Title:

BAM-1020 OPERATION MANUAL
WITH BX-970 TOUCH SCREEN DISPLAY

Drawing Number: BAM-1020-9803		Revision: M
Originator Approval: *Jeffrey Elisth*	Checker Approval: *Mark Thibeault*	Document Control: *Penny Hammers*

REVISIONS			
REV	**DESCRIPTION**	**DATE**	**BY**
A-G	These revisions do not exist for the touch screen BAM-1020 manual.	---	DAH
H	The BAM-1020-9803 manual for the touch screen version is based on the regular BAM-1020-9800 revision H manual. This is done because the EPA designations require the latest revision manual after rev F. Any future revisions to either version of the manual must take into consideration if the other version is affected. BAM-1020-9803 Revision H: Removed sections pertaining to the standard display/keypad and inserted touch screen display functions instead. All else is the same as BAM-1020-9800 rev H. Sections 6 and 7 are significantly different than the regular BAM manual due to different setup and test menu orders and functions.	6-2010	DAH
I	Do not use revision letter "I".	---	---
J	• Section 7.7: Revised zero test instructions to allow installing the zero filter on a short inlet inside the shelter in humid areas for better test results. • Section 2.2: Added notes about insulating the inlet tube during installation. • Section 5.6 (touch screen manual only): Added notes about the flow calibration screen still appearing even if the flow type is set to standard, but flow calibrations don't take effect. • Section 6 (touch screen manual only): Added QUERY and REPORTS setup screens and descriptions. Verified available QUERY parameters in normal, coarse, and EU configurations.	9-22-2011	DAH
K	• Revised serial letter/year table • 2.4: Added access to power switch requirement. • 2.5: Installation: Added lift point notes. Added Ethernet port and notes about BX-965 data port availability to back panel drawing. Added smart heater insulation and safety warnings. Re-revised smart heater relay box and plug-in location details. Added pump location and installation notes. • 2.6: Rewrote to an electrical service section. Added BAM AC current and power loads. Added fuse type and location notes. Added details about line voltage and frequency requirements. • 6.3: Added span check interval setting to SETUP description (section 6.5 for touch screen). • 7.4: Added electrical hazardous voltages locations and safety notes. • 9.7: Added firmware version notes for CPU, BX-965, BX-970, EU, etc. Added warnings about firmware compatibility and updates. • 10.2: Added new BX-597 sensor setups and scaling.	10-17-2012	DAH
L	• ECO 3162 • Replaced all 596+ references with 597. • 1.7: Added EQPM-0715-266 designation • Added URG part number to Accessories and Parts table.	2015-12-03	TG

M	ECO 3534 • REPLACE FILTER TAPE PN 460130 WITH 460180 PAGE 99 • CHANGED REV LEVEL TO M • REPAIRED THE FOOTER • Added File Path. • Added BAM 1020-9803 Manual Cover to Printer Instructions.	10-17-17 2020-08-13	TG JJE

File Path: K:\Products\BAM Units\BAM 1020\Drawings\Manual\BAM-1020-9803 Touch Screen Manual Rev M.doc

To update all fields in a document; Press Ctrl + A; Press F9.

Printer Instructions:

- **Print double-sided, black-and-white or gray scale, from the original file document BAM-1020-9803, latest revision.**

- **This manual is to be spiral-bound. The BAM 1020-9803 Manual Cover sheet is to be printed in color on heavy card stock. Blank heavy card stock is to be used for back cover.**

- **Do not include any of the document control revision history pages as part of the printed manual (this page and pages above).**

- **No copies of copies!**

- **The calibration certificate and settings sheet is no longer to be bound with the manual. It must be included with the unit separately.**

BAM 1020
PARTICULATE MONITOR WITH
BX-970 TOUCH SCREEN DISPLAY
OPERATION MANUAL

BAM-1020-9803 REVISION M

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Table of Contents

1 INTRODUCTION

1.1 About This Manual and the BX-970 Touch Screen Display Option

The BX-970 Touch Screen Display is an optional front door assembly for the BAM-1020. It provides a simpler user interface and a reorganized menu system for easier and more intuitive navigation. The touch screen option is ideal for any BAM-1020 users who frequently change settings for special purpose monitoring, or for applications where enhanced visibility is required. None of the standard BAM-1020 internal sub-systems are altered, and the standard BAM-1020 specifications, measurement methods, and data formats are all the same. This version of the BAM-1020 manual simply describes the different menu system layout for the touch screen display option.

