STANDARD OPERATING PROCEDURES
FOR THE OPERATION OF
MET-ONE INSTRUMENTS BETA ATTENUATION MASS MONITOR (BAM-1020)

AQSB SOP 400

Second Edition

MONITORING AND LABORATORY DIVISION

August 2019

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CALIFORNIA
AIR RESOURCES BOARD

Approval of Standard Operating Procedures (SOP) for
MET-ONE INSTRUMENTS BETA ATTENUATION MASS MONITOR (BAM-1020)

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REVISION HISTORY

Edition	Release Data	Changes
First	June 2003	New Document
Second	Aug 2019	ADA Remediation Added zero test procedure New zero test period, 48 hours Added troubleshooting section Added data reporting and validation guidance Updated QC and calibration forms

1.0 LIST OF ACRONYMS

AMNS - Air Monitoring North Section
AMSS - Air Monitoring South Section
AQDA - Air Quality Data Action
AQSB - Air Quality Surveillance Branch
ATP - Acceptance Test Procedure
BAM-1020 - Beta Attenuation Mass Monitor, Model 1020
CAN - Corrective Action Notification
CARB - California Air Resources Board
DMS - Data Management System
FEM - Federal Equivalent Method
FRM - Federal Reference Method
LPM - Liters per Minute
MFC - Mass Flow Controller
MFM - Mass Flow Meter
MLD - Monitoring and Laboratory Division
ODSS - Operations and Data Support Section
NIST - National Institute of Standards and Technology
PQAO - Primary Quality Assurance Organization
PST - Pacific Standard Time
QA - Quality Assurance
QAS - Quality Assurance Section
QA/QC - Quality Control/Quality Assurance
QMB - Quality Management Branch
SCC - Sharp Cut Cyclone
SLPM - Standard Liters per Minute, gas flow at standard temperature and pressure
SOP - Standard Operating Procedure
VSCC - Very Sharp Cut Cyclone
VLPM - Volumetric Liters per Minute
U.S. EPA - United States Environmental Protection Agency

2.0 GENERAL INFORMATION

2.1 Introduction:

The purpose of this Standard Operating Procedure (SOP) is to document the Met One Beta Attenuation Mass Monitor, model 1020 (BAM-1020) procedures utilized by the Air Quality Surveillance Branch of the California Air Resources Board (CARB). The goal of this SOP is twofold; to formalize BAM-1020 installation, configuration, and operation procedures in order to ensure comparability of all BAM-1020 data within CARB's network, and to describe supplemental information and modifications to the Met One BAM-1020 Operation Manual necessary to successfully integrate the BAM-1020 into CARB's ambient air monitoring network. The Met One Instrument's BAM-1020 Operation Manual Revision W contains a significant source of information pertinent to the operation, maintenance, and understanding of this instrument, and therefore CARB highly recommends a thorough review of the BAM-1020 Operation Manual.

2.2 Principle of Operation:

The BAM-1020 measures and records hourly particulate mass concentrations in ambient air. The monitor consists of three basic components; the central unit, the sampling pump, and the sampling inlet hardware. Each component is self-contained and may be easily disconnected for servicing and replacement.

The BAM-1020 utilizes beta ray attenuation to calculate collected particle mass concentrations in units of ug/m^3. A 14C element (60 μCi +/- 15 μC) emits a constant source of low-energy electrons, also known as beta particles. The beta rays are attenuated as they collide with particles collected on a filter tape. The decrease in signal detected by the BAM-1020 scintillation counter is inversely proportional to the mass loading on the filter tape. The spooled filter tape allows extended monitoring periods without operator intervention.

The BAM-1020 includes a reference membrane (approximately 0.800 mg/cm^2). The reference membrane values generated during each hourly cycle are instrument drift values, not to be confused with span values. Each BAM-1020 is deployed with a Met One Factory Calibration Certificate that is unique to that instrument that lists the calibration and membrane values specific to the serial number of the instrument indicated. These certificates are posted by serial number to the AQSB Shared 'S' Drive. The density of the reference membrane for the BAM-1020 is listed on the line labeled "ABS." Each hour or day, this membrane is automatically positioned in the beta path and analyzed for instrument drift. The analysis of this membrane is integrated and displayed on the BAM-1020 display screen as "LAST m:" during the following hour. The "LAST m:" value indicates the last measured value of the reference membrane.

The value should be very close or equal to the expected span value. The BAM-1020 has the capability to analyze and report this value internally. Factory default settings should flag hourly mass data and generate an internal alarm code when the “LAST m:” value differs more than +/- 5% from expected. If the "LAST m:" value is within 5 ug/mg^3 from the expected "ABS" number, it is an indication that the analytical aspects of the BAM-1020 are working properly.

2.3 Safety Precautions:

Only properly trained personnel should perform BAM-1020 testing, installation, operation, maintenance, and calibration procedures. As with all monitoring equipment, precautions should be taken when working around electricity, power tools, and above ground elevations.

The 14C radioactive source should never be dismantled, removed, or tampered with. It will never be necessary for any field personnel to adjust, replace, or touch the 14C source. All 14C issues will be handled by the manufacturer. When working with the BAM-1020 door open and in the immediate vicinity of the 14C beta source, wearing long sleeves and laboratory gloves may help reduce possible exposure to 14C beta rays.

There are no restrictions or special requirements (such as licenses or permits) to ship, receive or operate a BAM-1020 monitor within the State of California.

2.4 Interferences/Limitations:

Moisture: The Met One BAM-1020 is a mass analyzer, and therefore any component that is suspended on the filter tape and attenuates beta rays will subsequently affect the average mass value for that hour. Moisture in the ambient air can affect both monitor performance and hourly average mass values. An inlet heater is essential for all BAM-1020 applications throughout the State of California. The Met One BAM-1020 should include a Smart Heater inlet heater.

Smart Heater: The Smart Heater resembles a small aluminum can, rated at 200 Watts. The Smart Heater requires specific firmware, hardware, and other configurations to operate properly. The Smart Heater is controlled using both %RH and temperature. These set points can be adjusted using the BAM-1020 firmware. The %RH must be set to 35%.

Power Supply: The BAM-1020 pump requires a standard external 120 VAC outlet. Using the same power source for the monitor and the pump may help reduce potential problems. If the BAM-1020 monitor is in normal sampling operation mode, a flow of 16.7 LPM is expected. If the BAM-1020 pump fails to operate during the sampling period, the monitor will acknowledge a flow

error. Flow errors can be difficult for an operator to detect and the BAM-1020 cannot pin point the fault. Therefore, do NOT plug the BAM-1020 into different power circuits. Plug in both the pump and monitor into the same power source. The BAM-1020 is designed to resume normal operation after any power failure.

Grounding and Surge Protection: A 'good' (the measured resistance of the BAM-1020 chassis to an independent ground at 0.0 ohms) station ground and an adequate surge protector are highly recommended with all monitoring equipment, and are especially significant for proper operation of the BAM-1020. A poor or absent BAM-1020 chassis ground and/or surge protector can cause temporary or permanent damage to the BAM-1020 monitor. Using an UPS will not provide a chassis ground and most likely will not provide adequate surge protection. Outlet power grounds are also not adequate.

The inlet tube should also be grounded to the BAM-1020 chassis. To ground the inlet tube, be sure to firmly tighten the two hexagonal head screws to the inlet tube. The two hexagonal head screws are located at the top inlet connection area of the BAM-1020 monitor. This ground can be checked by scraping a small spot near the bottom of the inlet tube and measuring the resistance between that spot and the chassis ground terminals on the back of the BAM-1020; the resistance should be 0.0 ohms.

Offset: Offset is used to set the lower end of the BAM-1020 measurement range, and could more accurately be called a "range offset". The default value for OFFSET for $PM_{2.5}$ FEM monitoring is -0.015 mg. This value causes the entire range of the BAM-1020 to shift down so that it reports from -0.015 to 0.985 mg, instead of from 0 to 1.000 mg (assuming the RANGE is set to 1.000 mg). This shift allows the unit to measure slightly negative concentration numbers, which is helpful to differentiate between normal noise and a failure such as punctured filter tape.

2.5 Personnel Qualifications:

Only properly trained personnel should perform BAM-1020 testing, installation, operation, maintenance, and calibration procedures. A basic understanding of the principles governing ambient air sampling is assumed.

EPA Quality Assurance Guidance Document 2.12 (U.S. Environmental Protection Agency, 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 BAM-1020 in the field must be very conscientious and attentive to detail in order to report complete and high-quality PM data. Persons qualified to perform BAM-1020 field operations should be able to:

- operate the BAM-1020;
- calibrate, audit, and troubleshoot the BAM-1020; and
- use common methods to determine temperature, pressure, and flow rate.

3.0 INSTALLATION PROCEDURE

The BAM-1020 Installation procedure has been separated into the following twelve (12) areas. Each area is described in further detail.

1) List of tools/supplies.
2) Physical Inspection.
3) Instrument Siting.
4) Installing BAM-1020 Central Unit.
5) Drilling Inlet Tube Hole.
6) Attaching Inlet Support Hardware.
7) Tape Loading.
8) Pump Connection.
9) Outside Temperature (OT) and Pressure Connection.
10) CARBLogger Connection.
11) Operational Verification.
12) Zero Background Test.

3.1 List of Tools/Supplies:

1) Hole saw/bits (1 3/8" and 2 1/4").
2) Weather proof silicon or roof sealant (i.e. Flex Seal).
3) Serial cables.
4) Tape (i.e. Scotch or masking).
5) 4 lag screws adequate for roof mounting plate.
6) Rack mounting screws.
7) Tools that include drill, screwdriver and socket set.
8) Certified flow standard capable of measuring 16.7 LPM.
9) Certified temperature and pressure standard.

3.2 Physical Inspection:

Upon receipt of a BAM-1020, inspect equipment and accessories for completeness and for shipping damage. If shortage or damage is found, immediately notify your supervisor and your agency's shipping department.

NOTE: The BAM-1020 should never be moved unless the two hard foam packing rings (referred to as donuts) are placed around the transport rollers and a white plastic shim between a nozzle and vane. A nozzle should be on down position. Failure to install the donuts can cause severe damage to the tape advance mechanism. Do not ship or transport the BAM-1020 with filter tape installed.

List of BAM-1020 Components:

1) BAM-1020 central unit.
2) Vacuum pump.
3) Inlet Tubing.
4) PM10 FRM Inlet.
5) PM2.5 Sharp Cut Cyclone (SCC) or Very Sharp Cut Cyclone (VSCC) Inlet.
6) Smart Heater Kit.
7) Inlet Support Brackets.
8) Pump tubing and wiring.
9) Outside Temperature and Pressure Sensor.

3.3 Instrument Siting:

The BAM-1020 monitor has specific physical requirements that should be considered prior to installation. In addition, all CARB BAM-1020 monitors (PM2.5, PM10, and TSP), should be deployed following 40 CFR 58 PM2.5 siting requirements to ensure data continuity. The BAM-1020 central unit and pump is neither waterproof nor water-resistant and must be protected from moisture. The BAM-1020 was designed to operate in a temperature-controlled enclosure (between 0 degrees C and 40 degrees C), and where the relative humidity is not condensing and does not exceed 90 percent.

It is important to minimize temperature fluctuations that occur within any given hour. Temperature fluctuations of more than a few degrees centigrade within a single sampling hour can cause concentration measurements on the order of several micrograms. All CARB BAM-1020 monitors will be deployed inside a weather proof and temperature controlled structure. Heating, ventilating, and air conditioning (HVAC) cycling commonly occurs multiple times per hour in small or poorly insulated enclosures. Adequate insulation should be taken into consideration during the enclosure selection process.

