen



The TOGGLE FLG soft-key in this menu allows the user to set the CAL DATA FLAG value ON or OFF, which marks the data with an **M** flag to indicate a maintenance was performed during that time, such as a flow check. This feature is rarely used, as most maintenance requires stopping the sample anyway. The VOLT / ENG soft-key toggles the displayed values between units and voltages, useful for diagnostic checks on external sensors.

9.3.11 The AVERAGE Screen

The AVERAGE screen is similar to the INST screen, except that the concentration and flow are presented as the previous hour's average values, and the six external data logger channels are average values over the average period of the data logger (set by the MET SAMPLE value in the SETUP > SAMPLE menu - usually also 60 minutes).

9.4 Acceptance Testing

After the system components have been verified against the packing list, and the assembled on a bench and an acceptance test should be performed. This acceptance procedure, or bench test, should include a minimum battery of tests to ensure that the equipment is operational and meets manufacturer's specifications before it is moved to the field site.

Note that the 72-hr zero filter, or background, test is required at the time of field installation to meet the requirements of FEM EQPM-0308-170. It is important that this test be conducted at the field site to account for site-specific background noise.

Table 9-3 lists suggested acceptance testing protocols for the FEM BAM-1020 with references to the applicable sections of this SOP and of the BAM-1020 Operation Manual (Rev H).

Table 9-3. Suggested Acceptance Testing Procedures for the FEM BAM-1020

Test	Location	Comments	SOP Section	BAM-1020 Operation Manual (Rev H) Section
Power on and warm up	Bench	Verify that BX-596 temperature and pressure readings are realistic; also a good opportunity to check any auxiliary sensor signals	9.3.1	3.1
Self-test	Bench	Load tape and run self-test	9.3.4	3.5
Leak check	Bench	Should be < 1.5 LPM; preferably ≤ 0.5 LPM	10.1.4	3.7
Zero test	Field	A field zero test is required by the FEM $PM_{2.5}$ designation. A Field zero test in not required for FEM PM_{10}	9.5 (precautions listed)	7.7
Co-location with FRM	Field	If required	—	—

9.5 Zero Background Test

All BAM-1020 units configured as EPA FEM designated $PM_{2.5}$ monitors must have a zero filter background test performed when the unit is first deployed and commissioned at the field site. The test may also be repeated on an annual or semi-annual basis to verify the zero performance of the unit, and is optional for PM_{10} units. The background test requires the BX-302 Zero Filter Calibration Kit, which is included with all $PM_{2.5}$ units.

9.5.1 Setting the BAM for the zero background test

A. The BAM-1020 must be fully installed in the shelter at its permanent sampling site, and it fully configured with all the correct settings and accessories for normal operation, including the smart inlet heater. The unit should be warmed up for about 24 hours before starting the zero test to ensure best stability. Download the current data from the BAM 1020 before starting the background test. When the background is change, the BAM will erase all reading that were collected with the old background vale.

B. Calibrate the BAM Temperature, pressure and flows. Complete the calibrations/verification form DEP 03-20-B.

C. Remove the PM10 inlet and place a zero background filter on top of the VSSC. Make sure that the tygon tubing on the back ground filter is positioned so that water cannot enter the system.

D. Set the background setting in the BAM 1020 to zero. Set the BAM 1020 to sample normally for at least 72 hours.

E. At the end of the 72 hours sampling period, download the BAM 1020 data to a computer. The error log should not contain any error flags

during the test period. Open the downloaded CSV background data using a spreadsheet program. Open the BAM 1020 spreadsheet Form DEP 03-20-D

F. Copy the 72 hours background data into DEP Form DEP 03-20-D.

G. Review the background data for any anomalous values. The form will automatically calculate the new background value. The acceptance criteria embedded into the form will show whether the new background value is acceptable or not. Enter all the required information in Form DEP 03-20-D. If the background value does not meet the acceptance criteria, troubleshoot the instrument and re-run the background determination.

F. Enter the new BKGD value into the SETUP > CALIBRATE menu on the BAM. For example, the average of the data sample below is 0.0021 mg (2.1 µg), so the correct BKGD value is -0.0021.

G. Remove the BX-302 zero filter and reinstall the PM_{10} and $PM_{2.5}$ inlets. The BAM can then be set for collecting data. The background value will be applied to all readings. Note that the BAM 1020 unit will clear all previous reading from the memory.

10.0 MONITOR CALIBRATION AND VERICATION PROCEDURES

The procedures describe in this section are for calibrating the temperature, relative humidity, pressure, volumetric flow, and radiation detector for mass concentration measurements of the BAM 1020 monitor. The calibrations are performed by the operator upon initial installation of the monitor at an air monitoring station, at least twice per calendar year (equally spaced approximately 182-days), and subsequent to a QC check or instrument audit which exceeds the performance criteria specified in the QAPP and this SOP. If an abnormality in the equipment operation is detected during the course of any calibration, immediately halt the calibration procedure and determine the cause of the trouble. If corrective action is required to ensure proper operation, the necessary maintenance must be completed before restarting the calibration procedure.
The monitor verifications are conducted monthly. During the monthly verifications, an as-found leak check, temperature check, ambient pressure check and the flow rate check at 16.7 liters per minute are performed. If any check falls outside the required limits, a full calibration must be performed. An as-is flow verification must be perform before any calibration to bracket data prior to any adjustment or calibration that may impact previously collected data. Plan on starting and completing work between 10 minutes past the hour and the start of the following hour to limit data loss to one hour.
Prior to collecting samples, the monitor shall be calibrated, perform a background evaluation followed by a post calibration after the background evaluation.

The operator will document all calibrations on the corresponding forms specified in the procedures, below. The designated quality assurance personnel must review all calibration logs to verify all data entries and determine data validity.

10.1 BAM 1020 Calibration

10.1.1 One Point Flow Verification

The one point flow verification must be performed at least monthly. Perform a flow verification if the monitor has been collecting data. If it is the initial calibration, an initial flow verification is not required.

A. Secure a copy of the Calibration-Verification form. Complete the identification block with the date, site name, AQS number and all the instruments requested information.

B. Complete the Standards Block with the required information for the flow, temperature, pressure, humidity and Time standard information. Additionally, scroll through the BAM menus and record the setup and calibrations values for the BAM 1020.

C. Record the time the channel was taken off line. Log on to the data acquisition system and record the concentration of the BAM data and navigate to the BAM screen and record the displayed concentration on Form DEP 03-20-B. The difference should me less than 2µg/M3. Implement corrective action to adjust the DAS to match the BAM to ≤ ±2µg/M3.

D. Select **TEST** from the main menu. (Note: This will suspend ambient sampling. Then select **FLOW**. The screen will present prompts to verify Ambient Temperature and Barometric Pressure as well as Volumetric Flow Rate. The <CAL> symbol will appear next to the parameter for calibration. The ambient temperature (AT) and the pressure (BP) must be check first. The standard flow meter measures the flow rate.

E. Measure the ambient temperature with the reference standard temperature probe positioned near the ambient temperature probe. If the ambient temperature is within limits, continue to the pressure verification. Record the as found ambient temperature on the Calibration/Verification Form DEP 03-20-B

F. Press the next hot key to move the <CAL> indicator to the BP field, and repeat the same steps for the barometric pressure. Record the as found ambient temperature on the Calibration/Verification Form. Form DEP 03-20-B

G. If either ambient temperature or pressure is outside the required limits, then a calibration must be performed after the as found flow verification.

H. After the temperature and pressure are recorded, remove the PM10 from the inlet tube and install your reference flow meter onto the inlet. Press the NEXT hot key to move to the <CAL> indicator to the first flow point of 15.0 LPM. The pump will turn on automatically. Press the NEXT hot key to move to 16.7 LPM and allow the flow to stabilize. The BAM reading should be within the required limit. A greater than 3% variance from 16.7 LPM (+/- 0.5 liter/minute), would require adjustment. The flow rate on the reference meter should settle down to 16.7 LPM. Calibrate the BAM if the one point flow verification falls outside the required limit. The data is valid for a flow reading of ≤ ±4% for 16.7 LPM or 16.0 – 17.4 LPM.

I. Document all reading on the flow verification log sheet.

J. If the flow rate is un-adjustable or grossly different by 0.4 LPM from the reference flow rate, then a mechanical or electronic malfunction can be suspected and repairs are necessary.

K. Proper heater operation should also be checked by selecting **TEST>HEATER>HEATER ON.** The heater should warm up. This procedure may be by-passed if the heater already feels warm to the touch. Once heater operation is confirmed, select HEATER OFF.

10.1.2 Leak Check Procedure

Perform a leak test. The leak test must meet the required specification of ≤ ± 1.5 mm Hg. to bracket previously collected data and to continue to proceed

with the calibration. Perform any maintenance necessary to meet the leak test requirement.

The BAM 1020 must be leak checked at least monthly and whenever the filter tape is changed following the procedure below. Document the results of the adjusted flow response and any adjustments made in the log book entry. Failed leak checks must be investigated, repaired and documented. Failed leak check will cause the data to be questionable back to the last successful leak check.

Warning: The typical recommended threshold for invalidating data is an as found leak value before cleaning the nozzle and vane of ≤ 1.5 LPM (BAM 1020-9800 REV. H, page 35). See Section 5.3.3.2 for Nozzle/Stage Cleaning Procedure for leak check failures troubleshooting. Upon repair, a follow-up leak check must be performed.

Note: If the leak cannot be repaired by the operator, the supervisor must be informed immediately.

The leak check is performed as follows:

A. Remove the inlet and place a closed leak check/flow check adapter on the very sharp cut cyclone (VSCC).

B. Select **TEST** from the main menu, followed by **TAPE.** Select **ADVANCE** once. Sampling will stop.

C. Exit to the **TEST** menu again and select **PUMP** and **PUMP ON**.

D. Observe for about 30 seconds. The indicated flow rate should be 1.5 LPM or less. If the flow rate is >1.5 LPM, clean the nozzle/stage (See Section 5.4) and retest.

E. Turn the pump off by selecting **PUMP OFF**

F. Gently open leak check valve and remove adapter.

G. Reinstall, the inlet and sharp cut cyclone.

H. Exit back to the main screen

I. Make a log entry of the result.

J. Clean the nozzle if the leak check is > than 1.0 LPM.

10.1.3 Flow Calibration Procedure

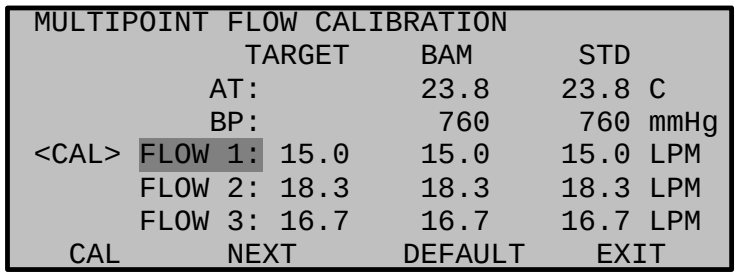
The Flow Rate Calibration **must be** performed **once every six months** following the procedure below. The results of the check must be documented on form DEP 03-20-B. See the BAM 1020 manual BAM 1020-9800 REV. H Section 5.6. The flow rate Calibration is show in the following steps.

A. Verify the flow rate measurement mode by selecting the **SETUP/CALIBRATE** screen.

B. The three (3) choices are **ACTUAL, METERED** and **STD. ACTUAL** should be chosen and saved (if not present on the screen). This will enable the calibration of the instrument using a one point volumetric measurement (at 16.7 liters/minute) using a flow calibrator ensure that data is expressed in milligrams per cubic meters. Once the **ACTUAL** mode has been confirmed, proceed to the **TEST** category on the main menu for flow rate verification and adjustment.

C. Select **TEST** from the main menu. (Note: This will suspend ambient sampling. Note the time down in the calibration form.) Then select **FLOW**. The screen will present prompts to verify Ambient Temperature and Barometric Pressure as well as Volumetric Flow Rate. The <CAL> symbol will appear next to the parameter for calibration. The ambient temperature (AT) and the pressure (BP) must be calibrated first. The Multipoint Flow Calibration screen is shown in Figure 10.1

Figure 10-1. Multipoint Flow Calibration Screen



D. Measure the ambient temperature with your reference standard positioned near the ambient temperature probe. Enter the value from your reference standard into the standard 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. Record the reading on Form DEP 03-20-B: Calibration/Verification Form.

E. Press the next hot key to move the <CAL> indicator to the BP field, and repeat the same steps for the barometric pressure. Record the reading on Form DEP 03-20-B Calibration/Verification Form.

F. After the temperature and pressure is correct, remove the PM10 heads from the inlet tube and install your reference flow meter adapter onto the inlet. Press the NEXT hot key to move to 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. Measure the flow with the flow standard connected with the adapter on the VSCC. Enter the 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 you have entered all three flow calibration points. Enter the readings on the calibration verification form.

G. Press the NEXT hot key to move the <CAL> indicator to the second flow point of 18.4 LPM and repeat the process. Record the reading on Form DEP 03-20-B: Calibration/Verification Form.

H. 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>. Record the reading on Form DEP 03-20-B: Calibration/Verification Form.

I. When all of the calibrations are complete, the BAM-1020 flow readings should match the traceable flow standard readings at 16.7 LPM, ±0.1 LPM. Exit the calibration menu.

J. When the calibration is complete, the BAM-1020 flow readings should match the traceable flow standard readings at 16.7 LPM, ±0.1 LPM. Exit the calibration menu. Record the reading on Form DEP 03-20-B: Calibration/Verification Form.