This document is organized with the most important information toward the front of the manual, such as site selection, installation, setups, and field calibrations. Toward the back are sections that provide in-depth information on subjects such as theory, diagnostics, accessories, and alternate settings. These sections provide valuable information which should be consulted as needed. Electronic versions of this manual are also available.

This manual is periodically revised for maximum accuracy, and to incorporate new features or updates.

1.2 Technical Service

This manual is structured by customer feedback to provide the required information for setup, operation, testing, maintaining, and troubleshooting your BAM-1020 unit. Should you still require support after consulting your printed documentation, we encourage you to contact one of our expert Technical Service representatives during normal business hours of 7:00 a.m. to 4:00 p.m. Pacific Standard Time, Monday through Friday. In addition, technical information and service bulletins are often posted on our website. Please contact us and obtain a Return Authorization (RA) number before sending any equipment back to the factory. This allows us to track and schedule service work and to expedite customer service.

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All BAM-1020 units have a serial number on the label on the back panel, embossed on the two metal NRC tags, and printed on the calibration certificate. This number is needed if you contact the technical service department to request information about repairs or updates for your unit. The serial number begins with a letter which represents the year of manufacture, followed by a unique four or five digit number. Example: F8029 was built in 2006.

Letter	Year	Letter	Year
W	1998	H	2008
X	1999	J	2009
Y	2000	K	2010
A	2001	M	2011
B	2002	N	2012
C	2003	P	2013
D	2004	R	2014
E	2005	T	2015
F	2006	U	2016
G	2007	W	2017

1.3 BAM: *Beta Attenuation Monitor*

The Met One Instruments model BAM-1020 automatically measures and records airborne particulate concentration levels using the principle of beta ray attenuation. This method provides a simple determination of concentration in units of milligrams or micrograms of particulate per cubic meter of air. A small C-14 (Carbon 14) element emits a constant source of high-energy electrons known as beta particles. These beta particles are detected and counted by a sensitive scintillation detector. An external pump pulls a measured amount of dust-laden air through a filter tape. After the filter tape is loaded with ambient dust, it is automatically placed between the source and the detector thereby causing an attenuation of the beta particle signal. The degree of attenuation of the beta particle signal is used to determine the mass concentration of particulate matter on the filter tape, and hence the volumetric concentration of particulate matter in ambient air. A complete description of the measurement cycle is included in Section 4. In addition, a scientific explanation of the theory of operation and the related equations is included at the back of the manual.

1.4 Beta Radiation Safety Statement

The Met One Instruments BAM-1020 contains a small C-14 (Carbon 14) beta radiation-emitting source. The activity of the source is **60 μCi** ±15μCi (microcurries), which is below the "Exempt Concentration Limit" of 100 μCi as defined in 10 CFR Section 30.71 – Schedule B. 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 C-14 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 C-14 source nor the beta particle detector 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.

1.5 Model BAM 1020 PM$_{10}$ U.S. EPA Equivalent Method

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 as of August 3, 1998.

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

The EPA designation applies to G, -1, G-1, and later BAM-1020 PM$_{10}$ Beta Attenuation Monitors, when used in conjunction with the following requirements. Users are advised that configurations that deviate from this specific description may not meet the applicable requirements of 40 CFR Parts 50 and 53:

- The BAM-1020 is operated to obtain a daily average of the hourly measurements, with a filter change frequency of one hour.
- The inlet must be equipped with the standard BX-802 EPA PM$_{10}$ 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-967 internal span membrane system.

Updates – Using newer BAM-1020 units and newer firmware for PM$_{10}$
- 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 configured for PM$_{10}$ sampling may use the BX-827 or BX-830 Smart Inlet Heaters for humidity control of 35 to 45%, no delta-T control.
- The BKGD (background) zero correction for PM$_{10}$ BAM-1020 units may be determined in the field using the BX-302 zero filter kit if desired, although it is not a requirement.
- It is no longer required that the BAM-1020 only be operated with a 50 minute sample time and 4 minute count times for PM$_{10}$ sampling. The 42 minute sample time and 8 minute count times used for the PM$_{2.5}$ FEM configuration may be used for PM$_{10}$ sampling as well. See Section 6.2.
- PM$_{10}$ data is usually reported in EPA standard conditions. Newer BAM-1020 units (firmware 3.0 and later) have a CONC TYPE setting which must be set to STD, and a FLOW TYPE setting which should be set to ACTUAL for PM$_{10}$ sampling. This will cause the BAM to regulate the flow to actual conditions for a proper inlet cut-point, but store the concentration and flow volume based on standard conditions for reporting purposes. Older BAM-1020 units (firmware 2.58 and earlier) only had a FLOW TYPE setting, which must be set to STD for PM$_{10}$ monitoring. See Sections 5.2 and 6.3.
- PM$_{10}$ units may use either the BX-592 or the BX-596 ambient temperature sensor.