The effort towards maintaining a consistent temperature for the BAM-1020 throughout each hour of each day is to ensure a quality baseline by limiting the number of variables.

In general, when choosing the location for BAM-1020 monitor, it may help to consider the following items:

1) Inlet radius clearance: The BAM-1020 inlet must have a one (1) meter radius free of any objects that may influence airflow characteristics, including the airflow radius of another instrument. For example, if a BAM-1020 is to be installed at a station with another BAM-1020 or a PM2.5 FRM filter sampler, the inlets of each sampler must be no less than two (2) meters apart from each other. If installing near a PM10 SSI HiVol sampler, the distance between the inlets of the BAM-1020 and the HiVol must be no less than three (3) meters. These distances are Federal EPA requirements (40 CFR Part 58), and are designed to limit inlet airflow interference. The inlet should also be greater than two (2) meters from any parapet or roof line.

2) Distance between BAM-1020 and station ceiling: A minimum distance of at least eight (8) inches is required between the top of the BAM-1020 and the station ceiling. This distance is necessary to safely accommodate the Smart Heater.

3) Smart Heater Kit: The Smart Heater resembles a small aluminum can. When installed, the Smart Heater should be located around the lower end of the inlet tube, just where the BAM-1020 and the inlet tube intersect (about 2" above). The Smart Heater will cover approximately four (4) inches in length of the inlet tube. The Smart Heater should be a minimum of two (2) inches away from any object, such as the instrument rack or ceiling.

4) Inlet: The straight, vertical inlet tubing of the BAM-1020 limits the placement of the BAM-1020 central unit. The BAM-1020 inlet tubing is a 1 5/16" OD, 8' long rigid aluminum tube. The lower end of the inlet tube inserts directly into the top of the BAM-1020 housing, the other end points vertically upward through all roofing material and above the roofline. The selected particle size inlet(s) are mounted on the upper end of the inlet tube. The BAM-1020 FRM PM10 head should be installed so that its height is equal to the inlet height of the PM2.5 FRM or HiVol SSI filter sampler heads (2 meters +/- 0.2 meters above the roof line). Provisions must be made during installation to allow future removal, maintenance, and re-installation of all equipment.

   Total inlet tube length should not exceed sixteen (16) feet (two 8' lengths

with coupling).

5) Specifications: Specifications for siting a BAM-1020 will mirror the Federal EPA PM2.5 criteria listed in the Code of Federal Regulations (40 CFR, Part 58).

3.4 Installing BAM-1020 Central Unit:

The BAM-1020 can be rack mounted, placed on a table, shelf, or other flat surface, however, rack mounting is preferred. As with all instrumentation installations, the racks, table, or fixture must be secure and the overall installation must protect both the instrument and personnel.

Because the BAM-1020 connector fitting for the inlet tube is located on top of the BAM-1020 central unit, installation of the BAM-1020 does not allow for other instruments to be mounted above it. Wherever the BAM-1020 is installed, space for the vertical position of the inlet tube, inlet hardware, and heater must be taken into account.

3.5 Drilling Inlet Tube Hole:

Applications may vary due to structural and material makeup. After locating a suitable place for the BAM-1020 monitor, the holes for the BAM inlet tube can be drilled. Protect instruments from falling debris. The inlet support hardware includes a rooftop mounting plate for stations with a flat roof. The mounting plate has a circular ridge that protrudes beneath the surface and therefore a 2¼" diameter recess must be made on top of the roof in order to accommodate the ridge.

Inside station ceiling hole: The hole on the inside of the station should only be large enough to accommodate the outside diameter of the inlet tube. Use a 1 3/8" diameter hole saw. A plumb bob can help locate the best position on the ceiling of air monitoring stations. Drill a 1 3/8" hole vertically through the ceiling DIRECTLY ABOVE the BAM-1020 monitor inlet spout. STOP drilling when the tip of the guide bit just begins to poke through the top of the roof. The drill bit hole will be used as a guide when drilling from above and therefore do NOT drill a 1 3/8" hole all the way through the roof.

Outside roof top hole: Relocate to the topside of the roof after drilling the 1 3/8" inside ceiling hole from underneath (remember to only drill until the hole saw bit just pokes through the roof top). Using the hole created by the guide drill of the 1 3/8" hole saw bit, drill downward with a 2¼" hole saw until the hole is deep enough to accommodate the roof mounting plate.

3.6 Attaching Inlet Support Hardware:

Affix the inlet mounting plate to the top of the roof with plenty of weatherproof sealant and four lag bolts. Attach the supplied inlet coupler to the mounting plate. Slide the inlet tube through the coupler, plate, roof, and ceiling. From inside the station, gently insert and seat the bottom end of the inlet tube into the top of the BAM-1020 central unit. Leak test the seal using water. Two (2) additional lag screws, the two supplied inlet brackets and the single (1) supplied hose clamp can be used to help support the inlet tube. The inlet(s) can now be attached to the top end of the inlet tube. Be sure to firmly tighten both BAM-1020 hexagonal inlet screws to the inlet tube.

3.7 Tape Loading:

Refer to Figure 1, for photo of installed filter tape.

The filter tape must be loaded before accessing other BAM-1020 functions. Before loading tape, ensure that the nozzle is up. Begin by lifting the pinch roller (the pin with the black roller located in the upper front of the BAM) and lock the roller into position with the latch (located immediately to the left of the pinch roller). Remove both clear spool caps by unscrewing the black knobs (bottom left and bottom right spools). Unroll approximately 2 to 3 feet of tape and slide the roll onto the bottom right spool (supply spool) of the BAM-1020. Position of the supply spool so that as the tape unwinds on the spool, the roll turns counter clockwise. The tape will 'S' around the two center rollers by feeding around the left supply tension roller located just above and to the left of the supply spool, then around the right side of the right end roller located slightly above and to the right of the tension roller. The tape slides in the slit located between the source and detector, and between the pinch roller and capstan shaft (the thin metal shaft located just below the pinch roller). 'S' the tape around the left side of the left end roller (roller on the upper left), around the right side of the take-up tension roller (just below and to the right), then tape onto to the take-up spool (located bottom left). An empty core tube MUST be installed on the left take-up spool. Never fasten the filter tape directly to the aluminum hub. Wrap the tape approximately 1½ times around the take-up spool. The left side tape configuration should be a mirror image of the right side.

Lift up on the pinch roller (the latch will automatically unlock). Gently lower the

pinch roller until it completely touches the filter tape against the capstan roller. Visually check tape for binding, tears, or other obvious problems. Wherever the tape comes in contact with the rollers, the entire width of the tape should be on the roller with a little bit of the roller's edge showing. Some rollers have an indented groove to line up tape with during installation.

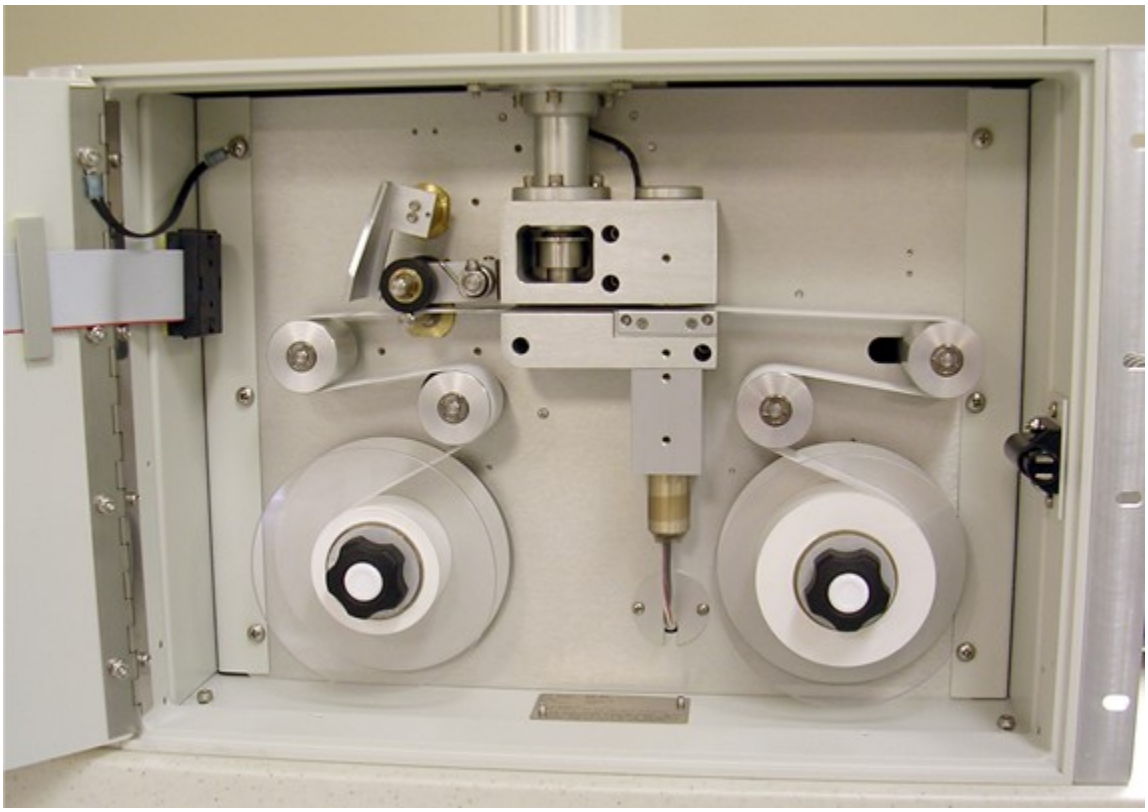


Figure 1. Loaded Filter Tape.

3.8 Pump Connection:

The pump connects to the BAM-1020 with the supplied clear vacuum tube and 2-lead wire.

Pump tubing: Insert one end of the supplied clear tubing to the only flow 'inlet' connector of the pump, and the other end of the tubing to the only tube connector located to the lower rear of the BAM unit. Push each end of the tubing all the way in, then pull back slightly to ensure a good seal. The tubing should remain at least 6 feet in length to help reduce any possibly flow fluctuations caused by the pump.

Pump wiring: Refer to Figures 2 and 3. Attach one end of the supplied 2 lead wire to the two inside terminals on the pump, the other end to the terminals on the rear of the BAM unit labeled 'PUMP CONTROL'.

3.9 Outside Temperature (AT) and Barometric Pressure (BP) Connection:

Refer to Figures 2 and 3.

All CARB deployed BAM-1020 monitors will be configured for volumetric flow control. This will require the installation of the supplied temperature and pressure sensor. The BAM-1020 temperature sensor must be calibrated by Site Secondary/Calibrator prior to the BAM-1020 monitor flow calibration.

Connect the sensor cable wires to the orange input blocks on the BX-596 translator located on the back of the BAM-1020 as per the chart below.

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

Table 1. BX-596. Terminal Connections.

3.10 Data Logger Connection:

Refer to AQSB SOP 605, CARBLogger for more information on identifying port assignments and connections for the BAM-1020. Refer to figures 2 and 3 of this document for connection visuals.

For a BAM-1020 PM10, connect two RS232 cables from the BAM-1020 to the CARBLogger:

1. Connect RS232 cable (timer control) to the "RS-232" port on the BAM-1020 (topmost RS-232 port). Note the number "Pn" on the CARBLogger RS-232 connector as this indicates the installation port.

2. Connect a 2nd RS232 cable to "Report" port on the BAM-1020 (third RS-232 port from the top). Note the number "Pn" on the CARBLogger RS-232 connector as this indicates the installation port.