11.0 INSTRUMENT MAINTENANCE

Once the FEM $PM_{2.5}$ BAM-1020 is installed and configured, a regularly recurring protocol of maintenance and QC procedures must be established to ensure that a continuous stream of high quality hourly $PM_{2.5}$ concentration data is obtained. The same maintenance procedure shall be performed for the BAM-1020 when it is being operated as a PM10 monitor. The main difference is that the VSCC cyclone is not included in the sample path. Table 11-1 lists the Met One recommended maintenance and QC procedures, frequencies of recurrence, and the sections of this SOP that describe the sequential steps needed to perform each maintenance or QC procedure. In practice, it may be helpful to provide field technicians responsible for implementing the procedures with an actual calendar, or simple table, with the site-specific target dates for each protocol.

The frequency at which these QC protocols are conducted is site and agency-specific. Some of these protocols in Table 11-1 can performed more frequently(e.g., biweekly) than listed in the table to minimize the need to invalidate data because of a failed QC test (e.g., failed leak check), which requires that data be invalidated back to the most recently passed QC check. This increased frequency is generally based on experience—if monthly leak checks are failing because of debris buildup under the nozzle, the logical solution is to clean the nozzle bi-weekly. Since most QC protocols require that the sampling cycle be interrupted, more frequent QC procedures need to be balanced against the one to two hours of data that are lost.

Tolerance levels for verifications of flow, temperature, pressure, and leak checks, must be specified so that field technicians understand when adjustments are needed and when they are not. Table 11-2 list the required specific action and critical tolerances for the QC checks.

Table 11-0-1. Met One-recommended maintenance and QC protocols, frequencies, and SOP section references

Maintenance or QC Item	Suggested Period	SOP Section(s)
Verify Flow Rate	Monthly	11.1.1
Conduct Leak Check	Monthly	11.1.5
Clean the Nozzle and Vane	Monthly	11.1.8
Clean the Capstan Shaft and Pinch Roller Tires	Monthly	11.1.9
Clean the PM_{10} Inlet	Monthly	11.1.10
Clean the VSCC™	Monthly	11.1.11
Check the Error Log	Monthly	11.1.12
Download the Digital Data Log	Monthly	11.1.13
Compare BAM-1020 Data to External Data logger Data	Monthly	11.1.14
Replace Filter Tape	2 Months	11.2.1
Run SELF-TEST Function	2 Months	11.2.2
Verify Flow and Conduct Volumetric Flow Calibration P and T checks implied here	2 Months	11.2.3
Verify BAM-1020 Settings and Check Real-Time Clock	2 Months	11.2.4
Replace or Clean Pump Muffler (if used)	6 months	11.3.1
Test Filter Temperature and RH sensors	6 months	11.3.2
Test Smart Heater	6 months	11.3.3
Perform 72 hour BKGD (BX-302 zero filter) test	6 months	11.4.1
Clean Internal Debris Filter	12 Months	11.4.2
Check Membrane Span Foil	12 Months	11.4.3
Perform Beta Detector Count Rate and Dark Count Test	12 Months	11.4.4
Clean Inlet Tube	12 months	11.4.5
Test Analog DAC Output (if used)	12 Months	11.4.6
Independent audit	12 Months	11.4.7
Replace lithium coin cell battery on 3032 circuit board	12 Months	11.4.8
Rebuild Vacuum Pump	24 months	11.5.1
Replace Nozzle O-ring (Special tools required)	24 months	11.5.2
Replace Pump Tubing	24 Months	11.5.3

Table 11-0-2. Quality Control Action and Critical Criteria for the Met One Instruments BAM-1020

QC Check	Tolerance	Class	Procedure
Flow Rate 16.7 LPM	≥ ±4% (16.00-17.34)	Action	Troubleshoot Leak and/or Recalibrate Instrument Flow Rate.
Leak Check	>1.5 LPM		
Flow Rate 16.7 LPM	> ±5% (15.89-17.67)	Critical	Troubleshoot Leak and/or Recalibrate Instrument Flow Rate And Invalidate data back to last good flow verification.
Leak Check	>1.5 LPM		
Temperature	± 2.5 °C	Action	Recalibrate Instrument.
Pressure	± 10 mm Hg		
Temperature	± 4.0 °C	Critical	Recalibrate Instrument And Invalidate data back to last good Audit.

11.1 Monthly Maintenance and QC Checks

The monthly site visits and associated tasks are essential for maintaining optimal instrument performance. All data pertinent to the monthly maintenance and QC procedures should be documented, using an appropriate form. The QC forms (electronic or hard copy) provided in Appendix A.

Order of events recommended for monthly QC:

1. Flow verification (as found)
2. Leak check (as found)
3. Nozzle and vane cleaning
4. Capstan shaft and pinch roller cleaning
5. PM_{10} inlet and Very Sharp Cut Cyclone cleaning
6. Leak check (as left)
7. Flow verification (as left)
8. Error log check
9. Digital data download

11.1.1 Flow Verification

While the BAM-1020 can be set to any of three flow types—Metered, Standard, or Actual (Volumetric)—FEM designation EQPM-0308-170 for $PM_{2.5}$ mass dictates that it be configured for volumetric sampling. Complete descriptions of the flow modes are given in the BAM-1020 Operation Manual (Rev H, pages 33-34).

The volumetric flow rate of 16.7 LPM should be verified at least on a monthly

basis.

11.1.2 Flow Rate tolerances

The BAM-1020 is designed to operate with an airflow rate of 16.67 LPM. The particle separators require this flow rate in order to properly separate the correct sizes of particles from the air stream. These separators use the inertia of the particles as they flow through the inlet to sort out the ones above a certain size (cut point) so that they won't be measured by the instrument. If the airflow rate is not maintained within ±5% of the design value flow rate of 16.67 LPM, then particles of the wrong size may be allowed through or sorted out.

Flow rate tolerances differ between QC procedures implemented by the field operator and QA procedures implemented by an independent auditor, and the distinction is important (see Section 4). The Code of Federal Regulations (CFR) states that, for QA audit purposes, the FRM sampler flow display must be within 4% of the reference standard flow reading, and the reference standard reading must be within 5% of the design flow rate of 16.67 LPM. From the perspective of field-implemented QC protocols, the CFR-stated FRM flow criteria for a flow check is 4% from the expected 16.67 LPM (16.00-17.34 LPM). By applying these FRM standards to the FEM BAM-1020 field QC procedures, a flow rate within ±4% of the expected 16.67 is set as the tolerance for flow verifications.

11.1.3 Equipment Needed

Tools needed for flow rate verification include a NIST-traceable flow reference standard capable of volumetric flow measurements in the range of the BAM-1020 nominal flow rate of 16.7 LPM, which can be attached to the BAM-1020 inlet tube. The flow inlet adapter (Met One BX-305) may be needed to make this connection, depending on the flow reference standard that is used.

11.1.4 Perform "As Found" Flow Rate Verification

It is recommended that the *timing* of the flow verification relative to the sample cycle be taken into consideration. It is best to interrupt the cycle just after the top of the hour when the I_3 count finishes and the BAM writes the recent hour's data to memory. This timing provides a full hour to perform the flow verification and the other monthly maintenance and QC procedures before the next sample cycle begins.

The following steps enable "as found" flow rate verification:

A. Allow the flow reference standard to equilibrate with ambient conditions. This step can take up to 30 minutes, depending on where the flow standard was stored (e.g., inside a hot vehicle).

B. From the Main menu, press the TEST Soft Key and stop the sample cycle.

C. Select the TEST > FLOW menu to access the MULTIPOINT FLOW CALIBRATE screen (see Figure 10-7). (Note: do not use the TEST > PUMP menu selection to verify the volumetric flow rate because that flow rate is given in standard conditions, not volumetric.)

D. Press the NEXT Soft Key until "FLOW 3" is highlighted. The pump will be running and the flow controller will be regulating the flow to 16.7 LPM volumetric.

E. Remove the PM_{10} inlet (leave the VSCC™ attached to the inlet down tube).

F. Attach the reference flow standard to the inlet tube and allow the reading to stabilize.

G. Record the "as found" volumetric flow rate from the flow reference standard.

H. Record the flow rate from the CALIBRATE screen shown under the BAM column for FLOW 3.

I. If the "as found" flow reference standard reading is more than 4% different from 16.67 LPM (±0.67 LPM, or outside the range 16.0 to 17.34 LPM), a flow calibration must be performed.

J. Continue with other maintenance and QC procedures and, when complete, replace the PM_{10} inlet and the VSCC™, and place the BAM into OPERATE mode.

11.1.5 Conduct a Leak Check

A. The "as found" leak check should be performed *after* the "as found" flow verification.

B. From the Main menu, press the TEST Soft Key and stop the sample cycle.

C. Remove the PM_{10} inlet from the inlet tube (leave the VSCC™ attached to the inlet down tube). Install a BX-305 or BX-302 leak test valve (or equivalent valve for auditing FRM samplers) onto the inlet tube. Turn the valve to the OFF position to prevent any air from entering the inlet tube.

D. In the TEST > TAPE menu, advance the tape to a fresh, unused spot.

E. In the TEST > PUMP menu, turn on the pump. The flow rate should drop below 1.0 LPM. If the leak flow value is 1.0 LPM or greater, the nozzle and vane need cleaning, or there may be another small leak in the system.

F. 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.

G. Turn the pump off, remove the leak test valve, and re-install the inlet heads.

Most air leaks in the BAM-1020 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 concentration to be incorrect because, even though the flow controller may be maintaining the flow rate at 16.7 LPM, the portion of the flow coming through the leak is not from the outside ambient air, and it has not passed through the separator inlet. A significant leak at the nozzle will also cause the air flow at the inlet to be outside the ±4% tolerance of the 16.7 LPM nominal flow rate. Allowing a leak to persist may invalidate an unknown amount of data!

Leak checks should be performed at least monthly and whenever the filter tape is changed. A significant "as found" leak (nominally greater than 1.5 LPM) will require that data be invalidated all the way back to the last known good leak test (see "Leak Check Tolerances" below). The nozzle and vane cleaning require the removal of the filter tape from the nozzle interface, so a follow-up, or "as left", leak check should be performed—even if the "as found" leak check was within tolerance.

Whatever interval is used, it is probably best to include the nozzle and vane cleaning on the same schedule, requiring an "as found leak test", then a nozzle and vane cleaning, followed by an "as left" leak test.

11.1.6 Leak Check Tolerances

Leak check tolerances vary by agency. In July 2003, Met One lowered the tolerance for the leak check from 1.5 LPM to 1.0 LPM. Some agencies choose to adopt tighter tolerances for the leak test, such as requiring a leak value of 0.5 LPM or less after the nozzle and vane are cleaned. The typical recommended threshold for invalidating data is the existence of an "as-found" leak value (before cleaning nozzle and vane) of 1.5 LPM or higher. One way to view the leak check is to consider anything under 0.5 LPM to be "good", with readings between 0.5 and 1.0 LPM indicating potential problems, such as the beginning of debris problems at the nozzle/tape interface. Readings between 1.0 and 1.5 LPM may not cause data to be invalidated, but should certainly prompt investigation and perhaps corrective action.

11.1.7 Leak Isolation

Since most leaks occur at the nozzle/tape interface, regular cleaning will normally prevent or correct this problem. However, there are many other places in the air sample train from inlet to pump where leaks are possible. If

nozzle and vane cleaning fail to cure a leak, then a second cleaning is recommended—perhaps something was missed the first time.

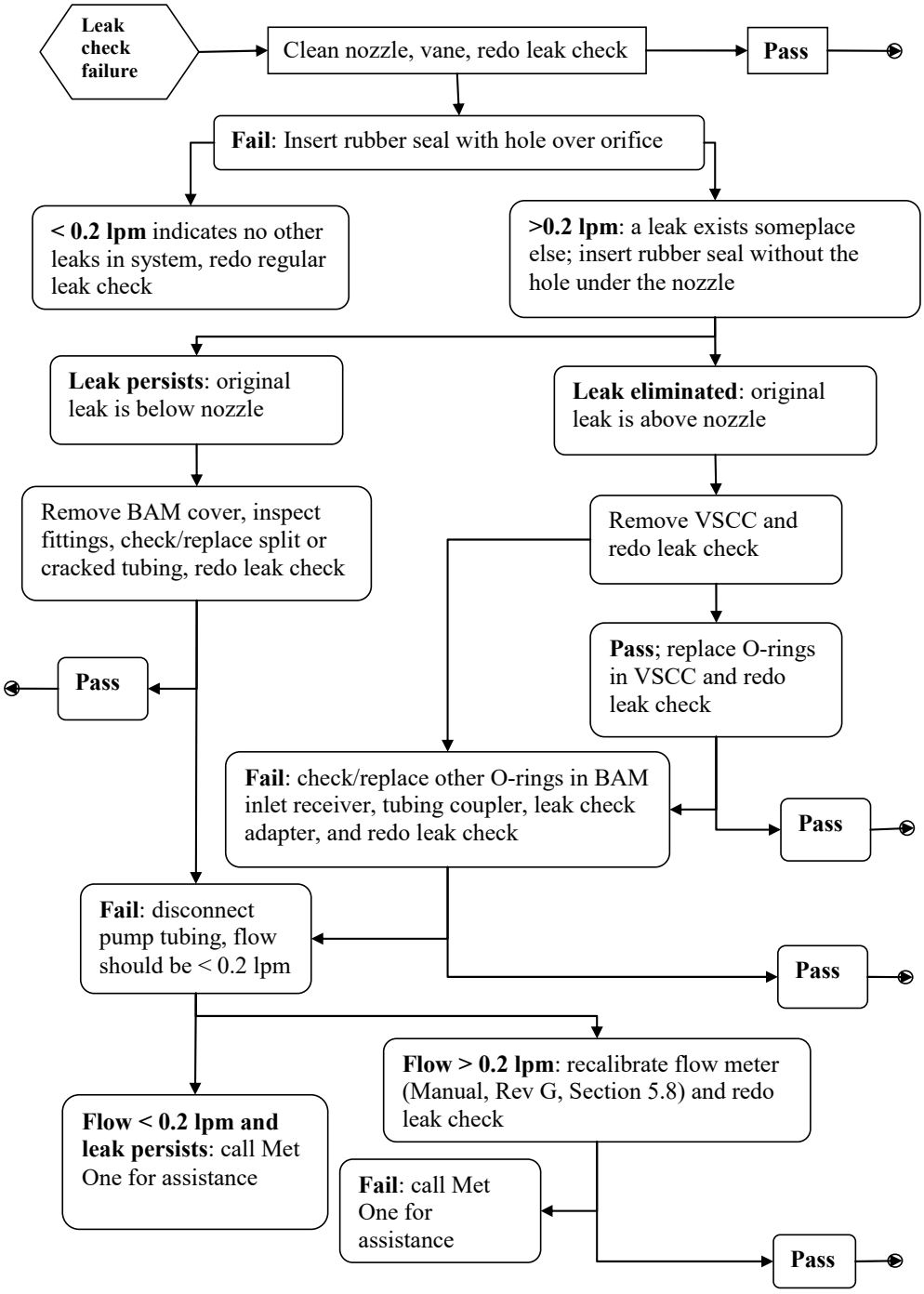
A leak that persists must be tracked down. Met One now offers a soft rubber sheet with a ¼ inch hole in it (PN 7440), which is highly recommended as a tool to have on hand. Figure 11-1 is a flow chart depicting the sequential steps to take when tracking down a leak