1.6 Model BAM-1020 PM$_{2.5}$ U.S. EPA Equivalent Method

The Met One Instruments, Inc. Model BAM-1020 Beta Attenuation Mass Monitor - PM$_{2.5}$ FEM Configuration, is designated as an equivalent method for PM$_{2.5}$ monitoring in accordance with 40 CFR Part 53 by the United States Environmental Protection Agency as of March 12, 2008.

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

All of the following parameters and conditions must be observed when the BAM-1020 is operated as an EPA designated PM$_{2.5}$ FEM particulate monitor:

- The inlet must be equipped with an EPA-designated PM$_{2.5}$ Very Sharp Cut Cyclone (VSCC™-A by BGI, Inc.). The Met One stock number for the VSCC™ is BX-808.
- The inlet must also be equipped with a standard EPA PM$_{10}$ Size-Selective Inlet head. Met One model BX-802.
- The unit is operated for hourly average measurements. The PM$_{2.5}$ concentration is calculated (external to the BAM) as a daily average of the hourly concentration measurements made by the BAM-1020.
- The unit must be equipped with firmware revision 3.2.4 or later.
- The BAM-1020 must be operated in proper accordance with this operation manual, revision F or later. A supplemental BGI Inc. manual is also supplied with the VSCC™.
- The unit must be equipped with a BX-596 ambient temperature and barometric pressure combination sensor. This is used for flow control and flow statistics.
- The unit must be equipped with the internal BX-961 automatic flow controller, and must be operated in Actual (volumetric) flow control and flow reporting mode.
- The unit must be equipped with a BX-827 (110V) or BX-830 (230V) Smart Inlet Heater, with the heater RH regulation setpoint set to 35%, and Delta-T control disabled.
- The unit must be equipped with the 8470-1 rev D or later tape control transport assembly with close geometry beta source configuration. All BAM-1020 units manufactured after March 2007 have these features standard. Older units will have to be factory upgraded and re-calibrated to the latest specifications.
- The unit must be operated with standard glass fiber filter tape.
- The COUNT TIME parameter must be set for 8 minutes, and the SAMPLE TIME parameter must be set for 42 minutes.
- The BX-302 zero filter calibration kit is a required accessory. This kit must be used to audit the BKGD (background) value upon unit deployment and periodically thereafter, as described in this manual and the separate BX-302 manual.
- The unit may be operated with or without a BX-823 eight foot inlet tube extension and with or without weatherproof outdoor enclosures BX-902 or BX-903.

Non-EPA Designated PM$_{2.5}$ Configurations:

Some other countries do not require the full U.S. EPA FEM criteria for their PM$_{2.5}$ continuous monitoring networks. These BAM-1020 units may be supplied with a model BX-807 PM$_{2.5}$ Sharp-Cut Cyclone instead of the more expensive VSCC cyclone. In addition, the simpler BX-592 temperature sensor may be used, the BX-302 zero filter may be omitted, and the firmware may not be capable of performing 8 minute counts. *These compromises may come at the expense of less optimal accuracy*. Met One cannot guarantee the PM$_{2.5}$ FEM accuracy specifications if the BAM-1020 is used with downgraded accessories and firmware.

1.7 Model BAM-1020 PM$_{2.5}$ U.S. EPA Equivalent Method (URG)

The Met One Instruments, Inc. Model BAM 1020 Beta Attenuation Mass Monitor - PM$_{2.5}$ FEM Configuration, is designated as an equivalent method for PM$_{2.5}$ monitoring in accordance with 40 CFR Part 53 by the United States Environmental Protection Agency as of August 18, 2015.