For a BAM-1020 PM2.5, connect one RS232 cable from the BAM-1020 to the CARBLogger:
Connect a RS232 cable to "Report" port on the BAM-1020 (third RS-232 port from the top). Note the number "Pn" on the CARBLogger RS-232 connector as this indicates the installation port.

Refer to Section 3.2 of this document for configuring CARBLogger for a BAM-1020.

3.11 Operational Verification:

Perform a 'SELF TEST' following the BAM-1020 installation, after routine filter tape change, when troubleshooting, and after correcting any problem. Refer to Section 4.0 of this document for more information on performing the 'SELF TEST.'

3.12 Zero Background Test:

The zero background test is required at the time of field installation and annually thereafter. Refer to Section 5.0 of this document for test procedures.

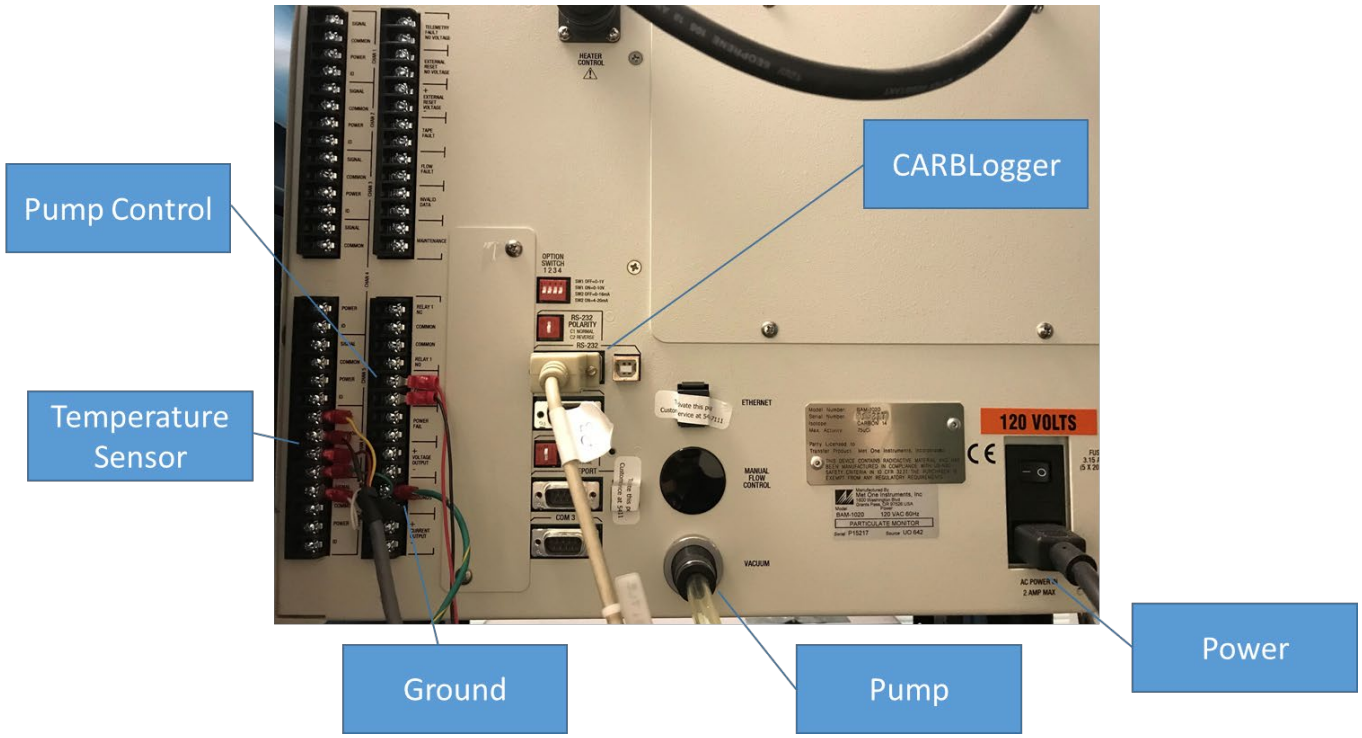


Figure 2. PM2.5 Connections.