11.1.8 Clean the Nozzle and Vane

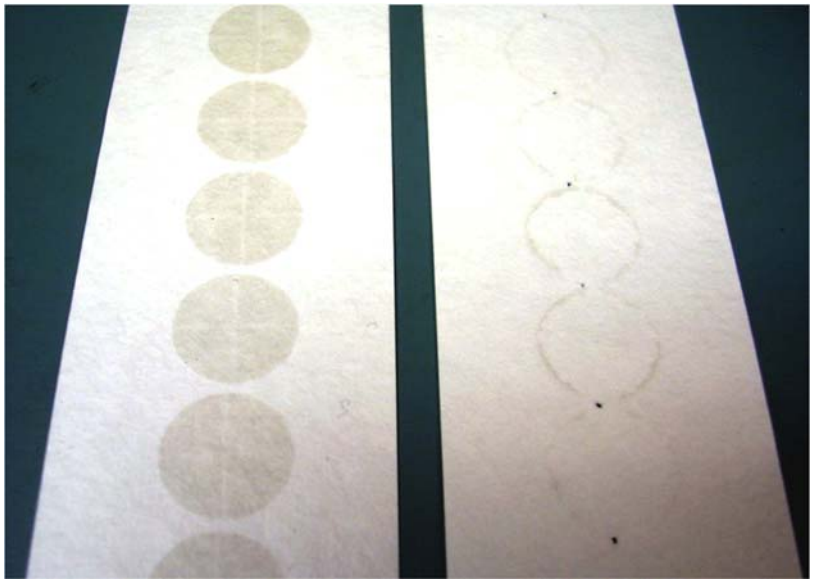
Regularly cleaning the BAM-1020 nozzle may be the single most important factor in preventing failed leak checks and optimizing data accuracy. Monthly cleaning (and at every filter tape change) has generally proven adequate for this procedure, but more frequent cleaning may be necessary in some environments. High leak values normally indicate a build-up of filter material at or near the nozzle/filter paper interface, compromising the interface "seal", allowing air to be drawn in around the nozzle perimeter. Left uncorrected, the accuracy of the measurements can be affected and, in some situations, negative concentration values and/or low correlation with reference equipment may result. When the nozzle is lowered, the downward pressure on these pieces of filter material can punch a hole in the tape (Figure 11-2, right panel). A puncture in the tape allows the beta particles to pass through without attenuation. This defect may reduce the post-sample count, and, in situations of low ambient $PM_{2.5}$ concentrations, may cause this count to be larger than the pre-sample count, resulting in a negative concentration.

Theoretically, nozzle and vane cleaning would be performed only when the tape is changed, and the BAM-1020 should be operate hole-punch-free the entire time between tape change periods. Hole-punching that occurs between tape change periods indicates that a problem exists and needs to be corrected, especially if the hole-punching reoccurs regularly.

Figure 11-1. A decision tree/flow diagram for identifying leaks in the BAM 1020



0-1Figure 11-2. Filter Tape with a satisfactory sample tape and one with a hole and unsatisfactory sample tape.



11.1.9 Nozzle and Vane Cleaning Procedure

The following steps are needed to clean the nozzle and vane. Refer to the photos in Figure 11-3.

A. Raise the nozzle in the TEST > PUMP menu. Remove the filter tape (if installed) from the nozzle area. It is not necessary to completely remove the tape from the spools.

B. With the nozzle up, use a small flashlight to inspect the cross-hair vane.

C. Clean the vane with a cotton-tipped applicator and isopropyl alcohol. Hardened deposits may have to be carefully scraped off with the wooden end of the applicator or a dental pick or similar tool.

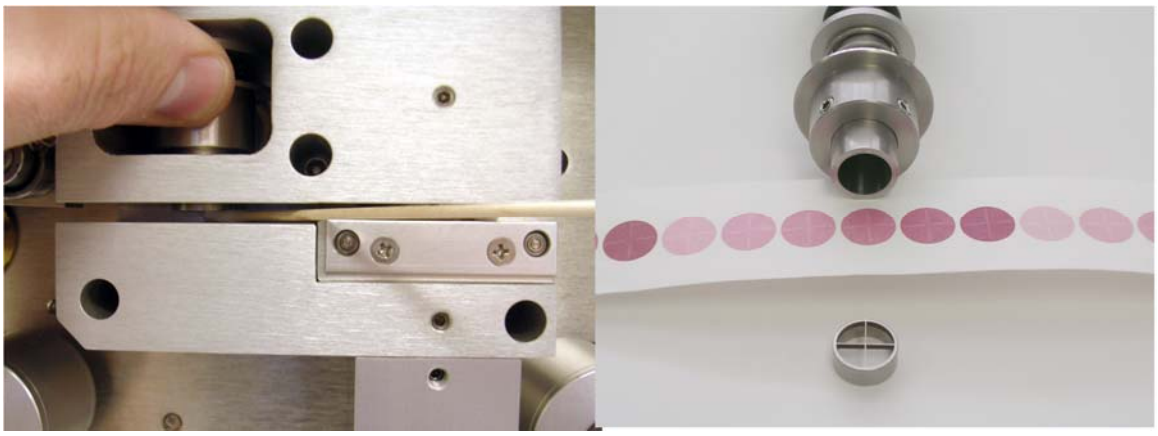
D. Lower the nozzle in the TEST > PUMP menu. Lift the nozzle with your finger and insert another cotton swab with alcohol between the nozzle and the vane. Let the nozzle press down onto the swab with its spring pressure (Figure 10-3, left panel).

E. Use your fingers to rotate the nozzle while keeping the swab in place. A few rotations should clean the nozzle lip.

F. Repeat the nozzle cleaning until the swabs come out clean.

G. Inspect the nozzle lip and vane for any burrs which may cause leaks or tape damage.

Figure 11-3. A cotton-tipped applicator and isopropyl alcohol are used to clean the BAM-1020 nozzle and vane (left panel). A view of the nozzle, sampled filter tape, and filter tape support vane are shown in the right panel.



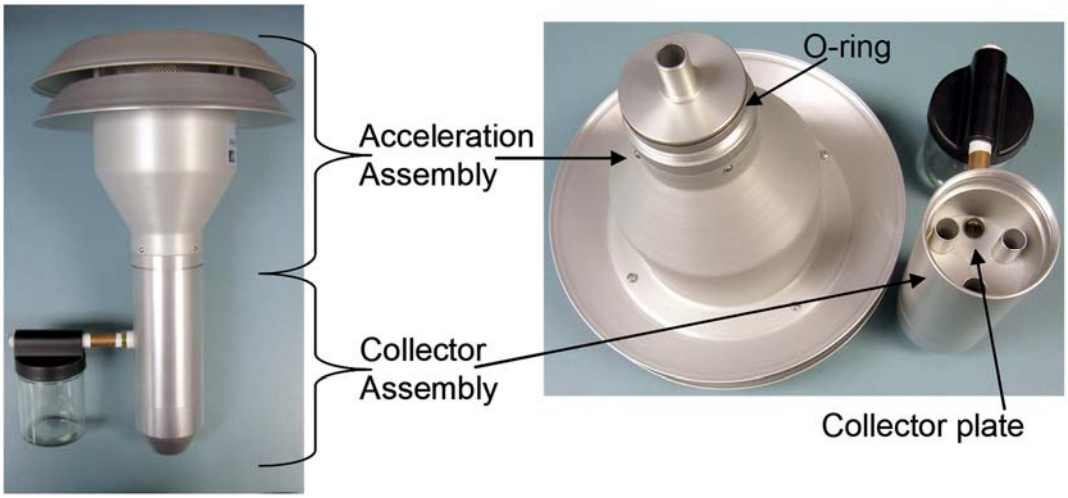
11.1.10 Clean the Capstan Shaft and Pinch Roller Tires

Figure 9-4 shows the location of the pinch rollers. The capstan shaft is the stainless steel shaft that the rubber pinch roller rests on. Use a cotton tipped swab moistened with isopropyl alcohol to wipe down the pinch roller tires and the capstan shaft. This action is easiest to do when the pinch roller is latched in the UP position.

11.1.11 Clean the PM10 Inlet

The PM_{10} inlet needs to be disassembled and cleaned periodically. As a general recommendation, the inlet should be cleaned every 30 days (same schedule as FRM, with a 30-day maximum for the VSCC™). Instruments in environments with high ambient PM_{10} concentrations or in areas prone to fugitive dust emissions may require more frequent cleaning of PM_{10} inlets than those in cleaner environments. Some agencies clean FEM inlets on the same schedule as an FRM inlet (monthly). Met One currently recommends that the particle trap (or collector plate) located in the top part of the Collector Assembly (Figure 11-4) be cleaned monthly, and that the acceleration chambers be cleaned quarterly. (The California Air Resources Board [CARB] requires cleaning both sections on a monthly schedule.) Met One offers a BAM Inlet Cleaning Kit specifically for this purpose (PN BX-344), which includes a pull-rope, tube brush, microfiber rags, cleaning brushes, O-ring grease, and cotton applicators. Generic equivalents of these items may be used (soft bristled paint brushes, pipe cleaners, “lint free” cloths etc.). A #2 Phillips screwdriver is needed to remove the top plates from the acceleration assembly of the PM_{10} inlet. Hands should be clean for this procedure.

Figure 11-4. The PM10 inlet has two primary components, the Acceleration Assembly and the Collector Assembly



11.1.12 Clean the Collector Assembly (Monthly)

A. Remove the condensation jar and set it aside.

B. Unscrew the Collector Assembly (Figure 10-4, bottom portion of inlet) from Acceleration Assembly (Figure 10-4, top portion of inlet).

C. Use a brush, lint free cloth and/or cotton swabs to clean the bottom collector plate and the collector assembly walls around the three vent tubes, and the weep hole in the collector plate. Water can be used if needed. Allow to dry.

D. Clean inside the vent tubes by running a moistened cloth through them.

E. At the bottom of the Collector Assembly, wipe out the inside area where the two O-rings are situated.

F. Inspect the O-rings and replace if needed. Apply a thin film of O-ring grease on the O-rings.

G. Wipe out the condensation jar and the jar lid. Apply a thin film of grease to the cork seal inside the lid. Clean hands here too, before reassembling (e.g., using wet wipes.

11.1.13 Clean the Accelerator Assembly (Quarterly)

A. Set the Acceleration Assembly upside-down on its top plate and remove the four pan head screws on the bottom side. If the stand-offs turn, hold them in place with pliers.

B. Lift the Acceleration assembly off the top plate. Lift the lower plate up and carefully remove the insect screen.

C. Clean all the inlet parts of the Acceleration Assembly inside and out (top plates, insect screen, and the Accelerator Assembly body). Parts may only need to be wiped with brushes or a lint-free cloth, or blown out with compressed air. Alternatively the parts may actually be "washed" in clean water; this is the only good way to remove any caked deposits that may have accumulated in hard-to-reach places. Parts must be thoroughly dried before re-assembly. Pay special attention to the acceleration nozzle at the base of the cone-shaped body: clean the inside of the nozzle by pushing a moistened piece of cloth through it. Inspect the large diameter O-ring at the base of the Accelerator Assembly.

D. Replace the O-ring if necessary, or apply a thin film of O-ring grease on the O-ring and a thin film on the aluminum threads of the acceleration assembly.

E. To avoid contamination of other items, clean hands with a wet wipe or similar material to clean off O-ring grease.

F. Reassemble the PM_{10} inlet.

11.1.14 Clean the VSCC™

The BGI VSCC™ (Figure 11-5) is an essential component of the inlet system. It needs to be diligently maintained or it will corrode. The VSCC™ should be cleaned every 30 days (i.e., treat the inlet as one would for an FRM). Disassemble and clean the VSCC™ following these steps:

A. Remove the VSCC™ from its installed position in the instrument.

B. Pull off the side transfer tube. If it is too tight to remove by hand, pry it off with a rigid plastic lever. Care should be taken to not damage the two O-ring seals.