<center>Designation Number: **EQPM-0715-266**</center>

All of the following parameters and conditions must be observed when the BAM 1020 is operated as an EPA designated PM$_{2.5}$ FEM particulate monitor:

- The inlet must be equipped with an URG-2000-30EGN PM2.5 cyclonic separator. The Met One stock number for the URG is BX-809.
- The inlet must also be equipped with a standard EPA PM$_{10}$ Size-Selective Inlet head. Met One model BX-802.
- The unit is operated for hourly average measurements. The PM$_{2.5}$ concentration is calculated (external to the BAM) as a daily average of the hourly concentration measurements made by the BAM 1020.
- The BAM 1020 must be operated in proper accordance with this operation manual, revision K or later.
- The unit must be equipped with a BX-596 ambient temperature and barometric pressure combination sensor. This is used for flow control and flow statistics.
- The unit must be equipped with the internal BX-961 automatic flow controller, and must be operated in Actual (volumetric) flow control and flow reporting mode.
- The unit must be equipped with a BX-827 (110V) or BX-830 (230V) Smart Inlet Heater, with the heater RH regulation set point set to 35%, and Delta-T control disabled.
- The unit must be equipped with the 8470-1 rev D or later tape control transport assembly with close geometry beta source configuration. All BAM 1020K units manufactured after March 2007 have these features standard. Older units will have to be factory upgraded and re-calibrated to the latest specifications.
- The unit must be operated with standard glass fiber filter tape MOI PN 460180.
- The COUNT TIME parameter must be set for 8 minutes, and the SAMPLE TIME parameter must be set for 42 minutes.
- The BX-302 zero filter calibration kit is a required accessory. This kit must be used to audit the BKGD (background) value upon unit deployment and periodically thereafter, as described in this manual and the separate BX-302 manual.
- The unit may be operated with or without a BX-823 eight foot inlet tube extension and with or without weatherproof outdoor enclosures BX-902 or BX-903.

<center>**Non-EPA Designated PM$_{2.5}$ Configurations:**</center>

Some other countries do not require the full U.S. EPA FEM criteria for their PM$_{2.5}$ continuous monitoring networks. These BAM 1020K units may be supplied with a model BX-807 PM$_{2.5}$ Sharp-Cut Cyclone instead of the more expensive VSCC cyclone. In addition, the simpler BX-592 temperature sensor may be used, the BX-302 zero filter may be omitted, and the firmware may not be capable of performing 8 minute counts. *These compromises may come at the expense of less optimal accuracy*. Met One cannot guarantee the PM$_{2.5}$ FEM accuracy specifications if the BAM 1020K is used with downgraded accessories and firmware.

1.8 Model BAM-1020 PM$_{10\text{-}2.5}$ U.S. EPA Equivalent Method

The Met One Instruments, Inc. Model BAM-1020 PM$_{10\text{-}2.5}$ Measurement System is designated as an equivalent method for PM$_{10\text{-}2.5}$ (PM-Coarse) monitoring in accordance with 40 CFR Part 53 by the United States Environmental Protection Agency as of June 15, 2009

Designation Number : **EQPM-0709-185**

The following conditions must be observed when a pair of BAM-1020 units are operated as a PM$_{10\text{-}2.5}$ FEM continuous measurement system:

- One of the BAM-1020 units is configured as a PM$_{2.5}$ FEM (EQPM-0308-170).
- The other unit is configurable as a PM$_{2.5}$ FEM, but set to measure PM$_{10}$ by excluding the PM$_{2.5}$ cyclone.
- The two monitors are collocated within 1 and 4 meters apart at the inlet.
- The units are equipped with the BX-COARSE sampling kit, which allows the two units to be directly connected together to provide concurrent sampling and reporting of the PM$_{10\text{-}2.5}$ concentrations.
- Both units are operated in accordance with the PM-Coarse manual addendum (document BX-COARSE-9800), revision 5-5 or later. The revision A and later manual supersedes all beta release revisions 5-5 and earlier.

The PM$_{10\text{-}2.5}$ BAM-1020 units use different firmware which contains extra setup menus and extra data array parameters for the coarse measurement. The system reports U.S. EPA FEM designated measurements for PM$_{10}$, PM$_{2.5}$, and PM$_{10\text{-}2.5}$ all in a single data array. The data must be collected digitally from the master BAM-1020 in the system. See the BX-COARSE manual addendum for details about the system.