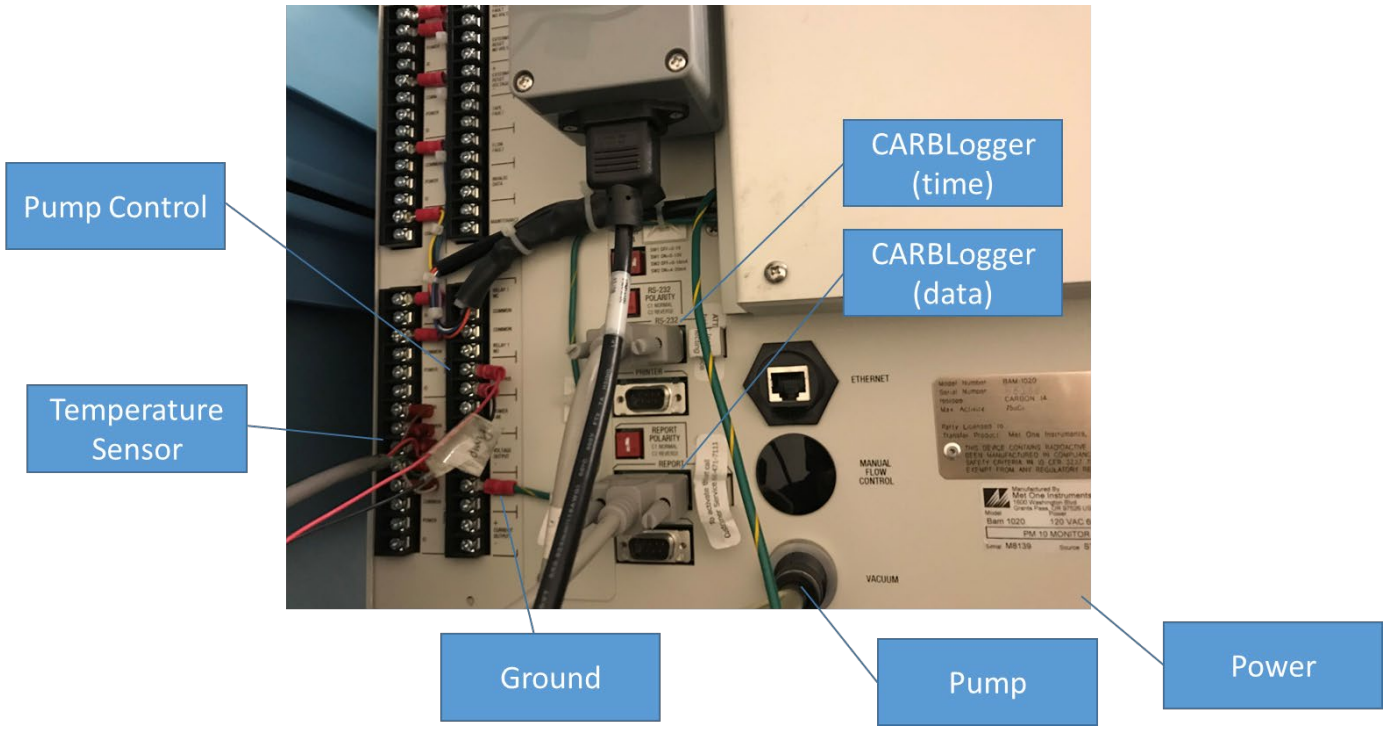


Figure 3. PM10 Connections

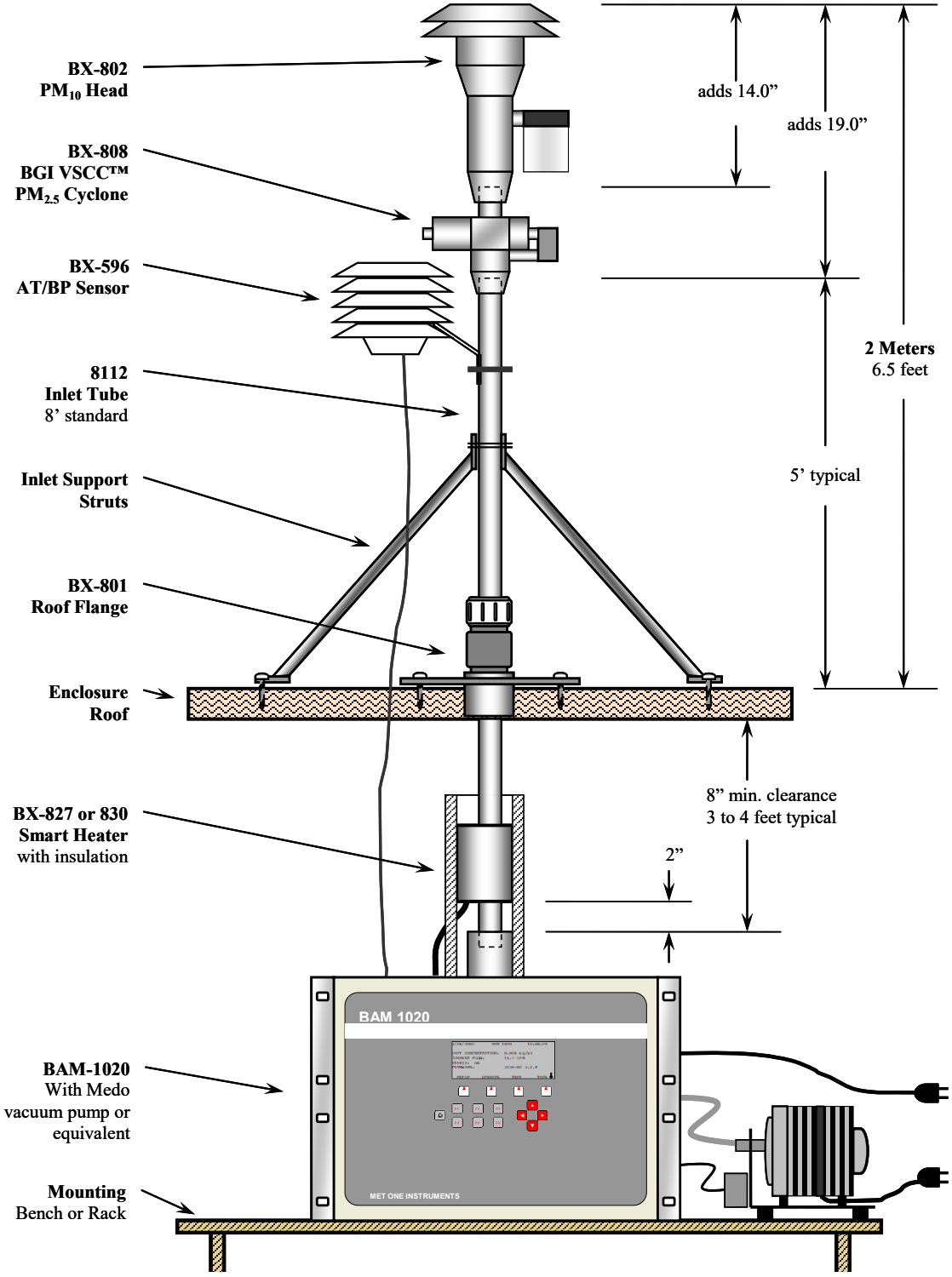


Figure 4. Basic installation configuration

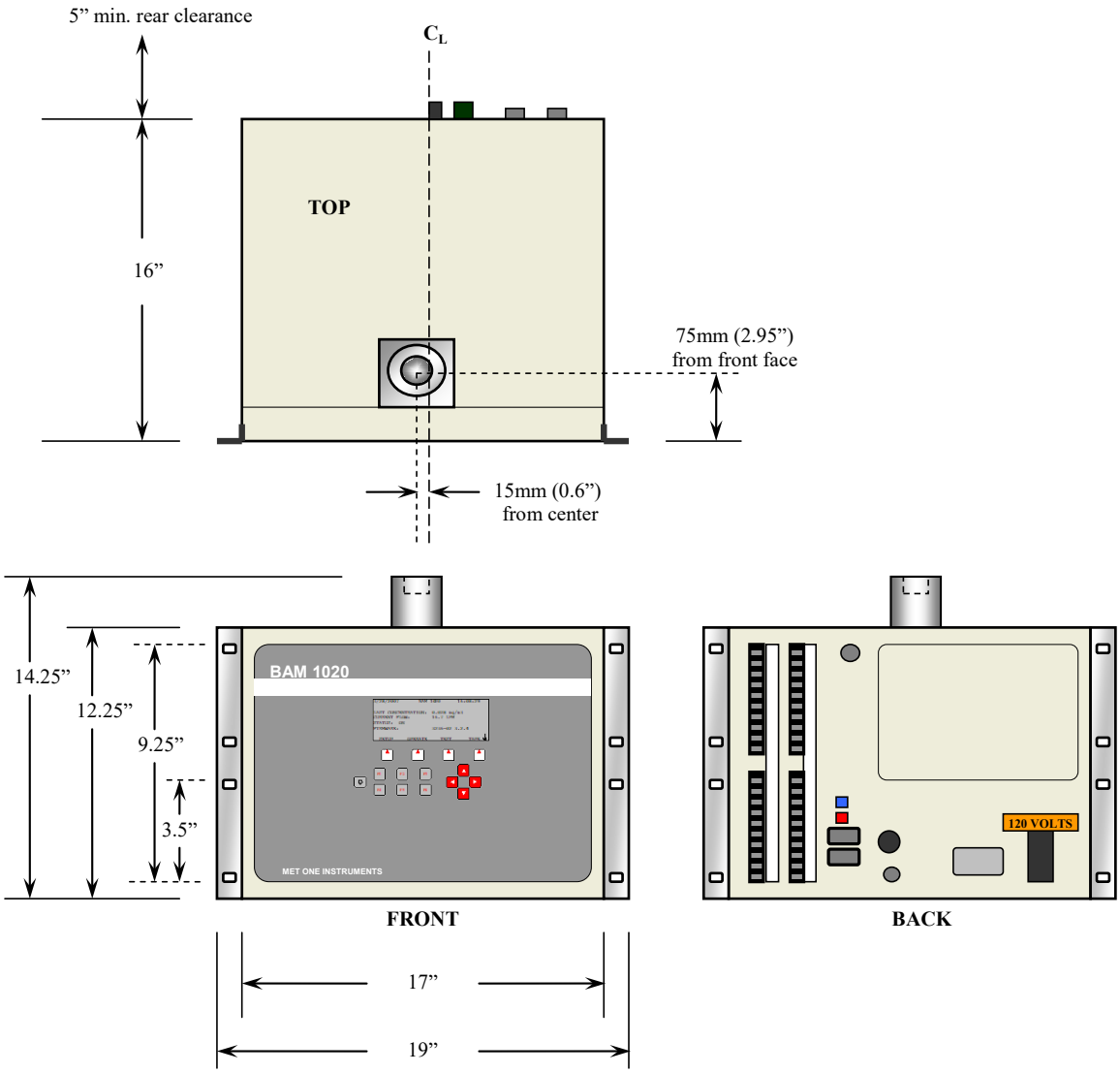


Figure 5. Mounting dimensions. Diagram of Met One BAM.

4.0 CONFIGURATION

BAM-1020's operated in CARB's ambient air monitoring network are configured dependent on the type of data being collected by the instrument. Currently there are five (5) different PM continuous parameters collected by CARB network BAM-1020 samplers (*BAM 2.5 FEM, BAM 2.5 Non-FEM, BAM 10 FEM, BAM 2.5 Coarse, and BAM 10 Coarse*). To collect proper PM parameters, each BAM-1020 must be configured in accordance with its proper United States Environmental Protection Agency (U.S. EPA) method designation.

The table below provides general information between the similarities and differences in configurations associated with BAM-1020 units used by CARB.

BAM-1020 Configuration	Sample Time	Beta Count	Qtot	Firmware	Cyclone Type (1,2)
2.5 FEM	42	8	0.701	V3.2.4 & above	VSCC
2.5 Non-FEM	42	8	0.701	R2.58	SCC
10 FEM	50	4	0.835	V3.2.4 & above	N/A
2.5 COARSE	42	8	0.701	V3.2.4 & above	N/A
10 COARSE	50	4	0.835	V3.2.4 & above	N/A

Table 2. BAM 1020 Configuration types.

Note: If 2.5 FEM configured monitor is to be used to collect 2.5 non-FEM data, the monitor must be operated with a standard sharp cut cyclone (SCC).
[1]VSCC (Very Sharp cut cyclone), BX- 808
[2]SCC (Sharp cut cyclone), BX-807

Prior to operation, several components of the BAM-1020 sampler and the CARBLogger require additional configuration. Those configurations are described below.

4.1 BAM-1020 Configuration:

Each BAM-1020 is calibrated at the factory and therefore has unique calibration settings. The correct settings for BAM-1020 are located in Appendix B of the BAM-1020 Operation Manual. When configuring the BAM-1020, a password is required. The default password is F1 F2 F3 F4.

As with any instrument, after making changes, it is always important to exit out

to the main menu and return back to check if the changes were in fact saved. If changes in the configuration have not been saved, the cause is often due to a configuration parameter that is out of the BAM-1020 operating range or a value that is significantly different than the current operating conditions.

When configuring or calibrating the BAM-1020, it is important to exit out to the main menu before proceeding to the next parameter. This will ensure that each change has been saved and that the BAM-1020 has updated its memory to the new configuration or set point. When the bottom of the display reads the words "SETUP", "OPERATE", "TEST" and "TAPE", the BAM-1020 is at the main menu. Refer to Figure 6 for keypad and main menu screen.

Clock: When configuring the BAM-1020, set the clock to the CARBLogger clock. The CARBLogger clock syncing program will automatically adjust the clock on a daily basis to minimize drift. The clock should be set to Pacific Standard Time. To set the clock:

1) Press the "SETUP" soft key.

2) Ensure that the cursor is in the word 'CLOCK and press the "SELECT" soft key.

3) Use the cursor arrows to adjust the BAM-1020 date and time.

4) Press the "SAVE" soft key.

5) Press the "EXIT" soft key.

6) Confirm BAM-1020 date and time display in main menu.

BAM-1020 'offset' voltage output configuration: All CARB BAM-1020 monitors are initially configured with a negative offset of -0.015 VDC. With this negative offset, the CARBLogger has the capacity to calculate and store negative values.

To configure the BAM-1020 monitor with the correct offset:

1) Press the "SETUP" soft key.

2) Use the arrow keys to move the cursor over to the word 'sample' and press the key under the word "SELECT".
3) Using the side arrow keys, move the cursor down to the bottom right (offset). With the up and down arrow keys, change the offset value to -0.015.

4) Press the “SAVE” soft key.

5) Press the “EXIT” soft key.

6) Confirm offset configuration by performing steps 1 through 3.

Volumetric flow mode configuration: There are different configurations for flow depending on the firmware version. For Federal Reference Method (FRM) PM2.5 filter comparability, all CARB deployed BAM-1020 monitors are configured for 'ACTUAL' flow control. To check the BAM-1020 for 'ACTUAL' flow control configuration:

1) Press the “SETUP” soft key.

2) Use the arrow keys to move the cursor over to the word ‘Calibrate’ and press the “SELECT”.

3) The word 'ACTUAL' should be displayed to the immediate right of ‘FLOW TYPE’. If not, use the arrow keys to set correct flow type. Also verify that the FLOW RATE is set at 16.7 LPM and change if necessary.

4) Press the “SAVE” soft key.

5) Press the “EXIT” soft key.

6) Confirm 'ACTUAL' flow control configuration by performing steps 1 through 3.

Sample and Count Time: To meet Federal Equivalency Method (FEM) designation requirements, the BAM SAMPLE (the amount of time that the vacuum pump is on per cycle) and COUNT TIME (the amount of time the unit takes to perform pre and post zero measurements) parameters must be set to 42 minutes and 8 minutes, respectively for PM2.5 sampling and 50 minutes and 4 minutes respectively for PM10 sampling. Press “SETUP” soft key, then “SAMPLE” to verify sample time settings for your sampling application.

Smart Heater configuration: The HEATER screen is accessed from the SETUP menu to verify or change the settings. The RH Control must be set to YES, RH Set point must be set to 35%, Delta-T Set point must be set to 99 degrees C, and Delta-T Control must be set to NO. The Smart Heater will be automatically turned on to full power whenever the humidity of the sample stream exceeds the RH Set point, helping to minimize positive artifact resulting from water sorption by the PM on the filter. If BAM-1020 sampler is running Firmware 3.14x, Delta-T settings will not be available to change.

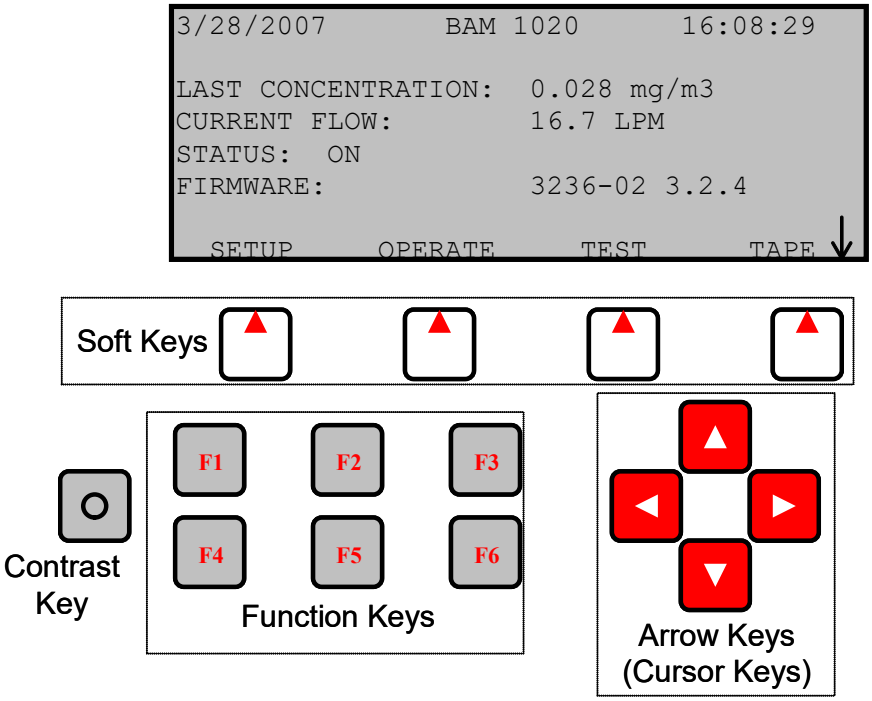


Figure 6. Keypad and main menu screen.

4.2 CARBLogger Configuration:

1) Use PuTTY SSH Client on CARBLogger to confirm successful connection from BAM to CARBLogger ports using the following procedure (Refer to Appendix D of this document for more information on communications with the BAM-1020 using PuTTY).