C. Unscrew the top cap and the grit pot.

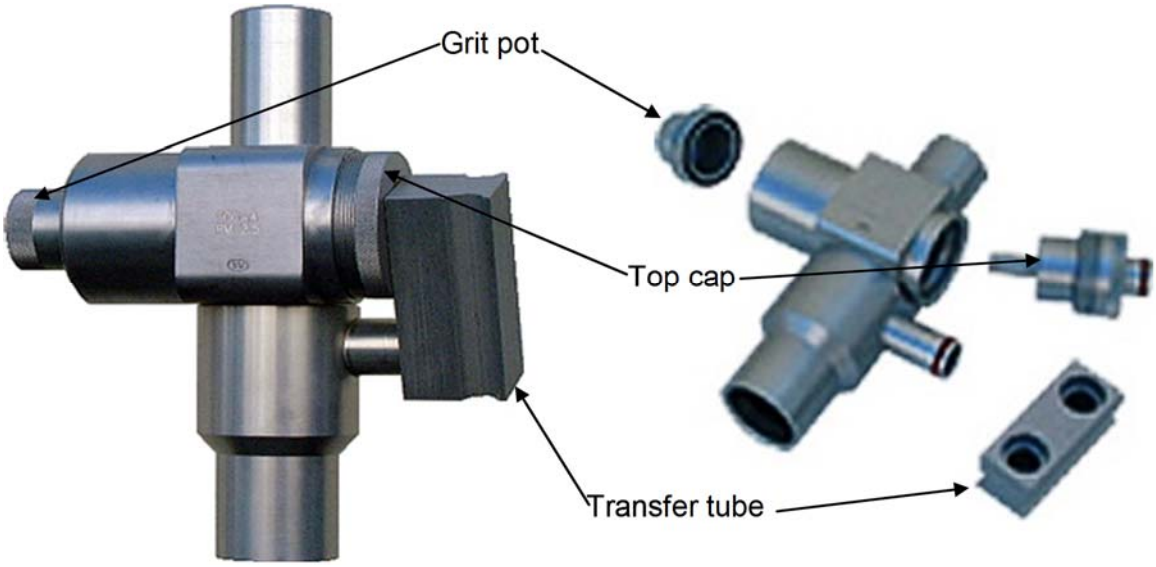
D. Use alcohol wipes, or if unavailable, a dampened cloth, to remove all visible deposits. These deposits are most likely to be found at the bottom of the cone (located beneath the grit pot) and inside the grit pot.

E. Inspect all O-rings for shape and integrity. If at all suspect, replace. Lubricate all O-rings with light grease. It is important to well lubricate the transfer tube to avoid difficult disassembly.

F. Clean hands with alcohol wipe or similar media.

G. Assemble in reverse order and reinstall.

Figure 11-5. The VSCC™ particle separator



11.1.15 Check the Error Log

There are two methods to check the BAM-1020 error log. The F3 function key (Error Recall) will return up to 100 errors logged during the most recent 12 days, sorted by date. The F3 key can be used without interrupting a sample cycle. These methods are handy for QC checks during regular maintenance. If analog data are being recorded and the BAM-1020 is set up to report errors with the analog output signal (with errors causing full scale voltage output), it is important to check the error log as part of the monthly routine. Some errors will cause the voltage output to go to full scale, but there is nothing wrong with the concentration data. These data would have to be retrieved digitally from the BAM-1020 memory. One example of this voltage error would be a failure of an external reset of the BAM-1020 clock by an external relay. The concentration data are valid, but because of the failure of the clock synchronization protocol, the time stamp associated with the analog data may be in error.

A listing of error flags more than 12 days old requires that the digital data be downloaded and reviewed (Section 10.1.8).

11.1.15 Download the Digital Data Log

It is very important to download the digital data log from the BAM-1020 soon after the installation is complete to confirm that any externally logged data are accurate. It should be part of the regular monthly maintenance schedule in situations where there is no external data acquisition system in place. The amount of internal memory in the BAM-1020 is limited to 4,369 records (182 days at 1 record per hour, but only 15 days if 5-minute meteorological data are being stored). Any catastrophic failure (e.g., fire) may cause loss of all stored data.

Complete descriptions of the methods for digital data retrieval are given in the BAM-1020 Operation Manual (Rev H, pages 80-87). The most common way, described here, is to retrieve the data with a desktop or laptop computer through the BAM-1020 2-way RS232 serial port, using the HyperTerminal® communications program, or a similar terminal program. Met One provides a there software Comet that is also used to download data from the BAM through the RS-232 serial port. The data is provided in a CSV format and the information is the same as using the other method. A female-to-female 9-pin RS232 cable is required, and modern laptops may need a USB-to-RS232 serial adapter (e.g., Belkin F5U109), or an optional PCMCIA card that has a serial port.

Follow these steps to download the BAM-1020 data via HyperTerminal®:

A. Connect one end of the 9-pin cable to the COM port connector on the BAM-1020 (the upper RS232 connector on the back of the unit), and the other to the computer.

B. Ensure that the BAM-1020 user interface is in the main top-level menu or the OPERATE menu. The serial port is disabled in all other menus.

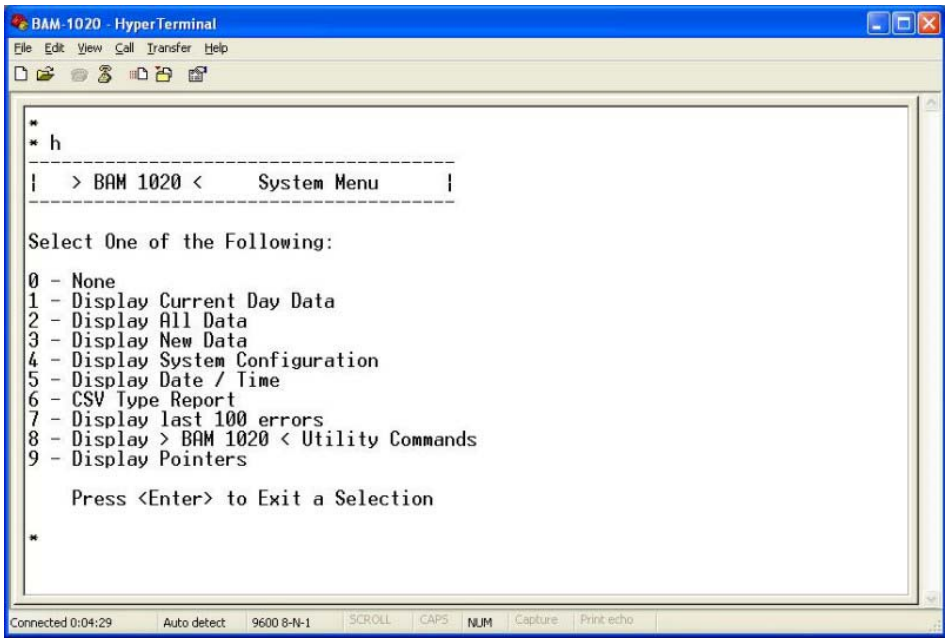
C. Open HyperTerminal® and set the communication properties (File>Properties>Connect To Tab>Configure Button):
   1. Bits per second: 9600
   2. Data bits: 8
   3. Parity: None
   4. Stop bits: 1
   5. Flow Control: None

D. The data should be saved to a file; so from the HyperTerminal® Transfer Menu, choose Capture Text, select a location for the file, and click the “Start” button. When the download begins, HyperTerminal® will automatically store the data to the text file.

E. Hit the return (ENTER) key three times and an asterisk (*) will appear on the screen, signifying that the BAM-1020 is ready to communicate.

F. Once communication is established, press the "h" key to view the BAM-1020 System Menu (Figure 11-6). You can now send any of the characters in the menu (0-9) to retrieve the designated files. The menu options are described in the BAM-1020 Operation Manual (Rev H, pages 72-78).
Once communication has been established with the BAM-1020, pressing the "h" key will display the System Menu, allowing the choice of several types of files to be downloaded.

Figure 11-6. BAM 1020 Hyper Terminal View



G. The recommended data retrieval method is File Type 6, the "CSV Type Report". This file type can be opened in Excel or other spreadsheet programs. When "CSV Type Report" is requested, the BAM-1020 responds with a second menu:

```
* 6
CSV Type Reports

2 - Display All Data
3 - Display New Data
4 - Display Last Data

5 - Display All Flow Stats
6 - Display New Flow Stats

7 - Display All 5-Min Flow
8 - Display New 5-Min Flow
```

H. File options 5-8 are only available in BAM-1020 units configured for FEM $PM_{2.5}$ sampling. They are described in the BAM-1020 Operation Manual (Rev H, page 77).

I. An excerpt from a file produced by selecting option 3 (Display New Data) is shown in Figure 11-7.

Figure 11-7. BAM 1020 Instantaneous Data

```
Time,Conc(mg/m3),Qtot(m3),WS(MPS),WD(DEG),BP(mm),RH(%),Delta(C),AT(C),E,U,M,
I,L,R,N,F,P,D,C,T
        10/02/07 17:45,  0.001, 0.700, 0.110,0,0,36,1.3,23.0,0,0,0,0,0,0,0,0,0,0,0,0,
        10/02/07 18:00,  0.001, 0.700, 0.127,0,0,38,1.4,23.2,0,0,0,0,0,0,0,0,0,0,0,0,
        10/02/07 18:15,  0.001, 0.700, 0.130,0,0,38,1.2,23.6,0,0,0,0,0,0,0,0,0,0,0,0,
        10/02/07 18:30,  0.001, 0.700, 0.110,0,0,36,1.1,23.5,0,0,0,0,0,0,0,0,0,0,0,0,
        10/02/07 18:45,  0.001, 0.700, 0.110,0,0,37,1.2,24.0,0,0,0,0,0,0,0,0,0,0,0,0,
        10/02/07 19:00,  0.003, 0.700, 0.127,0,0,38,1.1,24.6,0,0,0,0,0,0,0,1,0,0,0,0,
        10/02/07 19:15,  0.003, 0.700, 0.129,0,0,38,1.1,24.8,0,0,0,0,0,0,0,0,0,0,0,0,
        10/02/07 19:30,  0.003, 0.700, 0.109,0,0,37,0.9,24.0,0,0,0,0,0,0,0,0,0,0,0,0,
```

J. The data include a date/time stamp, concentration for the last hour (CONC), flow volume for last hour (Qtot), and all six individual met sensor channels. The user-defined labels for these channels will vary, but will always appear in the data array, even if they are unused. In this example the six channels start with “WS” and end with “AT”. At the end of the array are twelve error bits, each representing a different possible error. “0” indicates no error of that type, and “1” indicates an error. In this example, the “M” and “T” bits are high, indicating that the unit has been taken out of operation, and that the tape has run out

K. Another useful file to download is “Display System Configuration” (Option 4 from the System Menu, Figure 10-5). This file will contain a list of most of the BAM-1020 settings and calibration values. This is useful for verifying the BAM-1020 setup parameters. A typical report from a BAM-1020 configured for FEM $PM_{2.5}$ sampling is shown below:

Figure 11-8. BAM 1020 Setup Parameters

```
BAM 1020 Settings Report
06/07/2007  14:19:45
     Station ID, 1
       Firmware, 3236-02 3.2.5
              K, 01.000
           BKGD, 00.000
            usw, 00.301
            ABS, 00.805
          Range, 1.000
         Offset, -0.015
          Clamp, -0.015
     Conc Units, mg/m3
      Conc Type, ACTUAL
             Cv, 01.000
             Qo, 00.000
      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
        DT Ctrl, NO
       DT SetPt, 99
         DT Log, NO
     BAM Sample, 42
     MET Sample, 60
     Cycle Mode, STANDARD
 Fault Polarity, NORM
 Reset Polarity, NORM
    Maintenance, OFF
   EUMILRNFPDCT
   000000000000
             AP, 000150
      Baud Rate, 9600
 Printer Report, 2
             e3, 00.000
             e4, 15.000

   Channel,     1,       2,       3,       4,       5,       6,
 Sensor ID,     255,     255,     255,     255,     255,     255,
Channel ID,     255,     255,     255,     255,     255,     255,
      Name,   XXXXX,   XXXXX,   XXXXX,   XXXXX,   XXXXX,   XXXXX,
     Units,     XXX,     XXX,     XXX,     XXX,     XXX,     XXX,
      Prec,       0,       0,       0,       0,       0,       0,
  FS Volts,   1.000,   1.000,   1.000,   1.000,   1.000,   1.000,
```

```
       Mult,   1.000,   1.000,   1.000,   1.000,   1.000,   1.000,
     Offset,   0.000,   0.000,   0.000,   0.000,   0.000,   0.000,
Vect/Scalar,       S,       S,       S,       S,       S,       S,
  Inv Slope,       N,       N,       N,       N,       N,       N,
```

11.1.16 Compare Internal BAM 1020 Data to External Data Logger Data

In most applications, an external Data Acquisition System (DAS) is used to collect the hourly data from the BAM-1020. When using an external DAS, a fundamental QC protocol is a monthly comparison of the internally stored data (assumed to be the "most correct") with the data stored by the DAS. This comparison is particularly important after a new installation so that any errors associated with the acquisition process can be identified and corrected to avoid continued propagation of the error. Digitally acquired data are less susceptible (although not immune) to acquisition errors than analog, which has some special requirements; **digital methods are recommended whenever possible**. Recommendations for digital or analog interfacing between the BAM-1020 with an external DAS are covered in Section 12.

The comparison of the BAM-1020 internal data with DAS data should focus on timestamps and the concentration data:

A. Digitally acquired concentration data in the DAS should agree exactly with the concentration data stored internally in the BAM-1020. If it does not, a time-stamping problem may exist. Compare a specific record in the DAS with the previous and following records (based on the time stamp) downloaded directly from the BAM-1020. If one of these records matches, a one-hour offset needs to be corrected in the data acquisition protocol or in post-processing. See Section 12.2 for a discussion of the possible causes of and solutions for mismatched time stamps in digital data.

B. Concentration data collected by the DAS from the *analog* output of the BAM-1020 should agree with the internal BAM-1020 digital data within 2 $\mu g/m^3$ (0.002 mg/m^3). Discrepancies of a few $\mu g/m^3$ may be attributable to faulty digital-to-analog-converter (DAC) electronics, or simply sloppy wiring between the BAM-1020 terminal strip and the DAS analog inputs. An Analog Output Test using the BAM-1020 DAC Test Menu should be conducted (BAM-1020 Operation Manual, Rev H, page 60).