1.9 BAM-1020 Specifications

PARAMETER	SPECIFICATION
Measurement Principle:	Particulate Concentration by Beta Attenuation.
U.S. EPA Designations:	EPA Class III PM_{10} FEM: EQPM-0798-122 EPA Class III $PM_{2.5}$ FEM: EQPM-0308-170 EPA Class III $PM_{10-2.5}$ FEM: EQPM-0709-185
Standard Range:	0 - 1.000 mg/m³ (0 - 1000 µg/m³)
Optional Ranges:	0 - 0.100, 0.200, 0.250, 0.500, 2.000, 5.000, 10.000 mg/m³ (special applications)
Accuracy:	Exceeds US-EPA Class III $PM_{2.5}$ FEM standards for additive and multiplicative bias.
Measurement Resolution:	0.24 µg/m³ (1.000 mg range). 2.4 µg/m³ (10 mg range).
Data Resolution:	1 µg/m³ (Concentration data stored and displayed in whole micrograms).
Sensitivity Std. Deviation: (σ) (1 hour)	Less than 2.4 µg/m³ (less than 2.0 µg/m³ typical). Auditable with zero filter test.
Lower Detection Limit: (2σ) (1 hour)	Less than 4.8 µg/m³ from 0.000 to 0.100 mg/m³ (less than 4.0 µg/m³ typical). Auditable with zero filter test.
Lower Detection Limit: (2σ) (24 hour)	Less than 1.0 µg/m³. Auditable with zero filter test.
Measurement Cycle Time:	1 Hour
Flow Rate:	16.7 liters/minute. Adjustable 0-20 LPM range. Actual or Standard flow.
Filter Tape:	Continuous glass fiber filter, 30mm x 21m roll. > 60 days/roll.
Span Check:	Automatic 800ug (typical) span foil verified hourly. Manually auditable.
Beta Source:	C-14 (carbon-14), 60 µCi ±15 µCi (< 2.22 X 10⁶ Beq), Half-Life 5730 years.
Beta Detector Type:	Photomultiplier tube with organic plastic scintillator.
Operating Temp. Range:	0° to +50°C. Shelter temperature should be stable to within ±2°C per hour.
Ambient Temp. Range:	-40° to +55°C standard. Optional -50 degree temperature sensors available.
Ambient Humidity Range:	0 to 90% RH, non-condensing.
Humidity Control:	Actively controlled inlet heater module, 10% - 99% RH setpoint (35% standard).
Approvals:	U.S. EPA, MCERTS, CE, NRC, TUV, CARB, ISO-9001.
Standard User Interface:	Menu-driven interface with 8x40 character LCD display and dynamic keypad.
Optional User Interface:	Graphic color touch screen display module, Model BX-970.
Analog Output:	Isolated 0-1 VDC output standard. 0-10V, 4-20mA, 0-16mA switch-selectable.
Serial Interface:	RS-232 2-way serial ports for PC or modem communications.
Printer Output:	Output-only serial port, data or diagnostic output to a PC or serial printer.
Telemetry Inputs:	Clock Reset (voltage or contact closure), Telemeter Fault (contact closure).
Alarm Contact Closures:	Data Error, Tape Fault, Flow Error, Power Failure, Maintenance.
Compatible Software:	Air Plus™, Comet™, MicroMet Plus®, HyperTerminal®, ProComm Plus®.
Error Reporting:	User-configurable. Available through serial port, display, and relay outputs.
Memory:	4369 records (182 days @ 1 record/hr). Extended memory Report Processor option
Power Supply:	100 - 230 VAC, 50/60 Hz. 0.4 kW, 3.4A max @110V. Not including shelter.
Weight:	24.5 kg (54 lbs) without external accessories.
Unit Dimensions:	H x W x D = 31cm x 43cm x 40cm (12.25" x 17" x 16").

Specifications may be subject to change without notice.

2 SITE SELECTION AND INSTALLATION

2.1 Unpacking, Inspection, and Evaluation Testing

If any damage to the shipment is noticed before unpacking, **a claim must be filed with the commercial carrier immediately**. Notify Met One Instruments after notification of the commercial carrier.

Unpack the unit and accessories and compare them to the packing list to make sure you have all of the required items for the type of installation you plan to perform. A separate quick setup guide with color photos of most of the common accessories should be included with the this manual. You can use the quick setup guide to fully configure and operate the BAM-1020 unit on a test bench if desired.

The BAM-1020 is shipped with one or two white foam rings and a white plastic shim inside the front of the unit, which prevent the moving parts of the tape control assembly from being damaged in transit. The rings and shim must be replaced anytime the unit is being transported in order to avoid damaging the tape control mechanism. Do not ship or transport the BAM-1020 with filter tape installed. Please keep the special shipping box and foam packing material which the unit came in. They should be re-used if you must return the unit to the factory for any reason. Met One is not responsible for damage to the unit if returned in non-original packaging, or without the foam rings in place. Contact Met One for replacement packing materials if necessary.