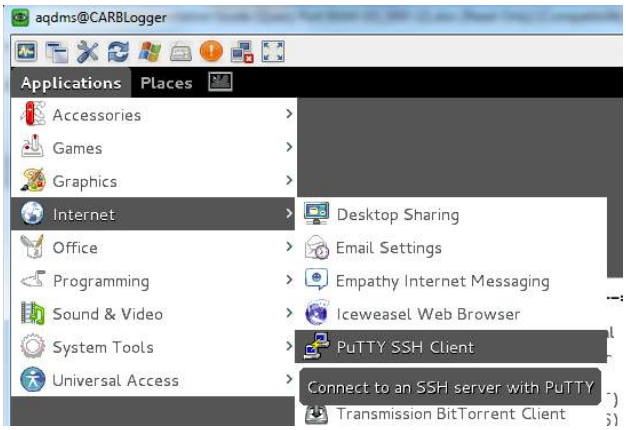


Figure 7. PuTTY SSH client on CARBLogger.

a. Both ports (one for the data port and one for the timer control port) which should operate at 9600 baud.

b. Hit return at least three times. The BAM should return at least one "*" symbol in response.

c. If the BAM does not respond, switch the parity of the port using the polarity switch above the RS-232 port. If changing the parity does not work, check the connections and the RS-232 cable.

d. If configuring a PM10, repeat the above steps for the "Report" port as well.

e. Close PuTTY once finished. If left open, PuTTY will "steal" the RS-232 communications from the driver and will not output data.

2) Next, add BAM-1020 drivers to CARBLogger.

For PM10, add the TSBAM10SQRY driver to the CARBLogger configuration by choosing "3" to add instrument, and type in the number of the driver which is listed in front of the TSBAM10SQRY_drv. Doing so will cause the "Edit Instrument" menu to display (see Figure 3 example). This menu is case sensitive. The following selections will need to be edited:

Press "d" followed by "enter" to set the serial port of the standard data port. Doing so will return you to the Edit Instrument menu.

Press "T" to Confirm Time Serial Port setting is in the correct CARBLogger serial port.

Press "m" to set the two-digit minute, which CARBLogger will use each hour to speak with the BAM. For the purpose of this installation, temporarily set this value to a couple minutes ahead of the current time in order to check the responses on the CARBLogger Display Data screen; it must be two digits. For instance, if it is currently 15:35, set the "m" value to "39".

Finally, press (s) to save settings. Doing so will cause CARBLogger to restart.

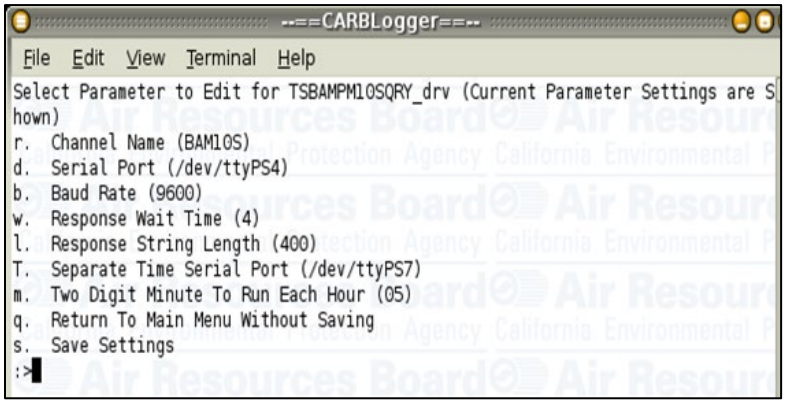


Figure 8. CARBLogger driver edit screen

For PM2.5, add the TSBAM1020_drv driver to the CARBLogger configuration by choosing "3" to add instrument, and type in the number of the driver which is listed in front of the TSBAM1020_drv. Doing so will cause the "Edit Instrument" menu to display (see Figure 3 example). This menu is case sensitive. The following selections will need to be edited:

Press "d" followed by "enter" to set the serial port of the standard data port. Doing so will return you to the Edit Instrument menu.

Press "m" to set the two-digit minute, which CARBLogger will use each hour to speak with the BAM. For the purpose of this installation, temporarily set this value to a couple minutes ahead of the current time in order to check the responses on the CARBLogger Display Data screen; it must be two digits. For instance, if it is currently 15:35, set the "m" value to "39".

Finally, press (s) to save settings. Doing so will cause CARBLogger to restart.

3) Verify the CARBLogger connection to the BAM. When the CARBLogger clock minute advances to the same time as was set for the "m" value in step 3, review the Display data on CARBLogger by pressing "8" from the main menu. The BAM-1020 data should be black and look similar to the CARBLogger display data screen below. If it doesn't show up or remains red, there is a problem and Operation Data and Support Section should be contacted for assistance.

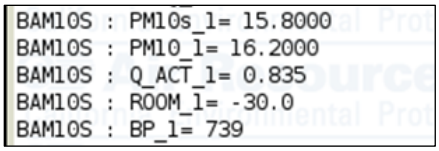


Figure 9. CARBLogger display data screen.

4) If BAM-1020 data display appears correct, go back to Edit Instrument, select the BAM-1020 channel and set (m) back to current minute time.

5.0 SELF TEST

Performing the BAM-1020 'SELF TEST' checks both the current operational status and resets any error codes that may exist. Codes will not be erased from stored memory. The BAM-1020 can generate an error code whenever an expected set point cannot be maintained, as when a low flow condition occurs or when the filter tape runs out. Perform a 'SELF TEST' following the BAM-1020 installation, after the routine filter tape change, after each flow and leak check, when troubleshooting, and after correcting any problem.

To perform the BAM-1020 self test:

1) In the BAM-1020 main menu, press the "TAPE" soft key.

2) Next, press the "SELF TEST" soft key.

3) If all BAM-1020 checks pass, the display will read 'Status: SELF TEST PASSED'. If the display reads 'FAILED', remedy the problem and rerun 'SELF TEST'. Most likely, the condition that caused the 'SELF TEST' failure will be indicated on the display.

4) At the completion of the BAM-1020 'SELF TEST', press the "EXIT" soft key to return to the main menu.

6.0 ZERO BACKGROUND TEST

The Background (BKGD) value is the zero correction (slope offset) for all BAM-1020 concentration data. This correction must be performed annually. This is determined by running the unit for 52 hours (the first four valid hours are discarded to account for acclimation) with a HEPA zero filter installed on the inlet so theoretically no particulates enter the instrument. The concentration data values over this time are averaged, and the BKGD value is the negative of this average. All of the subsequently reported concentration data contains this correction. The BKGD value varies from unit to unit, and is typically a number between +0.001 and -0.005 mg/m^3.

Historically the zero background test duration was 72 hours. However, with continued operational experience and to minimize loss of data, CARB is using a 48 hour background test to assess the BAM-1020's background values.

The BKGD value is factory calibrated for each BAM-1020 under laboratory conditions. All BAM-1020 monitors must have this value verified and/or adjusted by the user during initial field deployment of the instrument, and annually thereafter.

This field zero test corrects the BKGD value to compensate for minor variations caused by local conditions such as inlet heater operation, grounding, RFI/EMI, and shelter temperature control characteristics. It is not uncommon for the initial field zero test to result in a BKGD value that varies from the factory-set value by up to several micrograms. Subsequent field zero tests should result in the BKGD value staying consistent within about 1ug. If not, re-run background test or use another sampler.

6.1 Zero Background Test Procedures:

1) The BAM-1020 should be installed in its normal shelter at the field site where sampling is to be performed. The unit must be configured for normal operation in its usual environment.

2) Perform a flow and leak check as detailed in this document.

3) If flow check is >2% from true or if the leak check fails, troubleshoot and remedy before proceeding.

4) Disable channel in CARBLogger with the Zero Test flag.

5) Remove the PM10 inlet, and install the BX-302 zero filter assembly onto the top of the inlet tube (on top of PM2.5 cyclone if configured).

6) The BKGD (Background) value is located in the SETUP > CALIBRATE menu. Record the previous BKGD value, then change it to 0.0000, so the BAM is not performing any background corrections during the test. This simplifies the math and reduces mistakes. Exit back to the main menu.

7) Operate the BAM-1020 with the zero filter for a minimum of 52 hours. The unit should be operating just like it would be for routine PM2.5 sampling, only with the zero filter installed instead of the PM10 inlet.

8) After at least 52 hours of sampling, download the hourly concentration data from the Data Management System (DMS). The data should not contain error flags during the test period. Investigate any errors and repeat the test, if necessary. Note that raw BAM-1020 data and background are mg/m^3 units and DMS reports in ug/m^3 units. Divide

ug/m^3 values by 1000 to get mg/m^3 values.

9) The first four hours of data shall be discarded and the next consecutive 48 hours used for analysis. This sometimes improves the data set because of the tape tracking for the first few hours, if not perfectly centered when installed. Copy 48 hours of concentration data into the spreadsheet shown in FIGURE 8. For a BAM-1020 PM10 sampler, use 'ACTUAL' concentrations.

10) The spreadsheet calculates the average of the zero data to four decimal places. Calculate a new BKGD value for the unit by taking the negative of the average. For example, if the average of the zero data was +0.0016, the correct new BKGD value is -0.0016. During the 48 hours, there should not be any values higher than 20ug or lower than -14ug. If there are, repeat the test. The range of the values (min to max) should also be less than 13ug. If not, repeat the test. If the BAM-1020 continues to fail these criteria, replace the sampler.

11) Enter the new BKGD value into the BAM-1020 in the SETUP > CALIBRATE menu. Compare the new BKGD to the previous BKGD value recorded before the test. The two values should be similar within a microgram or two. If the values are considerably different, check the BAM-1020 for leaks at the nozzle and verify the temperature stability of the shelter.

12) Make a record of the test results and any BKGD value changes, and keep it with the other records for the BAM-1020 sampler. The Zero Background Microsoft Excel Spreadsheet shown in FIGURE 8 can serve as a good test record.

13) If zero background test fails, check for BAM-1020 or inlet tube grounding problems, leaks, zero filter condensation, close RFI or EMI sources, large changes in shelter temperature or pressure, improper filter RH control, etc. Excessive noise can also indicate a failing beta detector. After troubleshooting, re-run background test or use another sampler.

14) After the test, remove the BX-302 filter and reinstall the PM10 inlet, perform a SELF TEST, and resume normal operation.

6.2 Zero Background Test Apparatus for BAM-1020:

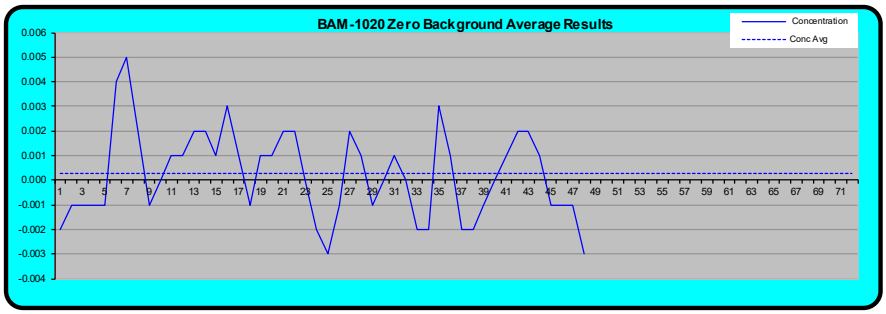
Met One Zero Test Kit (BX-302-9800)
Fully installed and operational BAM-1020 sampler
Zero Background Microsoft Excel Spreadsheet

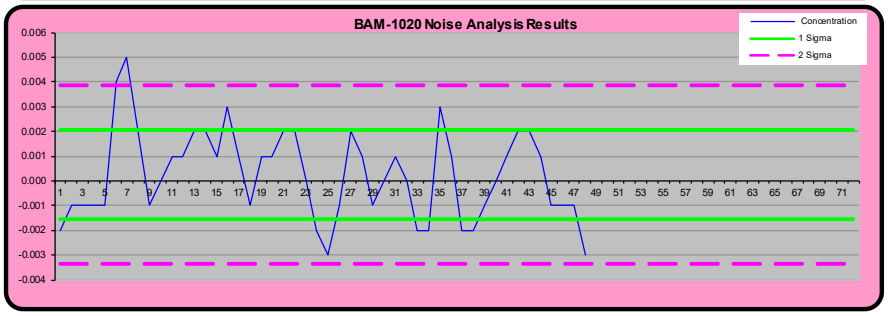
Figure 10. BX302-9800. Zero Test Kit Filter.