C. A consistent offset of 15 $\mu g/m^3$ suggests that the DAS has not been properly programmed to account for the 0.015 mg/m^3 OFFSET in the SAMPLE Settings screen that is the default OFFSET value for the FEM BAM-1020 (Figure 9-7).

D. Inconsistencies between analog and digital data of more than a few $\mu g/m^3$ can occur if the DAS uses an averaging function, and the clocks of the BAM-1020 and the DAS are not perfectly

synchronized. This inconsistency can result in hourly concentration values from adjacent hours being averaged together, making the resulting concentration difficult to match with digital data. Use of the EARLY operating mode can overcome this problem.

E. The scenarios described above regarding analog data can be additionally confounded if there is a time stamping problem with the analog data, so be sure to factor that into troubleshooting of discrepancies between downloaded digital data and analog data.

11.2 Two-Month Maintenance and QC Checks

Two-month maintenance and QC procedures include

- replacing filter tape (Sections 9.6.3, 11.2.1);
- conducting self-tests (Section 10.2.2);
- conducting pressure, temperature, and flow check and possibly calibrations (Section 11.2.3); and
- verifying BAM-1020 settings and checking the clock (Section 11.2.4

11.2.1 Replace Filter Tape

Refer to Section 9.6.3 or to the BAM-1020 Operation Manual (Rev H, page 24) for instructions on changing the filter tape. The tape in the BAM 1020 should be changed approximately every 60 days. The tape holds only holds a few days or so beyond 60, so it is imperative that change dates are kept track of. Log entries must also be made for extra services to the instrument or in the event of an instrument change.

Note: Do not change tape prematurely. Discard old tape to prevent accidental reloading

The procedure is also covered in Section 3.4 of the *Met One Instrument BAM 1020 Particulate Monitor Operation Manual, Revision G.*

Leak and Flow Q. C. checks **must be performed immediately prior to** a tape change and a log entry must be documented.

The procedure for loading the tape is as follows:

A. From the **Main Menu,** press **TAPE** and the **TENSION** to verify that the nozzle is in the "**UP"** position.

B. Lift the rubber pinch roller assembly and latch it in the **UP** position.

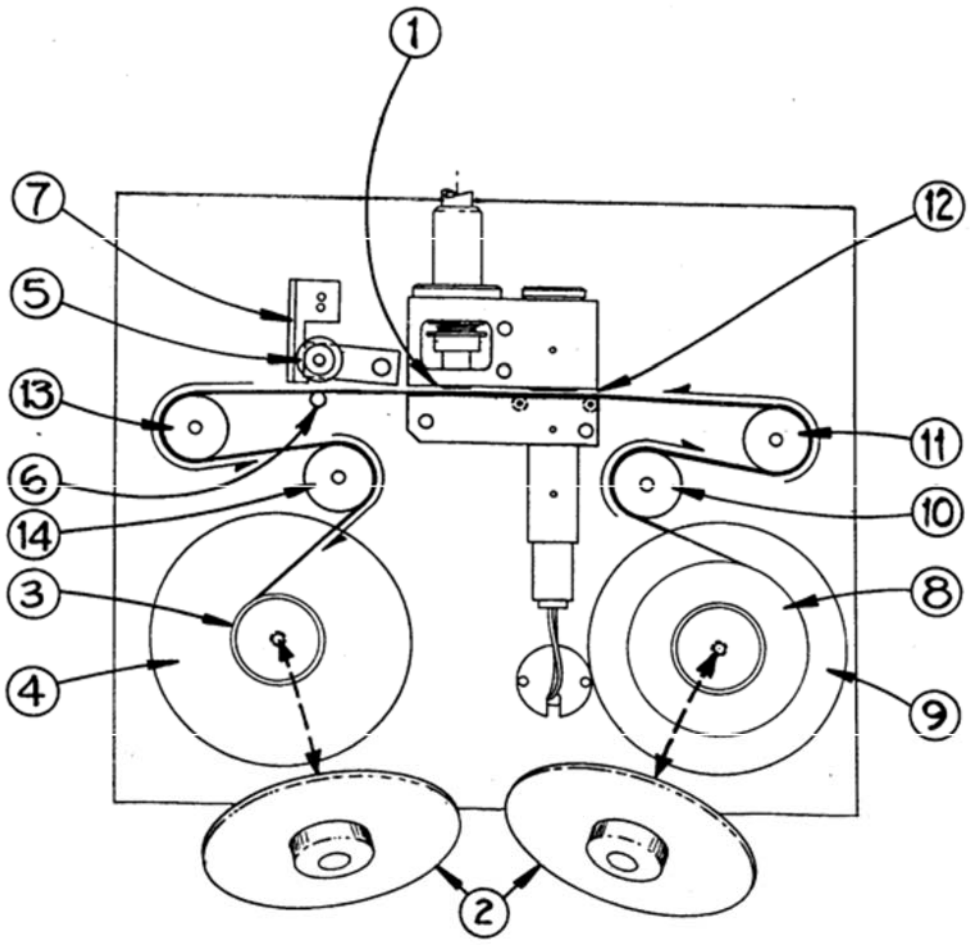
C. Remove both of the clear plastic spool covers by unscrewing the captive knobs.

D. An empty core tube must be installed on the hub of the take up spool. Never fasten the tape to the aluminum hub.

Note: Special care should be taken when handling unused filter tape. Gentle handling during filter tape loading will reduce filter tape breakage.

E. Load the new roll of filter tape onto the right (supply) reel, and route the tape through the transport assemble as shown in the drawing below. Attach the loose end of the filter tape to the empty core tube with cellophane tape or equivalent.

Figure 11-9. Filter Tape Mechanism Diagram



1----NOZZLE IN "UP" POSITION
2----CLEAR SPOOL COVER WITH KNOB
3----EMPTY CORE TUBE
4----TAKE-UP SPOOL
5----PINCH ROLLERS
6----CAPSTAN SHAFT
7----LATCH
8----FILTER TAPE
9----SUPPLY SPOOL
10--SUPPLY TENSION ROLLER
11--RIGHT END ROLLER
12--SAMPLING/MEASURING AREA
13--LEFT END ROLLER
14--TAKE-UP TENSION ROLLER

F. Rotate the tape roll by hand to remove excess slack, and then install the clear plastic spool covers. The covers will clamp the rolls to the hubs to prevent slipping.

G. Align the filter tape so that it is centered on all of the rollers.

H. Unlatch and lower the pinch roller assembly onto the tape. The will not function if the pinch rollers are latched up, and the unit has no way of automatically lowering the roller assembly.

I. Under **TEST>TAPE** Menu, select **ADVANCE TAPE** (6) positions. That will ensure that the tape is secured in position and is advancing properly.

J. Tension the tape by pressing **TAPE** and then **TENSION**, after the tape is tensioned then press **SELF TEST**. This will test the mechanical function of the instrument. After the instrument passes this test, return to the main menu by pressing the **EXIT** command.

K. Perform a leak and flow rate check upon completion of the tape change and document all results in the log entry

11.2.2 Run Self-Test Function

Refer to Section 9.6.4 or to the BAM-1020 Operation Manual (Rev H, Section 3.5, page 35) for instructions on performing the self-test. This test must be conducted each time the filter tape is changed and at any other time that the sampling cycle is interrupted.

11.2.3 Verify Flow, Temperature, Pressure, and Calibration if Needed

A flow calibration is nominally recommended every two months. However, if verifications establish that the instrument is operating well within the specified tolerances (see example Table 11-2), there is no “requirement” that the instrument be recalibrated. Recalibration if there is deviation from the prescribed acceptance criteria. The calibration procedure is shown in Section 10.1: Calibration of the BAM 1020 monitor

11.2.4 Verify the BAM-1020 Settings

The BAM-1020 settings should be verified every few months. Assuming that the setup parameters were input correctly and checked at installation, it is easy to forgo periodic verification of the BAM-1020 settings because the settings are rarely intentionally altered. However, it is not uncommon to access infrequently used screens and, once in those screens, it is easy to change numbers. Routine verification of BAM-1020 settings is good standard operating procedure.

Form DEP 03-20-A lists the settings that should be checked every two months. The screens where the setup parameters are stored are given as well.

The “Expected/Default” column contains the values (constants) of the setup parameters as required for FEM $PM_{2.5}$ sampling under EQPM-0308-170. Some setup parameters are user assigned or instrument specific. A copy of this table is provided in Appendix B as a form with provisions for recording date, BAM-1020 serial number, and technician name. The instrument specific calibration values are listed on the Calibration Certificate provided with each BAM-1020.

Form DEP 03-20-A: Verification of the BAM-1020 setup parameters requires accessing 8 separate SETUP screens, as listed below:

BAM-1020 FEM $PM_{2.5}$ and PM_{10} Setup and Calibration Values				
Screen	Parameter	Expected/Default	As Found Value	Adjusted Value
SETUP > CLOCK	Clock Time/Date	Local Std Time		
SETUP > SAMPLE	RS232	9600, 8, N, 1		
	BAM SAMPLE	42 min		
	STATION #	User assigned		
	MET SAMPLE	User assigned		
	RANGE	1.000 mg		
	OFFSET	-0.015 mg		
	CONC UNITS	µg		
	COUNT TIME	8 min		
SETUP > CALIBRATE	FLOW RATE	16.7 LPM		
	CONC TYPE PM2.5	Actual		
	CONC TYPE PM10	Standard		
	FLOW TYPE	Actual		
	Cv	Instrument specific		
	Qo	Instrument specific		
	ABS	Instrument specific		
	µ sw	Instrument specific		
	K Factor	Instrument specific		
	BKGD	Instrument specific		
	STD TEMP	25 C		
	HEATER	AUTO		
SETUP > EXTRA1	e1	-0.015 mg		
SETUP > ERRORS	Errors	User assigned		
	AP	150		
	FRl	10		
	FRh	20		
SETUP > PASSWORD	Password	F1 F2 F3 F4		
SETUP > INTERFACE	Cycle Mode	User assigned		
SETUP > HEATER	RH Control	YES		
	RH Set point	35%		
	Datalog RH	YES (Chan 4)		
	Delta-T Control	NO		
	Delta-T Setpoint	99		

11.3 Six-Month Maintenance and QC

A few maintenance items occur only every six months:

- Replace or Clean the Pump Muffler
- Test the filter RH sensor
- Test the filter temperature sensor
- Test the Smart Heater

11.3.1 Replace or Clean the Pump Muffler

The gray plastic pump mufflers clog after several months. Replace the muffler every six months, or, as a temporary fix, drill a hole in the end of it. The brass mufflers can often be cleaned with a solvent. One way to avoid pump muffler maintenance is to replace the pump muffler with a 30-inch length of Tygon

tubing. This tubing will not clog, reduces the pump noise as well as the mufflers, and improves pump performance.

11.3.2 Test the Filter Temperature and RH Sensors

To test the filter temperature sensor,

A. From the Main menu, select TEST and then FILTER-T. This screen 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 action allows the filter temperature sensor to equilibrate with ambient room air without the heating effects of the Smart Heater.
B. Allow the pump to run for at least 5 minutes to allow the sensor to equilibrate. During this same period, allow the reference standard temperature sensor to equilibrate with the room temperature.
C. Press the RESET hot key to clear out any past calibration values.
D. Enter the ambient room temperature from the reference standard into the REFERENCE field and press the CALIBRATE hot key. The BAM reading should change to match within **+/- 1 °C**.
E. The RESET hot key can be used to revert to default calibrations and start over if difficulty is encountered.

To test the filter RH sensor,

A. From the Main menu, select TEST and then RH. This screen, which functions exactly like the FILTER-T screen, is used to calibrate the filter RH sensor located in the air stream beneath the filter tape.
B. Allow the pump to run for at least 5 minutes to allow the sensor to equilibrate.
C. Press the RESET hot key to clear out any past calibration values.
D. Enter the ambient room relative humidity from the reference standard into the REFERENCE field and press the CALIBRATE hot key. The BAM reading should change to match within **+/- 4% RH**.
E. The RESET hot key can be used to revert to default calibrations and start over if difficulty is encountered.

11.3.3 Test the Smart Heater

A. From the Main menu, select TEST and then HEATER. This 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.

B. If the heater is on (warm to the touch), force it off to allow it to cool for several minutes. Turn it back on and verify that it warms up.

C. If the heater is cool to the touch when it is initially checked, force the heater on and verify that it warms after several minutes.

D. The heater automatically turns back off upon exit from the screen.

11.4 Twelve-Month Maintenance and QC

There are a number of procedures and tests that should be performed once a year. While most of these annual routines are based on recommendations from Met One, **the 72-hr BKGD or zero-filter test is *required*** by EQPM-0308-170 at the time the BAM-1020 is installed at the monitoring site, and "periodically" thereafter.

11.4.1 Perform 72-hr BKGD (BX-302 Zero Filter) Test

Instructions for completing this test are given in Section 9.6.10, BAM Installation. This test is important and is required at the time of installation. The frequency at which the test occurs, however, should be based on the factors discussed in Section 9.5.

11.4.2 Clean or Replace the Internal Debris Filter

An internal debris filter is located in the flow path of the BAM-1020 (see diagram in BAM-1020 Operation Manual, Rev H, page 33). This filter should be cleaned or replaced annually. The filter element can only be replaced (Met One PN 580292).