2.2 Enclosure Selection and Temperature Control

The BAM-1020 unit is not weatherproof. It is designed to be mounted in a weatherproof, level, low vibration, dust free, and temperature-stable environment where the operating temperature is between 0º C and +50º C, and where the relative humidity is non-condensing and does not exceed 90%. There are two standard configurations described below for providing a weatherproof location in which to install the unit. Please contact Met One for advice if you plan to have a non-standard mounting or enclosure configuration.

1. **A walk-in shelter or building:** These are usually semi-portable pre-fabricated shelters or portable trailers with a flat roof, or a room in a permanent building or structure. The BAM is mounted on a workbench or in an equipment rack, often with a variety of other instruments installed in the same shelter. The inlet tube of the BAM must extend up through a hole in the roof of the structure with appropriate sealing hardware. AC power must be available. Instructions for this type of installation are included in this section of this manual.

2. **BX-902/903/906 mini weatherproof enclosures:** Sometimes nicknamed "dog house" enclosures, these small pre-fabricated enclosure are just big enough for the BAM and related accessories, and are installed on the ground or on the roof of a larger building. They are available with a heater (BX-902), or with a heater and air conditioner (BX-903). A dual-unit air conditioned mini shelter is also available (BX-906). These enclosures are all specified by Met One to accept the BAM-1020, and are supplied with a supplemental installation manual.

Shelter Temperature Control Notes: The air temperature inside a BAM shelter or enclosure is not required to be regulated to any specific narrow range or setpoint (such as 25C), subject to the following caveats:

1. The shelter temperature must stay between 0 and 50C inside at all times or BAM alarms and failures may result. Remember that the BAM vacuum pump and inlet heater can contribute significantly to shelter heating.
2. The exact shelter temperature within the 0-50 degree range is not critical *as long as it fluctuates as little as possible during the course of any single sample hour*. This is important because the unit measures the beta particles through a small gap of air around the filter tape at the beginning and the end of each hour. Air density changes with temperature, so if the air temperature inside the enclosure changes rapidly by more than a couple of degrees per hour, the hourly concentration measurements can be noisier than usual by several micrograms.
3. Met One recommends logging the temperature inside non-air conditioned mini enclosures such as the model BX-902. The lower cost of these shelters comes at the expense of less effective temperature regulation. Met One can supply a BX-592-1 room temperature sensor which can be logged directly by the BAM-1020.
4. BAM users in hot climates where the ambient temperature exceeds 40C should consider using the model BX-903 air conditioned mini shelter or an air conditioned walk-in shelter to avoid over-heating the BAM-1020.
5. Air conditioned shelters in areas with very hot and humid air should not be set at too low of a setpoint, or condensation inside the BAM may occur. The solution is to set the shelter thermostat a little higher.

2.3 Site Selection and Inlet Positioning Criteria

Selection of a proper site for the BAM-1020 is critical for accurate measurements. These items must be correctly addressed in order for the collected data to be acceptable for regulatory requirements, such as EPA PM_{10} and $PM_{2.5}$ equivalent data reporting.

Specifications for site selection and inlet positioning generally match those for FRM samplers, and can be found in United States regulation **40 CFR, Part 58, Appendix D and E**. There are also a variety of EPA guidance documents and quality assurance documents which describe site criteria in detail. In any case, the Code of Federal Regulations takes precedence. Site selection and inlet position criteria may vary in other countries.

Inlet Height Criteria:

- The BAM-1020 total inlet height must be located in the "breathing zone", between 2 and 15 meters above ground level for neighborhood scale sites. Middle scale or microscale sites require a total inlet height of between 2 and 7 meters.
- If the unit is to be installed in an enclosure on ground level, then the inlet height must be at least two meters above the ground. The BX-902/903 mini shelters have a short inlet tube to locate the inlet two meters above whatever surface they are placed on.
- If the unit is located on (or through) the roof of a building, the inlet height must be no less than two meters above roof surface of the building. This matches the inlet height of most FRM samplers. The total height must still be no more than 15 meters above ground level.