Time	Concentration
3/15/2019 13:00	-0.002
3/15/2019 14:00	-0.001
3/15/2019 15:00	-0.001
3/15/2019 16:00	-0.001
3/15/2019 17:00	-0.001
3/15/2019 18:00	0.004
3/15/2019 19:00	0.005
3/15/2019 20:00	0.002
3/15/2019 21:00	-0.001
3/15/2019 22:00	0.000
3/15/2019 23:00	0.001
3/16/2019 0:00	0.001
3/16/2019 1:00	0.002
3/16/2019 2:00	0.002
3/16/2019 3:00	0.001
3/16/2019 4:00	0.003
3/16/2019 5:00	0.001
3/16/2019 6:00	-0.001
3/16/2019 7:00	0.001
3/16/2019 8:00	0.001
3/16/2019 9:00	0.002
3/16/2019 10:00	0.002
3/16/2019 11:00	0.000
3/16/2019 12:00	-0.002
3/16/2019 13:00	-0.003
3/16/2019 14:00	-0.001
3/16/2019 15:00	0.002
3/16/2019 16:00	0.001
3/16/2019 17:00	-0.001
3/16/2019 18:00	0.000
3/16/2019 19:00	0.001
3/16/2019 20:00	0.000
3/16/2019 21:00	-0.002
3/16/2019 22:00	-0.002
3/16/2019 23:00	0.003
3/17/2019 0:00	0.001
3/17/2019 1:00	-0.002
3/17/2019 2:00	-0.002
3/17/2019 3:00	-0.001
3/17/2019 4:00	0.000
3/17/2019 5:00	0.001
3/17/2019 6:00	0.002
3/17/2019 7:00	0.002
3/17/2019 8:00	0.001
3/17/2019 9:00	-0.001
3/17/2019 10:00	-0.001
3/17/2019 11:00	-0.001
3/17/2019 12:00	-0.003

Test Records	
BAM-1020 Serial Number:	M8139
Test Performed By:	Dustin Goto
Test Start Date:	3/15/2019
Test End Date:	3/18/2019
Previous BKGD Value:	-0.0009
BKGD Value During Test:	0.0000

Dataset Statistics (milligrams)		
Zero Data Average	**0.0003**	
Hourly Standard Deviation (σ)	**0.0018**	Within Lab Spec < .0024 mg
Background Setting (BKGD)	**-0.0003**	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 48 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 48 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.

Figure 11. Calculated zero background Microsoft Excel spreadsheet.

7.0 CALIBRATION

7.1 Calibration Introduction

The purpose of this section is to outline the BAM-1020 verification and calibration procedures used by the AQSB of CARB. The BAM-1020 Operation Manual is an important resource of information for BAM-1020 calibrations, and therefore CARB highly recommends a thorough review of the BAM-1020 Operation Manual. Calibrations are essential to ensure quality and defensibility of data.

7.2 Calibration Overview

The BAM-1020 requires calibration of the outside temperature/pressure sensor (OT), the external pressure sensor, and the volumetric flow controller. There are different flow configurations, depending on the firmware version of the BAM-1020. Older firmware designate "METERED' or 'VOLUMETRIC' flow. Current firmware versions designate 'METERED', 'STD', or 'ACTUAL' flow. The 'METERED' configuration controls flow at *standard* conditions and calculates the hourly average mass value in terms of standard flow conditions. Flow is *not controlled* using local temperature and pressure information. The 'STD' configuration controls flow using *actual* conditions (applying local temperature and pressure conditions) but will *calculate* the hourly averaged mass value at *standard* temperature and pressure conditions. 'ACTUAL' flow will *control and calculate* flow using *actual* (local temperature and pressure) conditions. All BAM-1020 monitors purchased by CARB will be configured in the 'ACTUAL' flow mode (thus requiring the installation of an OT sensor). When calibrating the BAM-1020, a password is required. The default password is F1 F2 F3 F4.

Calibrate the BAM-1020 following these steps:

1) Leak Check
2) BAM-1020 flow control check
3) Outside temperature/pressure (OT) calibration/verification
4) External pressure calibration/verification
5) Volumetric flow calibration/verification

Record all calibration information and data.

It is important to exit back to the main menu between each complete calibration parameter. As with most software driven monitoring equipment, returning to the main menu between calibrations can be imperative when adjustments are made to specific components that ultimately impact the calibration and/or operation of the instrument's other components. Exiting out of the calibration screen and returning to the main menu between calibrating each component allows the BAM-1020 to completely update any configurations

or changes made. Temperature and pressure changes are especially critical with respect to the BAM-1020's volumetric flow control.

Checking the BAM-1020 flow controller will help determine proper operation and aid as a troubleshooting technique. By checking the BAM-1020 16.7 volumetric liter per minute (VLPM) flow set point to a lower and a higher value, the operator can determine if the BAM-1020 flow controller is capable of re-adjusting and holding at the new flow value and therefore operating properly. The flow calibration program in the BAM-1020 uses 15.0 and 18.4 VLPM as a lower and higher flow set point, respectively. If the BAM-1020 adjusts and holds at both flow set points, then the BAM-1020 flow controller is most likely operating properly. If the BAM-1020 flow does not adjust to one or both flow set points, a problem is present that requires immediate correction. If the BAM-1020 can adjust and hold a flow lower than 16.7 VLPM but not a flow higher than 16.7 VLPM, a leak between the pump and flow meter or a tired pump could be the cause. If the BAM-1020 flow does not adjust downward to a set point lower than 16.7 VLPM, a bad flow controller is most likely the problem. When the BAM-1020 flow is adjusted, new calibration is integrated with older calibrations. After numerous calibrations, flows can become unstable or difficult to adjust. It is recommended to return sampler to 'default' settings once every two or three years or as necessary.

7.3 Calibration Apparatus for BAM-1020:

1) NIST-traceable mass flow transfer standard
2) NIST-traceable temperature standard
3) NIST-traceable pressure standard
4) Tubing (optional depending on flow standard used)
5) Leak check valve
6) Calibration forms or laptop computer

A transfer standard is defined as an instrument, device or apparatus which, together with associated operational procedures, is capable of accurately reproducing standard values (e.g. flows) or producing accurate assays of these standard values which are quantitatively related to an authoritative primary standard. The most common transfer standards for calibrating the BAM-1020 are the BGI Delta Cal or the Alicat FP-25, which are NIST-traceable mass flow transfer standards, temperature standards, and pressure standards all in one device. All calibration transfer standard equipment must possess up-to-date certification.

8.0 VERIFICATION (AS-IS AND QUALITY CONTROL FLOW CHECK)

An AS-IS Verification is essential to verify validity of all data collected back to previous calibration or flow check. Allow all AC and DC powered equipment to equilibrate to ambient conditions for a minimum of one (1) hour with flow until temperature is stable.

8.1 Flow Rate Verification:

The flow rate can be verified using one of two procedures. One flow verification procedure can be performed while the BAM-1020 is in 'normal' operating mode. The other flow verification procedure can be performed by keying into the BAM-1020 flow calibration screen and turning on the pump. Perform either flow rate verification procedure by removing only the PM10 inlet and measuring the flow through the inlet tube (leave on the PM2.5 sharp cut cyclone if configured). To meet flow verification criteria, the calculated volumetric flow must be within 4% of 16.67 VLPM (16.00 to 17.34 VLPM). However, when performing a verification for a calibration, the calculated volumetric flow must be within +/- 2% of 16.67 VLPM (16.34 VLPM to 17.00 VLPM) or an adjustment and a FINAL calibration is required. Before conducting any verification or calibration, disable the BAM-1020 channel in CARBLogger with the appropriate maintenance or calibration flag.

Verifying flow in 'normal' operating mode: To verify the flow in 'normal' operating mode, simply remove the FRM PM10 impactor and measure the flow. The BAM-1020 pump only operates for 42 or 50 minutes of each hour. Verify that the pump is running when the checking flow in the 'normal' operating mode.

Verifying flow in flow calibration mode: Verify BAM-1020 flow rate only through the "TEST" screen. Be sure NOT to press the "ADJUST/SAVE" soft key during this procedure. To verify the BAM-1020 the flow calibration:

1) Press the "TEST" soft key.

2) Using the right arrow key, move the cursor over to the word 'FLOW' and press the "SELECT" soft key.

3) Press the "PUMP ON" or "NEXT" soft key and allow pump to run for several minutes (the cursor will automatically move to the 'VOLUMETRIC FLOWRATE' row under the column labeled 'REFERENCE'. The value in the 'VOLUMETRIC FLOWRATE' row under the 'BAM' column must read 16.7.

4) At the inlet on the rooftop, remove the PM10 inlet and measure the standard flow rate through the inlet tube (leave the PM2.5 inlet on if present).

5) Compare the volumetric flow displayed on the BAM-1020 to the reading on your NIST-traceable mass flow transfer standard. The flow rates must be within +/- 2% of 16.67 VLPM as calculated on calibration form.

6) Press the "EXIT" soft key (pressing the "EXIT" soft key will automatically turn off the pump).

8.2 Temperature Sensor Verification:

To verify the BAM-1020 external OT sensor:

1) Press the "TEST" soft key.

2) Using the right arrow key, move the cursor over to the word 'FLOW' and press the "SELECT" soft key.

3) Compare the BAM-1020 temperature value listed on the row to the right of 'AMBIENT TEMPERATURE', under the column labeled 'BAM' to the corrected ambient temperature on your NIST-traceable temperature standard. The temperature must be within +/- 2 degrees Celsius as calculated on calibration form.

4) Remain in this screen for ambient pressure verification or press the "EXIT" soft key.

8.3 Barometric Pressure Verification:

To verify the BAM-1020 external BP sensor:

1) Press the "TEST" soft key.

2) Using the right arrow key, move the cursor over to the word 'FLOW' and press the "SELECT" soft key.

3) Compare the BAM-1020 internal barometric pressure value listed on the row to the right of 'BAROMETRIC PRESSURE', under the column labeled 'BAM' to the corrected ambient temperature on your NIST-traceable pressure standard. The barometric pressure must be within +/- 10 mmHG as calculated on calibration form.

4) Press the "EXIT" soft key.

If the flow rate, temperature or barometric pressure are outside of the ranges listed above, perform a calibration. A temperature or pressure calibration, requires a following flow rate calibration.

9.0 FINAL CALIBRATION

A FINAL calibration is done after adjusting the BAM-1020 flow, temperature, or pressure values to transfer standard values and verifies those adjustments thus validating any data collected moving forward.

9.1 Calibration Overview:

If during the Verification (AS-IS), any of the following is true, perform a calibration:

The difference in flow rates between the BAM-1020 and the NIST-traceable mass flow transfer standard are outside +/- 2% of 16.67 VLPM,

The difference in ambient temperature between the BAM-1020 and the NIST-traceable temperature standard are outside +/- 2 degrees Celsius of each other,

Or the difference in barometric pressure between the BAM-1020 and the NIST-traceable pressure standard are outside +/- 10 mmHG of each other.