11.4.3 Check the Membrane Span Foil

The membrane span foil is made of cellophane material that provides a span reference for the BAM-1020. The typical calibrated value of the membrane is around 800 µg, but this value is specific to each instrument (also known as the ABS value). The BAM-1020 performs a span check each hour by extending the reference membrane so that it is positioned between the beta source and the scintillation counter. A complete description of this span check process is given in the BAM-1020 Operation Manual (Rev H) on page 28. The value of this measurement is displayed on the NORMAL screen as the "LAST m". The LAST m value should be very close or equal to the ABS value given on the Calibration certificate. Values in excess of ±5% are flagged as errors (a "D" error for "Deviant Membrane Density"; also known as "Cal error"). If the D error bit is set to ON in the SETUP > ERROR screen, the analog voltage output will also go to full scale.

To check the membrane span foil,

E. from the Main menu, choose TEST > CALIBRATE, bringing up the CALIBRATION MODE screen for the reference membrane;

F. press the START Soft Key to begin the 8-minute test;

G. when complete, record the Calibration mass;

H. repeat the test two more times (total three tests);

I. Calculate the average mass; and

J. Compare this value with the ABS value in the SETUP >>CALIBRATE screen.

If the calculated average mass is higher than the ABS value for a particular instrument, this may indicate that there is a buildup of material on the membrane; either dirt, or water marks, or some other marking. An average lower than the ABS value could indicate that the high voltage to the Beta Detector tube is low, the count circuit is malfunctioning, or there is a hole or tear in the cellophane material. Inspect the reference membrane for signs of damage; if there is damage, call the Met One Service department.

11.4.4 Perform Beta Detector Count Rate and Dark Count Test

The TEST > COUNT screen allows the user to check the function of the beta detector and beta source separate from the rest of the mechanical or flow operations. Each count test will take 4 minutes, and will show the number of beta particles counted as they accumulate. The final count value will stay on the display after the counting is finished, and up to six count tests can be displayed on the screen at once. Count tests are usually performed with a clean section of filter tape between the source and detector, as in normal operation. The test also allows the membrane to be extended between the source and detector as well, if desired.

Press the GO Soft Key to start the 4-minute count test. The counting will immediately begin. After four minutes the counting will stop and wait for the operator to initiate another cycle or EXIT. The resulting COUNT value is the total number of beta particles counted during the four-minute test. This count will increment rapidly during the test. Typical 4-minute count values are between 600,000 and 1,000,000 counts through clean filter tape. The count total will be lower if the span membrane is extended. If the count total is less than 500,000, the beta detector is possibly wearing out.

11.4.5 Clean Inlet Tube

Annual cleaning of the inlet tube is recommended in the BAM-1020 Operation Manual (Rev H), but the site administrator should determine what frequency is most appropriate.

Proper cleaning of the inlet tube requires that the tube be lifted out of the inlet at the top of the BAM-1020. Note: take care to protect the inlet of the BAM-1020 receiver from any debris.

To clean the inlet tube,

A. loosen the set screws in the BAM-1020 inlet receiver;

B. loosen the white cap on the roof mounting flange;

C. loosen the clamp securing the support struts to the inlet tube;

D. drop a rope down the tube, and at the bottom end, tie on a clean cloth that can be pulled up through the tube to clean the walls;

E. repeat until clean.

11.4.6 Test the Analog DAC Output

If analog data are being recorded, the DAC operation should be verified. This includes verification at the terminal strip of the BAM-1020 and at the input terminals of the data logger. Multiple voltage levels should be checked.

The SETUP > TEST > DAC screen is used to test the function of the analog concentration output voltage and the DAC 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-1020 display value within ±0.001 volts at each point. If the analog output does not match the value on the TEST > DAC screen, contact the Met One Service department for instructions. Attach the voltmeter to the input of the data logger and repeat the test to verify that the correct voltages get to the data logger inputs. If the voltages at the data logger inputs do not match those measured at the terminal strip of the BAM-1020, check the integrity of the wiring between the BAM-1020 and the data logger. The DAC output cannot go negative.

11.4.7 Independent Audit

Appendix A contains a BAM-1020 Audit Form taken directly from the Met One BAM-1020 Operation Manual (Rev H), and covers flow parameters, mechanical condition, and a review of setup and calibration values. By following the monthly, bi-monthly, semi-annual and annual QC routines, all the audit parameters on this form will have been verified during the year, many at multiple times. A full audit, conducted annually by an independent reviewer, will provide added assurance that the BAM-1020 is being maintained and operated according to best practices. The auditor may be an individual within an agency not normally responsible for regular maintenance and operation of the instrument. Truly independent audits by an individual from an external agency is preferred.

11.4.8 Replace Lithium Coin Cell Battery on 3032 Circuit Board

The lithium coin cell battery location on the BAM-1020 3032 circuit board should be replaced annually. This battery provides the power to maintain the BAM-1020 clock and the stored configuration settings and sample data when the instrument is powered down. When changing the battery, the operator needs to pay careful attention to the electrical system as the battery must be changed with the AC power on, otherwise the date/time, data log, and error log will be lost

11.5 Twenty-four Month Maintenance

The 24-month maintenance items may need to be performed more frequently, depending on circumstances.

11.5.1 Rebuild the Vacuum Pump

The vacuum pump should be rebuilt every two years. The Medo 925A pump that ships with the BAM-1020 has the advantage of a very easy rebuild, which consists of removing four head bolts, sliding out the old piston and inserting a new one. Pump rebuild kits are available from Met One (PN 680839). Gast pump rebuild kits come with separate instructions.

11.5.2 Replace the Nozzle O-rings

Replacement of the nozzle O-rings requires special tools. Met One can provide these along with specific instructions accompanied by pictures to accommodate this process. No special skill are required, just attention to detail.

11.5.3 Replace the Pump Tubing

The pump tubing can crack and cause leaks that are difficult to detect. Replace the tubing between the pump and the back of the BAM-1020 at least every two years.

12.0 QUALITY ASSURANCE AND QUALITY CONTROL

Generally speaking, pertinent to data validation and QA protocols for FEM continuous $PM_{2.5}$ monitoring with the BAM-1020 are the following documents: (1) 40 CFR Part 50 Appendix N ("Interpretation of the National Ambient Air Quality Standards for $PM_{2.5}$"), (2) 40 CFR Part 50 Appendix L ("Reference Method for the Determination of Fine Particulate Matter as $PM_{2.5}$ in the Atmosphere"), (3) 40 CFR Part 58 Appendix A ("Quality Assurance Requirements for SLAMS, SPMs and PSD Air Monitoring"), and (4) EPA Quality Assurance Guidance Document 2.12 ("Monitoring $PM_{2.5}$ in Ambient Air Using Designated Reference or Class I Equivalent Methods"). These documents offer extensive details about procedures intended to ensure that $PM_{2.5}$ data meet data quality objectives (DQO). In practice, these procedures are based on some basic principles that, if followed diligently, will foster high rates of data capture and minimize the need to invalidate data. These core principles include the field QC protocols intended to keep the BAM-1020 operating in accordance with FEM designation EQPM-0308-170, and with the BAM-1020 User's Operation Manual (Rev H or later). The field protocols aid the post-processing data validation and QA protocols, during which collected data are judged under DQO criteria.

Field Quality Control Impacts Quality Assurance

The first line of defense against invalid data is the implementation of best practices in day-to-day QC operations affecting the data collection process:

- Understanding of the principle of operation of the equipment
- Acceptance testing of equipment
- Diligence in site selection followed by rigid installation procedures
- Scheduling and implementation of routine maintenance procedures (e.g., inlet cleaning)
- Scheduling and implementation of QC protocols (e.g., flow checks, instrument settings)
- Documentation/reporting of all field QC results and related field activities
- Daily review of real-time data via agency central data system
- Prompt troubleshooting of any observed operational problems.

12.1 Data Validation

Data validation is part of data Quality Assurance (QA). Two primary sources of information are directly related to validation of FEM $PM_{2.5}$ data from the BAM-1020. One is the sampling attribute data generated and stored by the BAM-1020 itself (Qtot and associated flow statistics and error codes), and the other is the site log information containing results from the periodic QC protocols.

12.1.1 BAM-1020 Generated Sampling Attribute Data

The FEM BAM-1020 internal data files, or content-equivalent digitally acquired files, should be the source files used for data validation and ultimate submittal to regulatory agencies. Analog data must be reconciled against the internal digital data in any case, so it behooves the data analyst to begin with the original digital data. Externally acquired (data logger) digital data proven to be a true replicate of the internally stored data can be used, with special attention to ensure that data logger-applied time stamps are accurate. This scenario is becoming more common as agencies switch to real-time digital data acquisition that flows directly into a permanent database. Flow statistics, now available from FEM BAM-1020 instruments, should be downloaded and utilized for QA and data validation. This step requires a separate data query to the BAM-1020 as these statistics are not part of the normal data record.

12.1.2 Field QC Generated Sampling Attribute Data

It is essential that the information, both qualitative and quantitative, be transmitted to the data analyst responsible for the data validation process. This information transfer should be prescribed–not left to chance. It may take the form of negative reporting, that is, only those field QC procedures that result in a "fail" condition need be reported, saving the data analyst from poring over data that the field technician has already documented as acceptable, or "passing". One method of implementing a negative reporting structure would be to keep a separate log of failed QC tests, containing information such as technician name, date, QC test performed, result, corrective action, retest result, etc., that would be periodically passed to the data analyst. Note, however, that some QC protocols are not "pass/fail", but only need verification that they were carried out (e.g., inlet cleaning). The instrument log shall be used to log activities and observation

12.1.3 Data Validation Criteria

The EPA documents noted in Section 12 were originally developed for 24-hr filter-based Reference Method sampling, and have been adapted in Table 12-1 to provide suggested guidelines for data validation criteria pertinent to continuous (hourly) $PM_{2.5}$ monitoring with the BAM-1020. The table is modeled on a table in Appendix D, "Measurement Quality Objectives and Validation Templates", of the QA Handbook, Volume II, Revision 1 (December, 2008).

The top panel of Table 12-1 lists the criteria that *must* be met to ensure the quality of the data. Failure to meet any one of these criteria is cause for invalidation, unless there is an otherwise compelling justification. One example of such justification would be known wildfires contributing to excessive filter loading. High filter loading can lead to flow perturbations, but these data are nonetheless highly valuable. These criteria include the 42-minute sampling period for hourly data (and extended to 24-hr data), hourly flow rate and flow rate variability (available from internally stored BAM-1020

flow statistics), and the monthly flow check and leak check. Note that the leak check failure is set at 1.5 LPM here. Some agencies may invalidate at different leak rates.

The bottom panel in the table lists criteria that indicate there *might* be a problem with the quality of the data and further investigation may be warranted before making a determination about sample validity. Example criteria in this category would be failure to perform manufacturer recommended inlet cleaning or less than optimal leak check results.

Table 12-0-1. Critical and operational data validation criteria for the Met One BAM-1020 under FEM designations EQPM-0308-170 and EQPM-0798-122 for PM_{10}.

Criteria		Frequency	Tolerances	Reference
Critical Criteria: These criteria represent the most important sampling attribute data				
Sampling period	Hourly	Hourly	42 minutes	BAM-1020 Manual, Rev H
	24-hr	Daily	1008 minutes	40 CFR Part 50 App L, Sec 3.3
Flow statistics (in BAM-1020 file memory)	Average Flow Rate	Hourly	±5% of 16.67 LPM	40 CFR Part 50 App L, Sec 7.4; Method 2.12, Sec 10.2
	Flow Rate Variability	Hourly	Coefficient of variation 2% or less	40 CFR Part 50 App L, Sec 7.4.3.2
Verification	Single point flow (Reference Std Reading)	Monthly	±5% of Design Flow	40 CFR Part 50 App L, Sec 7.4; Method 2.12, Sec 10.2
	Single point flow (BAM-1020 Flow Reading)	Monthly	±4% of Reference Std Reading	40 CFR Part 50 App L, Sec 9.2.5
	Leak Check	Monthly	≤1.5 LPM	
Operational Criteria: These criteria represent tolerances when corrective action may be needed to reestablish optimal sampling attributes				
Verification /Calibration	Leak Check	Monthly	≤1.5 LPM	
	Reference membrane	Hourly	±5% of ABS ("D" error)	BAM-1020 Manual, Rev H
	BX-596 Temp Verification	Monthly	±2°C	40 CFR Part 50 App L, Sec 9.3; Method 2.12, Sec 6.4
	BX-596 Temp Calibration	6 Months	±0.2°C	BAM-1020 Manual, Rev H
	BX-596 Barometric Pressure Verification	Monthly	±10 mm Hg	40 CFR Part 50 App L, Sec 9.3; Method 2.12, Sec 6.5
	BX-596 Barometric Pressure Calibration	6 Months	±1 mm Hg	BAM-1020 Manual, Rev H
	3-Point Flow Calibration	6 Months or on Failed Flow Check	±0.1 LPM	BAM-1020 Manual, Rev H
	Filter RH Calibration	6 Months	±4% RH	BAM-1020 Manual, Rev H
	Filter Temp Calibration	6 Months	±1°C	BAM-1020 Manual, Rev H
Cleaning	PM_{10} Inlet and VSCC™	Monthly	Cleaned	BAM-1020 Manual, Rev H; Method 2.12, Sec 9.3
	Nozzle, vane, pinch roller, capstan	Monthly	Cleaned	BAM-1020 Manual, Rev H
Other Mfg. Recommended Maintenance	Clean pump muffler; test Smart heater	6 Months	Verified	BAM-1020 Manual, Rev H
	Zero filter test, Clean internal filter; Beta detector test; check span foil; clean inlet tube	6 Months	Verified	BAM-1020 Manual, Rev H

12.1.4 Data Validation Steps

Table 12-2 lists suggested sequential steps, their components, and specific procedures for validation of continuous PM2.5 mass data collected with the BAM-1020 under FEM designations EQPM-0308-170 for PM2.5 and EQPM-

0798-122 for PM10. Data validation and corrective action checks for the flow and leak checks are shown in Table 12-3: BAM 1020 QA/QC Warning and Control limits for the BAM 1020.