- If the BAM-1020 is to be collocated with other particulate instruments, such as FRM filter samplers or other BAM units, then the air inlets must all be the same height within one meter vertically. Met One recommends a tighter tolerance of within 30cm (1 foot).
- Met One supplies a single 8 foot (2.5m) inlet tube unless otherwise specified. Shorter custom inlet tubes of any length are available. Two inlet tubes may also be coupled together for a maximum of 16 feet (5m). Account for the height of the PM_{10} and/or $PM_{2.5}$ heads when planning the required inlet tube length.
- If the BAM-1020 inlet is the highest metallic point on a building, then a lightning rod must be installed to prevent destruction of the BAM during electrical storms.

Inlet Spacing and Clearance Criteria:

- If the BAM-1020 is to be collocated with another instrument, such as an FRM sampler, then the inlets must be spaced between one and four meters apart. Two meter spacing is recommended where possible.
- If installed near a PM_{10} high-volume sampler, then the distance between the inlet of the BAM-1020 and the Hi-Vol should be no less than three meters.
- The BAM-1020 inlet must be unobstructed for two meters in all directions from any object that may influence airflow characteristics, such as walls, parapets, or structures on a rooftop.
- If located beside a major obstruction (such as a building), then the distance between the inlet and the building should be equal to twice the height of the building.
- There must be at least a 180 degree arc of completely unrestricted airflow around the inlet. The predominant wind direction during the highest concentration season must be included in the 180 degree arc.
- The inlet must be at least 10 meters from the drip line of any trees.

Particulate Sources: To avoid possible errors in the concentration measurements, the inlet must be located as far as possible from any artificial sources of particulate, such as blowers, vents, or air conditioners on a rooftop. Especially if any of these types of devices blow air across the inlet of the BAM-1020. Even sources of filtered air must not blow across the inlet.

Spacing from Roadways: Except for microscale studies, the BAM-1020 should usually not be located directly next to a major highway or arterial roadway, as vehicle exhaust will dominate the concentration measurement. Criteria for roadway spacing of particulate monitors can be complicated. See 40 CFR Part 58 - Appendix E, section 6.3 (July 2009).

- For general neighborhood scale monitoring, the BAM-1020 should be at least 10 meters away from a road with a daily traffic volume of less than 1,000 vehicles, at least 30 meters from a road with a volume of 20,000 vehicles, at least 100 meters from a road with a volume of 70,000 vehicles, and at least 250 meters from a road with a volume of greater than 110,000 vehicles.
- The unit should be located as far as possible from unpaved roadways, as these also cause artificial measurements from fugitive dust.
- The unit should not be installed in unpaved areas unless year-round vegetative ground cover is present, to avoid the effects of re-entrained fugitive dust.

2.4 Mounting Options in a Walk-In Shelter

When the BAM-1020 is to be located in a walk-in shelter, the unit will have to be installed either in an equipment rack or on a bench-top. Met One recommends using an equipment rack when possible, because it does a better job of keeping the unit in the correct placement and allows vertical adjustments. A rack also tends to be a cleaner installation. However, either method may be used as long as the mounting is level and allows the inlet tube to be perfectly vertical. Standard rack-mount screws are supplied with each unit. Take the following into account when planning the mounting:

- **Rear Access:** It is important that you leave plenty of access to the rear of the BAM-1020 unit for wiring connections and maintenance. At least five inches is required. Full access to the back is recommended whenever possible. There must be adequate access to the power switch located on the back of the instrument.

- **Top Access:** It is necessary to have a minimum of eight inches clearance between the top of the BAM inlet receiver and the bottom of the shelter ceiling to accommodate the smart inlet heater which mounts on the inlet tube directly above the BAM.

- **Mobile Shelters:** If the BAM-1020 is being installed into an equipment rack in a mobile trailer or van, then additional care should be taken to ensure that the mounting can handle the additional strain. The foam shipping rings must also be inserted any time a mobile shelter is moved with the BAM-1020 inside.

- **Rack Modifications:** It is usually necessary to modify the top plate of the equipment rack by cutting a 2 inch diameter (75mm) hole to allow the inlet tube to extend through to the ceiling. The BAM dimensional drawings below show the location of the inlet. *Note:* The inlet heater installs onto the inlet tube two inches above the top of the inlet receiver of the BAM-1020. If the BAM unit is to be mounted in a rack, it will be necessary to leave extra room above the BAM in the rack for the heater, or to make the hole in the top of the rack larger in order to clear the heater diameter. The heater is supplied with a foam insulation sleeve which may be modified as needed. Make sure these parts are going to fit before installing the BAM-1020.

2.5 BAM-1020 Installation Instructions

Installation of the BAM-1020 should be performed by personnel familiar with environmental monitoring equipment. There are no special precautions or handling concerns except for the normal level of care required for handling scientific equipment. Refer to the diagrams on the following pages.