When the BAM-1020 flow is adjusted, new calibration is integrated with older calibrations. After numerous calibrations, flows can become unstable or difficult to adjust. It is recommended to return sampler to 'default' settings once every two or three years or as necessary.

9.2 Calibration Procedures:

Temperature Sensor Calibration (OT): The BAM-1020 external OT sensor is calibrated by initiating the BAM-1020 temperature calibration sequence and entering a single ambient temperature value. Ensure temperature is stable on temperature standard before proceeding. Perform the following steps to calibrate the BAM-1020 OT sensor:

1) In the BAM-1020 main menu, press the "TEST" soft key.

2) Using the right arrow key, move the cursor over to the word 'FLOW' and press the "SELECT" soft key.

3) With the arrow keys, enter the corrected ambient temperature (in degrees Celsius from the certified temperature standard), on the row to the right of 'AMBIENT TEMPERATURE', under the column labeled 'REFERENCE'.

4) Press the "ADJUST/SAVE" soft key.

5) Press the "EXIT" soft key.

6) Confirm OT calibration by performing steps 1 through 3 and recording values on calibration form.

Barometric Pressure Sensor Calibration: The BAM-1020 internal barometric pressure sensor is calibrated by initiating the BAM-1020 barometric sensor calibration sequence and entering a single ambient pressure value. Perform the following steps to calibrate the BAM-1020 barometric pressure sensor:

1) Press the "TEST" soft key from the main menu.

2) Using the right arrow key, move the cursor over to the word 'FLOW' and press the "SELECT" soft key.

3) Press the "NEXT" soft key.

4) With the arrow keys, enter the corrected ambient pressure (in mmHg from the certified pressure standard) on the row to the right of 'BAROMETRIC PRESSURE', under the column labeled 'REFERENCE'.

5) Press the "ADJUST/SAVE" soft key.

6) Press the "EXIT" soft key.

7) Confirm the internal pressure calibration by performing steps 1 through 3 and recording values on calibration form.

Volumetric Flow Rate Calibration: The BAM-1020 volumetric flow controller is calibrated by initiating the BAM-1020 volumetric flow calibration sequence and entering three through-the-inlet volumetric flow value (15.0, 18.4, and 16.7 VLPM). To acquire the correct volumetric flow values, remove the PM10 inlet and measure the standard mass flow of the BAM-1020 (leave the PM2.5 SCC or VSCC inlet attached to the inlet tube if sampling PM2.5). Enter the calculated volumetric flows from a certified transfer standard into the BAM-1020 by:

1) Press the "TEST" soft key.

2) Using the right arrow key, move the cursor over to the word 'FLOW' and press the "SELECT" soft key.

3) Press the "PUMP ON" or "NEXT" soft key and allow pump to run for several minutes (the cursor will automatically move to the 'VOLUMETRIC

FLOWRATE' row under the column labeled 'REFERENCE'. The value in the 'VOLUMETRIC FLOWRATE' row under the 'BAM' column must read 15.0.

4) At the inlet on the rooftop, remove the PM10 inlet and measure the standard flow rate through the inlet tube (leave the PM2.5 inlet on if present).

5) With the arrow keys, enter the volumetric flow rate from the NIST-traceable mass flow transfer standard.

6) Press the "ADJUST/SAVE" soft key.

7) Repeat for 18.4 VLPM and 16.67 VLPM

8) Press the "EXIT" soft key (pressing the "EXIT" soft key will automatically turn off the pump).

9) Verify the 16.67 VLPM flow rate by repeating steps 1 through 3 and recording values on calibration form. The calculated volumetric flow must be within +/- 2% of 16.67 LPM (16.34 to 17.00 LPM). The FINAL flow verification should be +/- 0.02 LPM of the expected 16.67 flow rate.

10.0 LEAK CHECK

The BAM-1020 requires a leak check after installation and on a bi-weekly basis to ensure proper operation and data quality. In addition the leak check should be performed prior to temperature, pressure and flow calibration, and prior to zero background test. The bi-weekly leak check should be performed after the bi-weekly flow check. Leak check information should be recorded on the BAM-1020 monthly quality control maintenance check sheet (Appendix A).

1) To perform a leak check, remove the FRM PM10 inlet from the BAM-1020 inlet system. Cap off the flow at the inlet of the PM2.5 SCC if configured. Capping off the inlet flow can be achieved by using a PM2.5 FRM leak check valve adaptor with stopcock or a rubber stopper.

2) Press the "TEST" soft key.

3) Using the right arrow key, move the cursor over to the word 'PUMP' and press the "SELECT" soft key. Select 'PUMP ON.' Allow the flow to stabilize and close the leak check valve.

4) The flow display on the BAM-1020 must read less than 1.0 LPM with the inlet capped off to pass CARB's leak check specifications. The leak check flow value on the display screen of the BAM-1020 should stabilize in less than 20 seconds to within two to three tenths of a liter per minute (0.2 – 0.3 LPM). Whatman brand filter tape may have slightly higher leak check results (~0.5 LPM). Ensure that the leak check flow value remains stable for a minimum of fifteen (15) to twenty (20) seconds. Do NOT leave the BAM-1020 capped off in the leak check mode longer than necessary to perform the check.

   A leak check value between 0.7 and 0.9 LPM passes criteria but indicates the potential of a leak check failure in the near future and has been verified to report higher concentration readings.

5) Slowly re-open the leak check flow valve, allow the flow to stabilize, then select 'PUMP OFF.'

6) Remove leak check valve and reinstall the appropriate inlet head. Take care that no foreign material is allowed in the sample inlet tube.

7) Perform the BAM-1020 'SELF TEST' before returning to normal sampling operation. Performing a leak check will generate an error code in the BAM-1020 due to the insufficient flow through the inlet. Performing a 'SELF TEST' will reset the BAM-1020. The 'SELF TEST' procedure is described above in Section 4.0 of this document.

11.0 START SAMPLING

Upon completion of any maintenance, verification, or calibration, return the BAM-1020 to normal sampling mode.

1) From the main menu, press the "OPERATE" soft key.

2) Press the "NORMAL" soft key. If the BAM-1020 is set to operate in time to perform the pre-load measurements, the BAM-1020 will typically start sampling at the beginning of the next hour. Tape movement will occur before the beginning of the next collection cycle (for tape zero reading). The BAM-1020 pump will turn on at the beginning of the hour and run for 42 or 50 minutes depending on configuration.

3) Ensure channel is enabled on CARBLogger.

12.0 OPERATIONAL AND ROUTINE SERVICE CHECKS

Routine checks are essential for maintaining optimal instrument performance. Document all check information and maintenance on the Monthly Quality Control Maintenance Check Sheet (Appendix A) and in the station logbook.

Perform the following checks on the BAM-1020 at the intervals specified below. The checks may be performed more frequently but should be performed at least within the prescribed intervals.

12.1 Daily Checks:

Review data in DMS and CARBDATA emails for correct operation of BAM-1020.

12.2 Weekly Checks:

Check the BAM-1020 filter tape and replace when necessary. One roll of filter tape is 22 to 25 meters long and will last approximately 60 days. CARB currently utilizes the Whatman (460180) brand tape which is 25 meters long. Clean the nozzle when replacing tape to prevent future hole-punching on tape as per procedures below:

1) 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.

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

3) 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.

4) 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.

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

6) Repeat the nozzle cleaning until the swabs come out clean.

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

8) When reinstalling tape, grasp clear plastic disc firmly while tightening the black knob. This will limit future tape errors.

12.3 Biweekly Checks:

1) **Flow checks**: Perform a flow rate verification (Section 7.1). Compare and record the sampler's indicated flow rate to the flow measurement standard. This should not exceed +/- 4.1%. Compare and record the sampler's indicated flow rate to the design flow rate of 16.67 LPM. This should not exceed +/- 5.1%. Remove only the PM10 inlet when measuring flow.

2) **Leak check**: Perform a leak check (Section 9.0). A BAM-1020 display of less than 1.0 passes the manufacturers leak check specifications.

12.4 Monthly Checks:

1) Complete and submit the BAM-1020 Monthly Calibration Control Maintenance Check Sheet (AQSB Form 400, attached).

2) Thoroughly clean both the PM2.5 Sharp Cut Cyclone or Very Sharp Cut Cyclone (SCC or VSCC) and the PM10 FRM Inlets. Disassemble the SCC or VSCC and wipe clean with lint free cloth. Ensure that all 'O' ring surfaces are in excellent shape and are re-installed correctly. Use very light coating of Dow vacuum grease on 'O' rings to prevent drying out and cracking. Replace 'O' rings when needed. Repeat for the PM10 FRM inlet.

3) Ensure sampler is clean and dust free.

12.5 Semiannual Checks:

Perform semi-annual BAM-1020 verification/calibration (Section 7.0) of the external ambient temperature, internal pressure, leak check, and volumetric flow. Perform FINAL calibration if needed.

12.6 Annual Checks:

1) Perform zero background test (Section 5.0).

2) Clean the inlet tube.

3) Replace the BR2032 lithium battery on the circuit board. This battery provides power to maintain the clock and stored configuration settings.

12.7 As-Necessary Checks:

These maintenance tasks are performed as necessary on an irregular basis. They may need to be performed frequently, depending on circumstances.

1) Rebuild or replace vacuum pump. It is recommended to install a vacuum gauge on the pump to easily assess pump health. Vacuum of an optimally running pump should be between 20 – 24 in/H2O.

2) Replace 'O' rings on nozzle or inlets.

3) Replace the pump tubing. The pump tubing can crack and cause leaks that are difficult to detect. Replace pump tubing when 'yellowing' color is observed. In addition, cut approximately one inch from both ends annually to ensure a tight fit.

13.0 TROUBLESHOOTING

Below are common issues with the BAM-1020 and how to troubleshoot. Refer to the Met One Instrument's BAM-1020 Operation Manual Revision W for more information on common error codes and troubleshooting.

ISSUE	TROUBLESHOOTING CHECKS
External Reset Error	Set the BAM 1020 clock to match the data logger clock initially. This should cause subsequent clock synch events to succeed. Make sure the BAM lithium battery is functional.
Tape Break or Error	Verify clear tape spool caps are tight and the latch is in the correct position. Ensure tape is installed correctly as detailed in Section 3.7 of this document. Use the TEST > ALIGN menu to manually operate the motors and photo sensors to ensure correct operation.
Membrane Error	The reference membrane may not be mechanically extending or withdrawing properly or the reference membrane check differs more than +/-5% from expected. Use very light coating of Dow vacuum grease on sides of membrane mechanism and perform a zero background test. If zero background test fails, replace sampler.
Multiple Negative or Below MDL Values	Perform zero background test.
High or Failing Leak Checks	Inspect vane alignment and check for hole punching on tape. Clean nozzle as detailed in Section 12.2 of this document.
Difficult to Achieve Flow Set Point During Calibration	Return sampler to 'default' settings and recalibrate.
Hole Punching	Check for tape buildup or burrs on nozzle. Clean nozzle as detailed in Section 12.2 of this document.
Smart Heater Not Very Warm to Touch	Ensure relay module that plugs into the back of the BAM-1020 is properly connected and internal settings are correct as detailed in Section 4.1 of this document.
Noisy Zero Background Test Results	Check for BAM-1020 or inlet tube grounding problems, leaks, zero filter condensation, close RFI or EMI sources, large changes in shelter temperature or pressure, improper filter RH control. Excessive noise can also indicate a failing beta detector. After troubleshooting, re-run background test or use another sampler.
QTot Deviations	Firmware version 3.6 and higher will stop the sampler early under high loading, and make the concentration calculation based on the partial volume. This feature is designed to stop the sampler if the vacuum capacity of the pump is

ISSUE	TROUBLESHOOTING CHECKS
	about to be exceeded. Verify loading and concentrations during the hour and add appropriate null or qualifier codes in DMS.
General Firmware Anomalies	Replace the BR2032 lithium battery on the circuit board.