Table 12-0-2. Data validation steps for BAM-1020 FEM $PM_{2.5}$ data and FEM PM_{10}.

Validation Step	Component	Procedure
Verify Data Source	Digital: Direct Download	Download csv format file
		Download flow statistics (optional, useful)
	Digital: Data Logger	Collect Conc., Q_{tot}, Error codes, Flow statistics
		Compare time stamp to internal data
	Analog: Data Logger	Compare concentration to internal data (±1 µg)
		Compare time stamp to internal data
Review BAM-1020 Attribute Data	Full scale concentration, Analog data	Sort records for full scale data (0.985 mg); look for errors causing FS output but digital CONC data are valid (e.g., errors P, R, N, E), if found, retrieve digital data.
	Full scale concentration, Digital data	Usually maintenance (M) or power fail (L) errors: invalidate
	Q_{tot}	A good validation indicator. If Q_{tot} varies, suggests a problem with temperature or pressure probe, or pump. Recommend rigid tolerance for Q_{tot} (0.700 ±0.003 m^3)
	Error flags	Review specific errors and invalidate accordingly
Review BAM-1020 Flow Statistics (useful, but really only the Qtot is needed to judge sample volume)	Elapsed time	42 minutes
	Average flow	±5% of 16.67 LPM
	Coefficient of variation	< 2%
	Sample volume	Recommend rigid tolerance for Q_{tot} (0.700 ±0.003 m^3)
	Temperature and Pressure Stats	Average, Max, Min for reasonableness
Review Field QC (Operator log sheets)	Flow checks	±4% of 16.67 LPM
	Leak checks	> 1.5 LPM, invalidate back to last passing leak check
	Calibration	At least annually, or on failed verification
Maintenance procedures	Inlet cleaning	Verify inlets cleaned (30 days for VSCC™), agency-specific intervals.
	Periodic zero test	Verify and evaluate every six month
Periodic component tests	Test: Filter T and RH, Smart Heater, Beta Count Rate, Analog DAC	Verify (Operator log sheets)

Table 12-3. BAM 1020 QA/QC Flow Control Schedule

<table>
<tr><th>Parameter</th><th>Description</th><th>Frequency</th></tr>
<tr><td>Volumetric Flows</td><td>Check the volumetric flows and acceptance limits according to the following:
Total Flow is 16.67 ≤± 4%
<table>
<tr><th>Parameter</th><th>NIST Traceable Standard</th><th>Design Flow</th></tr>
<tr><td colspan="3">Field Activity:
Acceptable – No Action Required</td></tr>
<tr><td>PM2.5</td><td><3.5% Diff</td><td>≤5% Diff</td></tr>
<tr><td>PM10</td><td><3.5% Diff</td><td>≤5% Diff</td></tr>
<tr><td colspan="3">Marginal - Corrective Action Required</td></tr>
<tr><td>PM10</td><td>3.5 - 4 % Diff</td><td>≤5% Diff</td></tr>
<tr><td colspan="3">Out of Tolerance – Corrective Action Required</td></tr>
<tr><td>PM2.5</td><td>≥4% Diff</td><td>≥5% Diff</td></tr>
<tr><td>PM10</td><td>≥4% Diff</td><td>≥5% Diff</td></tr>
<tr><td colspan="3">Data Validation:
Acceptance Limits</td></tr>
<tr><td>PM2.5</td><td>≤±4% Diff</td><td>≤±5% Diff</td></tr>
<tr><td>PM10</td><td>≤±4% Diff</td><td>≤±5% Diff</td></tr>
</table></td><td>PM2.5/ PM10 Monthly</td></tr>
<tr><td>Leak Check</td><td>Leak Check- acceptance level ≤ 1.5 mmHg
<table>
<tr><th>Parameter</th><th></th><th>Comment</th></tr>
<tr><td colspan="3">Field Activity:
Acceptable – No Action Required</td></tr>
<tr><td>PM2.5</td><td>≤ 1.0 mmHg</td><td>Data satisfactory</td></tr>
<tr><td>PM10</td><td>≤ 1.0 mmHg</td><td>Data satisfactory</td></tr>
<tr><td colspan="3">Marginal - Corrective Action Required</td></tr>
<tr><td>PM10 / PM2.5</td><td>1.0 - 1.5 mmHg</td><td>Data satisfactory</td></tr>
<tr><td colspan="3">Out of Tolerance – Corrective Action Required. Invalidate Data.</td></tr>
<tr><td>PM2.5</td><td>> 1.5 mmHg</td><td>Invalidate.</td></tr>
<tr><td>PM10</td><td>> 1.5 mmHg</td><td>Invalidate</td></tr>
<tr><td colspan="3">Data Validation:
Acceptance Limits</td></tr>
</table></td><td>Monthly</td></tr>
</table>

Parameter	Description			Frequency
	$PM_{2.5}$	≤ 1.5 mmHg	Valid level	
	PM_{10}	≤ 1.5 mmHg	Valid level	

13.0 DATA ACQUISITION AND RECORDS MANAGEMENT

13.1 Data Acquisition System (DAS)

The BAM 1020 particulate monitor is connected to the data acquisition system (DAS) using analog wires or RS232/485 for serial connection. TCP/IP over Ethernet configuration is available for the newer BAM 1020 samplers. Operational and mass concentration data generated by the BAM 1020 for one hour averages are collect by the site data logger. This data is then transferred to our central office air monitoring database where electronic charts of the minute and hourly data are reviewed in the quality assurance process. Please note that although the minute data is collected, the BAM 1020 makes one reading at the end of each hour and then that value is transmitted over the following hour.

The BAM is configured to record pressures, temperatures, flow and concentration data and other ancillary data for each hour of operation. The operator must consult the instrument and DAS manuals for channel configuration. The data is captured by the BAM instrument and it is downloaded by serial cable via a computer.

13.2 Records Management

Documentation of the quality control activities such as, bi-weekly and quarterly QC checks, audits, and annual calibrations are documented on hardcopy or electronic forms and then submitted by the operator for data verification and validation processes.

All QA/QC records must contain the following items at a minimum:

A. Date QA/QC operation was performed and the name of the operator or auditor;

B. Station name or ID#;

C. Instrument manufacturer, model, a unique ID# (e.g. serial no. or property asset no.), and date it was last calibrated;

D. Each reference standard must include the manufacturer, model, and unique ID#;

E. Each QA/QC operation must include the actual measurement, indicated measurement, and the result of the check, verification, or calibration;

F. A signature and date block for the operator or auditor;

G. A signature and date block for the QA reviewer.

The forms and reports included in Appendix A of this SOP were developed in an electronic spreadsheet format and therefore contain embedded formulas for performing calculations and data validity checks. The reporting agency may retain these records in hardcopy or in electronic format.

14.0 REFERENCES

Code of Federal Regulation, Title 40, Part 53

Code of Federal Regulation, Title 40, Part 58, Appendix A

Code of Federal Regulation, Title 40, Appendix L to Part 50—Reference Method for the Determination of Fine Particulate Matter as PM2.5 in the Atmosphere

Quality Assurance Guidance Document 2.12, Monitoring PM2.5 in Ambient Air Using Designated Reference or Class I Equivalent Methods U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Assessment Division

RTP, NC 27711 January 2016 5.

Met One BAM manual rev H BAM 1020 Particulate Monitor Operational Manual BAM 1020-9800, Rev H, Met One Instruments, Inc., Grants Pass, OR 97526

APPENDIX A - FORMS

Form DEP 03-20-A: Verification of the BAM-1020 setup parameters

Form DEP 03-20-A Equipment Status Report Effective on: 07/2016

Verification of the BAM-1020 setup parameters requires accessing 8 separate SETUP screens

Identification Block							
Date Performed:		Site Name:		AQS #:		Parameter:	
Instrument Mfr:	Met One	Model:	1020	Serial #:		Date Calibrated:	

BAM-1020 FEM $PM_{2.5}$ and PM_{10} Setup and Calibration Values

Screen	Parameter	Expected/Default	As Found Value	Adjusted Value
SETUP > CLOCK	Clock Time/Date	Local Std. Time		
SETUP > SAMPLE	RS232	9600, 8, N, 1		
	BAM SAMPLE	42 min		
	STATION #	User assigned		
	MET SAMPLE	User assigned		
	RANGE	1.000 mg		
	OFFSET	-0.015 mg		
	CONC UNITS	µg		
	COUNT TIME	8 min		
SETUP > CALIBRATE	FLOW RATE	16.7 LPM		
	CONC TYPE PM2.5	Actual		
	CONC TYPE PM10	Standard		
	FLOW TYPE	Actual		
	Cv	Instrument specific		
	Qo	Instrument specific		
	ABS	Instrument specific		
	µsw	Instrument specific		
	K Factor	Instrument specific		
	BKGD	Instrument specific		
	STD TEMP	25 C		
	HEATER	AUTO		
SETUP > EXTRA1	e1	-0.015 mg		
SETUP > ERRORS	Errors	User assigned		
	AP	150		
	FRl	10		
	FRh	20		
SETUP > PASSWORD	Password	F1 F2 F3 F4		
SETUP > INTERFACE	Cycle Mode	User assigned		
SETUP > HEATER	RH Control	YES		
	RH Setpoint	35%		
	Datalog RH	YES (Chan 4)		
	Delta-T Control	NO		
	Delta-T Setpoint	99		

Operator's Comments

Performed by: Date:

QA Comments

Verified by: Date:

Instructions to complete Form DEP 03-20-A: Verification of the BAM-1020 setup parameters

The BAM-1020 uses a comprehensive system of setup menus which contain all of the settings and parameters needed to perform the measurement and operation of the unit. Most of these settings are set at factory default values which will be correct for most applications. Some settings may be altered by the operator to suit the specific needs of your monitoring program. This form is used to log the instrument's status as found and the adjusted reading if an adjustment is made.

1. Complete the site and instrument information in the Identification Block at the top of the form DEP 03-20-A. Select the [Parameter] type from the cell dropdown menu or write in the reading if a hard copy of the form is being used.
2. From the main menu of the BAM 1020 select "SETUP > SAMPLE" and log the reading on the instrument menu on to the form. Select each individual menu item and log the value on the form. The values must fall within the expected/Default range. If the value is adjusted enter the value in the adjusted column.
3. Populate the instrument specific value for the "SETUP>CALIBRATE" section of the form. The known values can be populated for the specific instrument ahead of the site visit. From the main menu of the BAM 1020 select "SETUP>CALIBRATE" and open each menu item and enter the value in the As Found Value column in the form. Note: These values should be the same for the instrument and they should not change. Any value that does not match the instrument specific value must be thoroughly investigated.
4. From the main menu, Select "SETUP>EXTRA1" and enter the value on the sheet.
5. From the main menu select "SETUP>ERRORS" and record the values on the form.
6. From the main menu, select "SETUP>HEATER" and record the readings for each set-point on the form.
7. Complete the Operator's Comment section of the form and sign and date the form.
8. Save the completed for on the laptop, network drive or email the file back to the office.
9. The QA officer shall review the form and address any concerns with the operator or other personnel.

Form DEP 03-20-B: Met One BAM 1020 Particulate Matter Monitor Calibration/Verification Form

DEP SOP 03-16
Revision No. 0
Revision Date: 5/6/2016

Form No. DEP 03-20-B Effective on: 07/2016

Met One BAM 1020 Particulate Matter Monitor Calibration/Verification Form

Pa

Identification Block							
Date Performed:		Site Name:		AQS #:		Parameter:	PM2.5
Instrument Mfr:	Met One	Model:	1020	Serial #:		Date Calibrated:	
Primary Data Logger		Model:		Serial #:		Date Calibrated:	
PM10-Size Selective Inlet Mfr:		Model:		Serial #:		Date Installed:	
PM2.5 Size Selective Inlet Mfr:		Model:		Serial #:		Date Installed:	
Primary Recorder Mfr:		Model:		Serial #:		Date Calibrated:	

Standards Block					
Flow Standard Mfg:		Model:		Serial #:	Date Certified:
Temp. Standard Mfg:		Model:		Serial #:	Date Certified:
BP Standard Mfg:		Model:		Serial #:	Date Certified:
Rh Standard Mfg:		Model:		Serial #:	Date Certified:
Time Standard Mfg:		Model:		Serial #:	Date Certified:

Primary Recorder Status	Time (hh:mm)
Channel Off-line:	
Channel On-line:	

BAM VS DAS Comparison	µg/M3	Difference Limits µg/M3
BAM Reading:		≤ ± 2µ/M3
DAS Reading		

Date/Time Calibration	Instrument	Ref. Std.	Difference	Limits	RESULT
As Found Date				0 days	
As Found Time				± 2 minutes	
Post Calibration Date				0 days	
Post Calibration Time				± 2 minutes	

Limi

Temperature/Rh Calibrations					
Ambient Temp (°C)	Instrument	Ref. Std.	Difference	Limits	RESULT
As Found Temp				± 2 °C	
Post Calibration Temp				± 2 °C	
Rel. Humidity (%)	Instrument	Ref. Std.	Difference	Limits	RESULT
As Found %				± 2 %	
Post Calibration %				± 2 %	

Pressure Sensor Calibrations					
Barometric Pressure	Instrument	Ref. Std.	Difference	Limits	RESULT
As Found (mmHg)				± 2 mmHg	
Post Calibration (mmHg)				± 2 mmHg	

Volumetric Flow Calibration					
Volumetric Flow Verification	Instrument	Ref. Std.	% Difference	Limits	RESULT
As Found (LPM)				≤ ± 4%	
Post Calibration (LPM)				± 4%	
Flow Calibration					
Flow - 15.0 (LPM)				± 2%	
Flow - 18.4 (LPM)				± 2%	
Flow - 16.7 (LPM)				± 2%	
Post Flow check (LPM)				± 2%	
Leak Test	Instrument			Limits(LPM)	
As Found (LPM)				1.5	
As Left (LPM)				1.5	

Setup And Calibration Values	Expected	As Found	Setup And Calibration Values	Expected	As Found
Flow Type			BKGD		
Cv			Offset		
Qo			CONC Units		
ABS			CONC Type		
µsw			RH Setpoint		

Mass Co

Operator Comments:

Performed by: Date:

QA Comments:

Verified by: Date:

Instructions to complete DEP Form 03-20-B: Met One BAM 1020 Particulate Matter Monitor Calibration/Verification Form

This calibration form is formatted as an electronic spreadsheet for performing QC Checks or calibration checks on the Met One BAM 1020 Beta Particulate Monitor. If this form is used in hardcopy format, the operator must perform calculations for each QC check and enter the RESULT as "PASS" or "CALIBRATE".

1. Complete the site and instrument information in the Identification Block at the top of the form. Select the [Parameter] type from the cell dropdown menu.
2. In the Standards Block, complete the instrument information for any NIST traceable standards used during this calibration check. Be sure to enter the date of the last calibration for each transfer standard referenced during this activity.
3. In the Primary Recorder Status Block, enter the times the DAS channels are taken off-line and placed back on-line to collect ambient data.
4. In the Date/Time Calibration Block, enter the indicated date and time [As Found], displayed, on the Met One BAM 1020 and observed on the reference standard. The electronic form will record the Difference for the As Found Date in days and As Found time in minutes, as an integer (mm) and display the RESULT.
5. Enter the [Post Calibration] Date and Time if an adjustment was necessary.
6. In the Temperature/Rh Calibrations Block, enter the [As Found] values and the observed values on the reference standards for Ambient Temperature, Flow Temperature, and Relative Humidity.
7. If an adjustment is necessary, record the [Post Calibration] values.
8. In the Pressure Sensor Calibration Block, enter the [As Found] values from the 5014i and the observed values on the reference standards for Barometric, Volumetric, and Flow Pressures.
9. If an adjustment is necessary, record the [Post Calibration] values.
10. In the Volumetric Flow Calibration Block, enter the [As Found] values from the Met One BAM 1020 and the observed values on the reference standards for Volumetric and Design Flows.
11. If an adjustment is necessary, record the [Post Calibration] values.
12. In the leak test section record the pre verification and ending verification values.
13. Complete the Setup and calibration values. Note: these values should be the same from on a continuing basis and they are specific to the instrument.
14. The Leak Test is typically (recommended) completed as the final step after instrument calibrations. Enter the indicated flow reading for the instrument and the reference flow standard.
15. Enter operator/technician comments in the comment box for [Operator Comments].
16. Enter/Sign the as [Performed by] with the operator's name and signature [Date].

The operator should provide a descriptive comment indicating the purpose for performing the calibration(s) and any adjustments performed. Once the form is complete, the operator will submit it to the QA officer for verification and data validation review. The QA officer may add comments in the [QA Comment] box, then sign and date the report/log.

Form DEP 03-20-C: Zero Background Determination Form

Form No. DEP 10-20-C

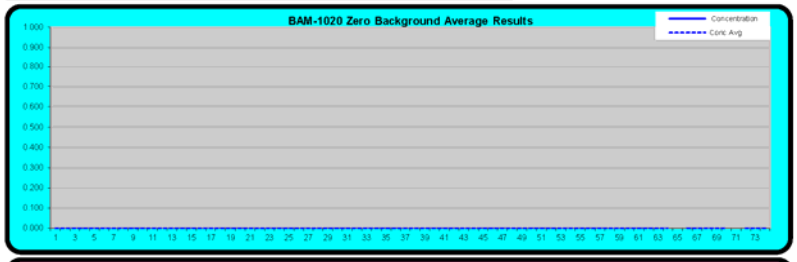
Met One BAM 1020 Particulate Matter Zero Backgroung Log

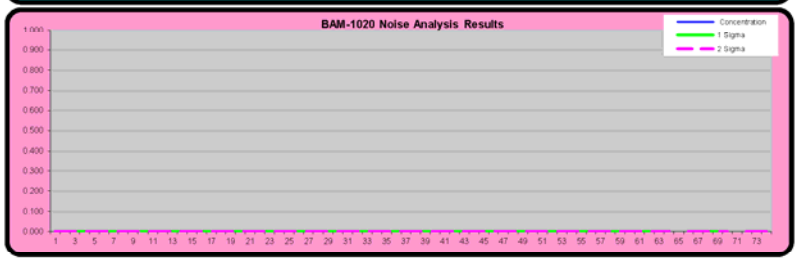
Identification Block							
Year:		Site Name:		AQS #:		Parameter:	
Instrument Mfr:	Met One	Model:	BAM 1020	Serial #:		Date Calibrated:	

Time	Concentration

Test Records	
BAM-1020 Serial Number:	
Test Performed By:	
Test Start Date:	
Test End Date:	
Previous BKGD Value:	
BKGD Value During Test:	0.0000

Dataset Statistics (milligrams)		
Zero Data Average	#DIV/0!	
Hourly Standard Deviation (σ)	#DIV/0!	#DIV/0!
Background Setting (BKGD)	#DIV/0!	Set this value in the BAM-1020





Test Instructions

1) The BAM-1020 should be completely installed and operational at its field site before starting a zero test.
2) Allow the BAM-1020 to warm up for several hours before starting a zero test, or plan on discarding the first 4 hours.
3) Perform a leak check, nozzle and vane cleaning, and flow check on the unit. See manual section 5.
4) In the SETUP > CALIBRATE menu, record the existing BKGD value, then set the BKGD to 0.0000 mg.
5) Remove the PM10 inlet and install the BX-302 zero filter. Run the BAM for at least 72 hours with the zero filter.
6) Download the data from the BAM-1020 serial port in .csv format. See manual Section 9.4.
7) Copy the 72 hourly concentration data points into this sheet and analyze the results.
8) The negative of the zero average is the correct BKGD (background) setting. Enter it into the BAM-1020.
9) Remove the BX-302 zero filter and resume normal BAM operation.
10) Save the results of this test. The test may be performed annually to audit the performance of the BAM.

Operator Comments:

Performed by: Date:

QA Comments:

Verified by: Date:

Instructions to complete Form 03-20-C: Zero Background Determination Form

1. The BAM 1020 should be completely installed and operating at its field site before starting a zero test
2. Allow the BAM-1020 to warmup for several hours before starting a zero test, or plan on discarding the first 4 hours.
3. Perform a leak check and flow verification if the BAM-1020 was in operation to bracket data going back to the last good flow check.
4. Perform a flow calibration before the start of the leak check.
5. In the SETUP > CALIBRATE menu, record the existing BKGD value on the Background form DEP 03-20-C. Then set the BKGD to 0000 mg.
6. Remove the PM10 inlet and install the BX-302 zero filter. Run the BAM for at least 72 hours with the zero filter.
7. Download the data from the BAM-1020 serial port in .csv format. See the manual section 7.7 of the BAM manual.
8. Enter the required information in the background spreadsheet for the Test information. Copy the 72 hourly concentration data points into the background spreadsheet and analyze the results.
9. The negative of the zero average is the correct BKGD (background) setting. Enter it into the BAM-1020
10 Remove the BX-302 zero filter and resume normal BAM operation. Set the new background in the BAM-1020 before the beginning of sample collection.
11. Conduct a leak, and flow verification after the background to ensure that the BAM 1020 is still performing satisfactory.
12. Save the data from the BAM-1020 serial port in CSV format and the spreadsheet used to determine the BAM-1020 BKGD. Submit the spreadsheet for review by the QA personnel.

Form DEP 03-20-D Equipment Maintenance Log

DEP SOP 03-16
Revision No. 0
Revision Date: 2/16/2016

Form No. DEP 10-20-B Form DEP 03-20-D Equipment Maintenance Log Effective on: 07/2016

Identification Block					
Year:		Site Name:		AQS #:	Parameter:
Instrument Mfr:	Met One	Model:	BAM 1020	Serial #:	Date Calibrated:
PM10 Size Selective Inlet Mfr:		Model:		Serial #:	Date Installed:
VSCC PM2.5 Size Selective Mfr:		Model:		Serial #:	Date Calibrated:

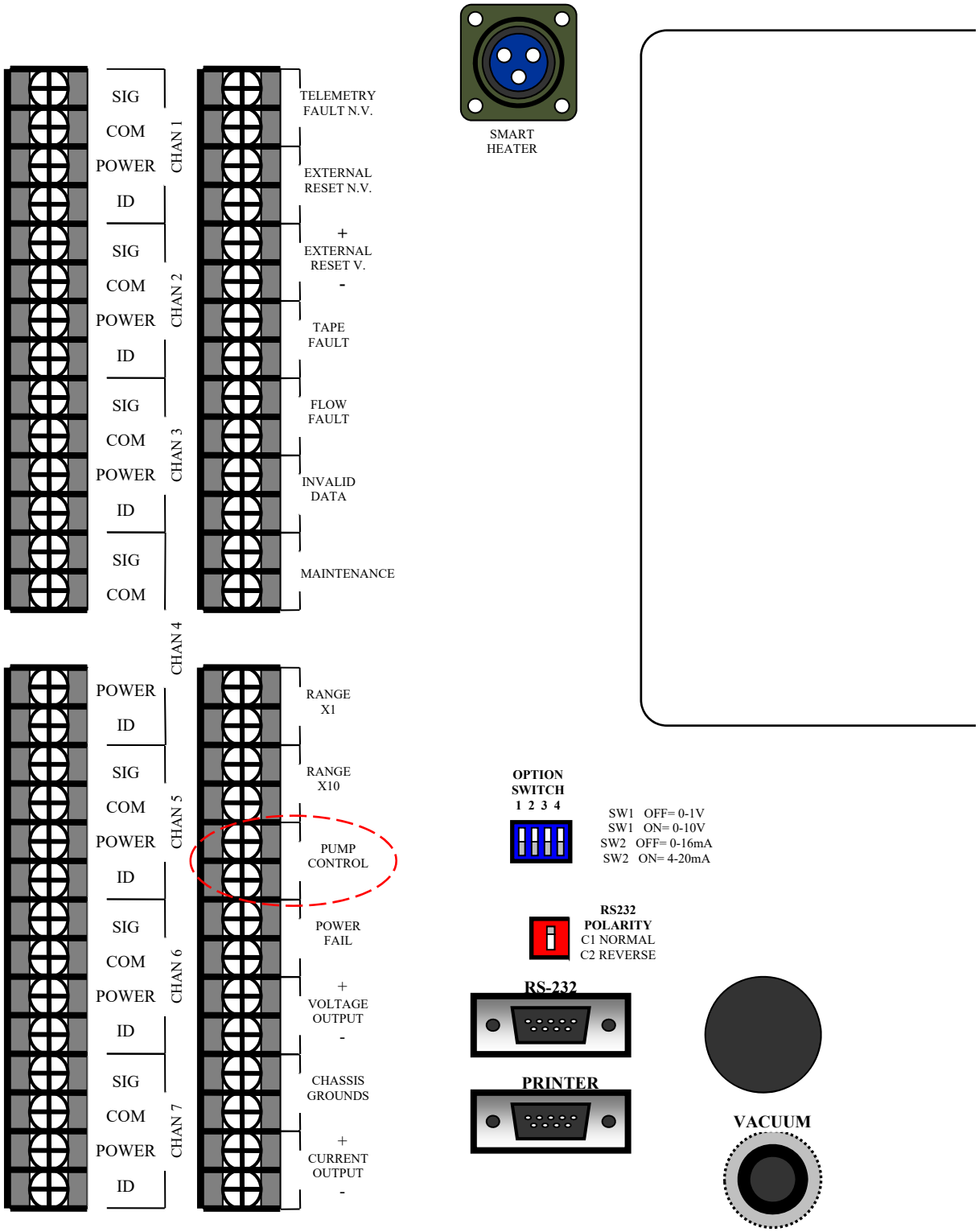
	Maintenance Activity	Inspect Water Collector and Seals	Clean PM2.5 VSCC	Clock Timer Verification	Clean PM10 Inlet	Inlet Flow Check	Replace Filter Tape as needed	Clean Temp & Rh Shield	Calibrate Monitor	Clean Inlet Probe line & downtube	Perform Background determination	Pump service		
	Frequency	Monthly	Monthly	Monthly	Monthly	Monthly	~Bi-Monthly	Quarterly	Semi-Annual	Annual	Semi-Annual	As Needed		
Maintenance Date	Operator												QA Reviewer	Review Date
Comments														

Instructions to Complete DEP Form 03-20-D: Equipment Maintenance Log

This Maintenance Log is formatted as an electronic spreadsheet used specifically for the Met One BAM 1020 PM monitor. It is completed for all scheduled or unscheduled maintenance activities.

1. Complete the site and instrument information in the Identification Block at the top of the form. Select the [Parameter] type from the cell dropdown menu.
2. Enter the 4-digit calendar year for the [Log Period].
3. Enter the [Maintenance Date] and [Operator] name.
4. For each maintenance activity listed, use the cell dropdown menu to indicate whether the maintenance activity was completed (e.g. YES, NO, NOT DUE).

APPENDIX B - REAR PANEL WIRING DIAGRAM



GLOSSARY

AQS	Air Quality System
BAM	Beta Attenuation Monitor
°C	Centigrade
CAL	Calibration
cm^3	cubic centimeter
Comet Software	Met One software used for downloading data files from the BAM 1020 sampler
CONC	Concentration
DEP	Department of Environmental Protection
FAMAS	Florida Air Monitoring and Assessment System
GPT	Gas Phase Titration
LPM	Liter per minute
PPB	Parts per billion
PPM	Parts per million
PQAO	Primary Quality Assurance Organization
QAPP	Quality Assurance Project Plan
QAP	Quality Assurance Plan
STD	Standard
TEMP	Temperature