Table 3. Common issues and troubleshooting for the BAM-1020.

14.0 DATA REPORTING AND VALIDATION

Data collected from the BAM-1020 are used to determine which areas of California are in attainment or non-attainment of federal and State air quality standards and/or the severity of air pollution in California. The data are also used in air models and real-time air quality public alerts. Therefore, it is imperative data are reviewed, validated, and legally defensible.

Refer to AQSB SOP 610, Data Review and Validation for information and procedures on performing data review for the BAM-1020.

In addition, contact Operation and Data Support Section for procedures on Back Polling CARBLogger, using PuTTY to access the BAM-1020 remotely, perform Instrument Configuration, Data Matrices, and other data related procedures and information.

QC CODE	OP CODE	NULL CODE	Reason
0	0		Valid data for record
13	64	AY	Zero background check
11	68	AT	Calibration
43	59	BR	Value less than negative MDL
22	51	BA	Routine maintenance or repairs including tape change
12	62	AX	Bi-monthly flow and leak check
14	60	BL	QA audit
44	50	AV	Power outage
41	40	AN	Machine malfunction
42	53	BK	CARBLogger down
46	41	SV	Low sample volume, Qtot below 0.167

Table 4. Common DMS QC/OP/Null code combinations for the BAM-1020

15.0 QUALITY CONTROL AND QUALITY ASSURANCE

To ensure that the ambient air monitoring data collected throughout California can be considered good quality data (data-for-record) and complies with procedures and regulations set forth by the U.S. EPA, CARB has a robust quality assurance program which includes several types of performance audit activities. SOPs ensure that all audits are conducted consistently and in accordance with federal requirements and can be found in Volume V of CARB's Quality Assurance Manual. When instruments are found to be operating outside CARB's Performance Criteria, a corrective action notification (CAN) or Air Quality Data Action (AQDA) request may be issued.

Since an accurate measurement of particulate matter is dependent upon flow rate, sampler flow audits, such as the BAM-1020, are conducted biannually. The accuracy of particulate samplers is determined by comparing the instrument's flow rate to a certified orifice or a calibrated mass flow meter. These devices are certified against a NIST traceable flow device or calibrator. The audit device is connected in-line with the sampler's flow path and the flow rate is measured while the sampler is operating under normal sampling conditions. The true flow rate is calculated from the audit device's calibration curve and then compared to the sampler's actual flow rate. A percent difference is calculated based on the readings to determine compliance.

The audit criteria for the BAM-1020 is +/- 4% of monitor flow display and +/- 5% from the design flow rate of 16.67 LPM.

16.0 REFERENCES

Met One BAM-1020 Operation Manual Revision U

AQSB SOP 605 CARBLogger

AQSB SOP 610 Data Review and Validation

Volume V of CARB Quality Assurance Manual

CARB Performance Criteria

Appendix A.

AQSB Monthly Quality Control Maintenance Check Sheet 400.

CALIFORNIA AIR RESOURCES BOARD
MONTHLY QUALITY CONTROL MAINTENANCE CHECK SHEET
Met One BAM-1020 AIR SAMPLER

PM 2.5 FEM ☐ PM 2.5 NON-FEM ☐ PM 10 FEM ☐

Location: ____________________ Month/Year: ____________________

Station Number: ____________________ Operator: ____________________

Property Number: ____________________ Agency: ____________________

Operator Instructions:

1) Daily checks: Review DMS, diagnostic emails, CARBLogger, and sampler for correct operation of BAM-1020.
2) Weekly checks: Check filter tape & replace when necessary (approx. 2 months per roll). Clean nozzle when filter tape changed.
3) Bi-weekly checks: Perform BAM-1020 flow and leak check.
4) Monthly checks: Complete and submit this Monthly Quality Control Maintenance Check Sheet. Thoroughly clean PM 2.5 SCC/VSCC inlets.
5) Semi-annual: Calibrate BAM-1020. Date last performed: ____________
6) Annual: Perform Zero Background Check.
   Zero Background Value: ________ Date last performed: ____________
   Clean inlet downtube. Date last performed: ____________
   Replace circuit board battery. Date last performed: ____________

Transfer Standard Used:

Make/Model	Serial/I.D.Number	Date Certified

Bi-Weekly Sampler Flow Rate, Ambient Temp, and Pressure Check Results:

Date:	Sampler	Standard	Difference	Control Limits*
Flow Rate				16.00 to 17.34(± .67 L/min)
Ambient Temp.				±2 °C
Ambient Press.				±10 mm Hg
Leak Check				< 1.0 L/min

Date:	Sampler	Standard	Difference	Control Limits*
Flow Rate				16.00 to 17.34(± .67 L/min)
Ambient Temp.				±2 °C
Ambient Press.				±10 mm Hg
Leak Check				< 1.0 L/min

Date:	Sampler	Standard	Difference	Control Limits*
Flow Rate				16.00 to 17.34(± .67 L/min)
Ambient Temp.				±2 °C
Ambient Press.				±10 mm Hg
Leak Check				< 1.0 L/min

If subsequent leak checks also exceed limits, initiate a course of action to troubleshoot the source of the leak, remedy, and if required, request a re-calibration.

Operator Comments: ____

Reviewed by: ____________________ Date: ____________________

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AQSB QC Form 400 (Met One BAM-1020) (10/19)

Appendix B.

AQSB BAM 1020 Calibration Report 400.

CARB Calibration Report - BAM-1020

Met One Beta Attenuation Mass Monitor

ID Information:

Station Name:	Station	As Is:	X
Site #:	00-000	Final:	
Property #:	20000000	Calib. Date:	02/17/03
Agency:	CARB	Last Cal:	08/08/01

Transfer Standard:

Flow Std. Make/Model:	BGI Delta Cal
Flow Std. ID#:	20000001
Flow Cert. Date:	01/02/03

Date/Time (PST):

BAM Display:	Std. Clock:
2/17/03 9:15	2/17/03 9:15

Temperature Sensor Calibration:

BAM Temp. Display:	Std. Temp. Display:	Diff. In degrees:	0.02	Temperature = +/- 2.0 Celsius
12.50	12.48			

Pressure Sensor Calibration:

BAM Press. Display:	Std. Press. Display:	Diff. In Pressure:	-4.0	Pressure = +/- 10 mm Hg
759	763			

Flow Verification:

BAM Display:	Std. Display:	% Diff.:	0.30%	Flow = +/- 2.0% (16.37 - 17.03 LPM)
16.7	16.72			

Leak Check:

BAM Flow Display:	0.3	Flow = < 1.0 LPM

Comments:			
Calibrated by:		Checked by:	

AQSB Calibration Form 400 (BAM-1020)
Revision 10/3/19

CARB Calibration Report - BAM-1020

Met One Beta Attenuation Mass Monitor

ID Information:

Station Name:	Station	As Is:	
Site #:	00-000	Final:	X
Property #:	20000000	Calib. Date:	02/17/03
Agency:	CARB	Last Cal:	08/08/01

Transfer Standard:

Flow Std. Make/Model:	BGI Delta Cal
Flow Std. ID#:	20000001
Flow Cert. Date:	01/02/03

Date/Time (PST):

BAM Display:	Std. Clock:
2/17/03 9:15	2/17/03 9:15

Temperature Sensor Calibration:

BAM Temp. Display:	Std. Temp. Display:	Diff. In degrees:	0.02	Temperature = +/- 2.0 Celsius
12.50	12.48			

Pressure Sensor Calibration:

BAM Press. Display:	Std. Press. Display:	Diff. In Pressure:	-4.0	Pressure = +/- 10 mm Hg
759	763			

Multipoint Verification:

BAM Display:	Std. Display:	
15.0 LPM:	15.00	Flow goal = +/- 0.02 LPM
18.4 LPM:	18.41	Flow goal = +/- 0.02 LPM
16.7 LPM:	16.67	Flow goal = +/- 0.02 LPM

Flow Verification:

BAM Display:	Std. Display:	% Diff.:	0.30%	Flow = +/- 2.0% (16.37 - 17.03 LPM)
16.7	16.72			

Leak Check:

BAM Flow Display:	0.3	Flow = < 1.0 LPM

Comments:			
Calibrated by:		Checked by:	

AQSB Calibration Form 400 (BAM-1020)
Revision 10/3/19

Appendix C.

CARBLogger Status Email

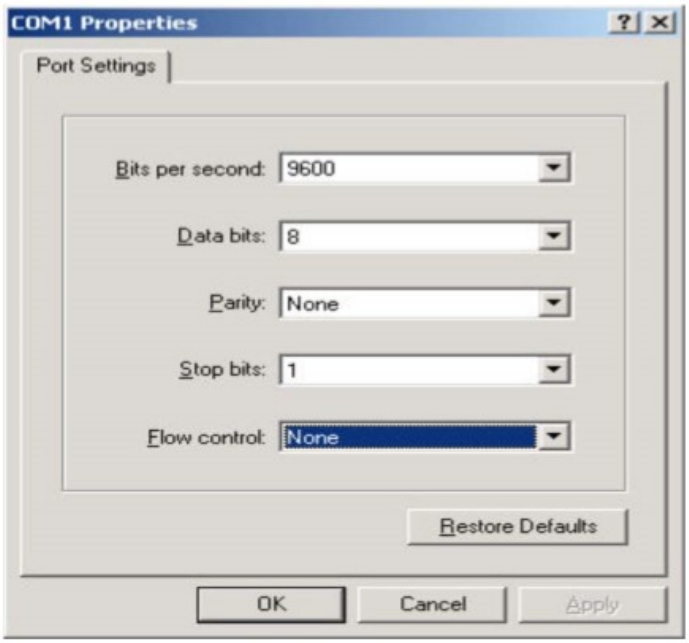
Appendix D.

Communication Set-Up using PuTTY

Printers, computers and modems may be connected to the RS-232 ports on the rear panel. Serial interface #2 is output only and may be used with serial printer or computer. The following gives details on how to download data using a terminal program with a computer directly connected to a BAM-1020.

1. Open the terminal software. If Windows HyperTerminal is used go to START / PROGRAMS / ACCESSORIES / COMMUNICATIONS / HyperTerminal.

2. Open HyperTerminal, enter a name and press OK. A 'Connect To' window will open like BAM-1020 Systems.



3. In communications protocol window set the Bits per second Window to match the setting on the BAM-1020. Note: the default setting is 9600. The other settings are 8 data bits, NONE parity, 1 stop bit, and NONE for flow control. Press OK and the setup is complete.

4. In the HyperTerminal window press ENTER 6 times.

5. Then press the number 1. This will download current data from the BAM-1020.

6. Create a path on the desktop where the downloaded data will be saved for editing and review.

The following is a list of available commands for the BAM-1020:

* H

Select One of the Following:

0 - None
1 - Display Current Day Data
2 - Display All Data
3 - Display New Data
4 - Display System Configuration
5 - Display Date / Time
6 - CSV File Output
2 - All Data
3 - New Data
7 - Display last 100 errors
8 - Display > BAM-1020 < Utility Commands
9 - Display Pointers