1. **Roof Modifications:** Determine the exact location where the BAM inlet tube will pass through the roof of the shelter, and drill a 2 ¼" or 2 ½" (60mm) diameter hole through the roof at that location. Make sure the hole is directly above where the BAM inlet receiver is to be located, so the inlet tube will be perfectly vertical. A plumb weight is useful for determining where to locate the hole. Note that the inlet receiver on the BAM is slightly off-center! BX-902/903 mini shelters do not require any roof drilling.

2. **Waterproof Roof Flange:** Apply all-weather silicone caulking around the top of the hole, and install the BX-801 roof flange onto the hole. The threaded barrel of the flange is usually installed downward. Secure the flange in place with four lag bolts or

self-tapping screws (not supplied). Caulk around the screws to prevent leaks. Apply Teflon tape to the threads of the gray plastic watertight fitting, and screw it into the roof flange tightly. BX-902/903 mini shelters come with a roof flange installed, and only need the watertight fitting. **Note:** Some BAM users prefer to fabricate their own roof flange instead of using the one supplied by Met One, due to factors such as high snow loading or a sloped roof. This is fine as long as no leaks occur. Damage from a leaking roof is usually not covered under warranty.

3. **Inlet Tube Installation and Alignment:** Remove the white threaded cap and rubber seal from the watertight inlet tube seal assembly. This makes it easier to install the inlet tube since the rubber seal is a tight fit. Lower the inlet tube through the flange assembly and into the inlet receiver on the BAM, making sure that the inlet tube is fully seated. It is very important for the inlet tube to be perpendicular to the top of the BAM. The nozzle may bind if the inlet is misaligned. 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 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.

   Note: Some users report improved RH control performance in the BAM-1020 when the vertical inlet tube is covered with a foam insulation sleeve from the bottom of the shelter ceiling down to the inlet heater, especially in applications where a shelter air conditioner may be blowing across the inlet tube. Met One now recommends insulating the inlet tube in walk-in shelters. Gray hot water pipe insulation is appropriate, and is available at any hardware store.

4. **Smart Heater Installation:** 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 onto the tube. Lift the inlet tube out of the top of the BAM, 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 smart 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 white 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. The insulation sleeve provides more consistent heating, and also prevents objects from coming into contact with the hot heater body.

5. **Smart Heater Electrical Connections:**   All generations of the BX-827/830 Smart Heater have the same green metal power connector. However, there are two different configurations for the way the heater plugs into the BAM depending on the heater control relay location. Make sure that you recognize which of the two following configurations you have.

   Most units built between 2008 and 2012 were supplied with an external gray relay module which plugs into a mating **black plastic connector on the back of the BAM-1020**. The Smart Heater connector plugs into the green connector on the top of this relay module, as shown in the left photo below. These external relay modules have their own AC power cord to supply power to the heater, and have a 3A fuse inside.

In the other possible configuration of the kit, the green metal Smart Heater connector simply plugs directly into the mating **green metal connector on the back of the BAM-1020**. The heater relay is located inside the BAM, and the heater power comes from the BAM AC power supply at line voltage and frequency, and is fused by the main 3.1A fuses in the power input module.

⚠️ *Warning! It is possible to incorrectly force the green metal heater connector into the black plastic connector on a BAM which is configured to use the external relay, even though both connectors have male pins. If this is done the BAM will not be damaged, but the heater will not function and no sample RH control will occur!*

⚠️ *Warning! The heater relay controls live AC line voltage to the green socket in either version. Treat the green socket like a live power outlet whenever power is applied. Do not open or service the relay module or heater module when power is applied.*

⚠️ *Warning! The Smart Heater has triple redundant safety features to prevent overheating, but the heater surface temperature can exceed 70 degrees C during high humidity conditions. Use the white insulation sleeve to prevent contact with the heater during operation.*

Smart Heater

Version A: Green metal heater connector plugs into green metal connector on the relay module. Relay module plugs into black plastic connector on the BAM.

Version B: Green metal heater connector plugs into green metal connector on the BAM, with no relay module.

Heater Power Cord

Two Different Smart Heater Power Configurations

6. **Tightening the Inlet:** After the inlet tube is aligned and the heater installed, 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 first. Tighten the white plastic cap. Tighten the two set screws in the top of the BAM inlet receiver.

7. **Inlet Support Struts:** The BX-801 inlet kit 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 ty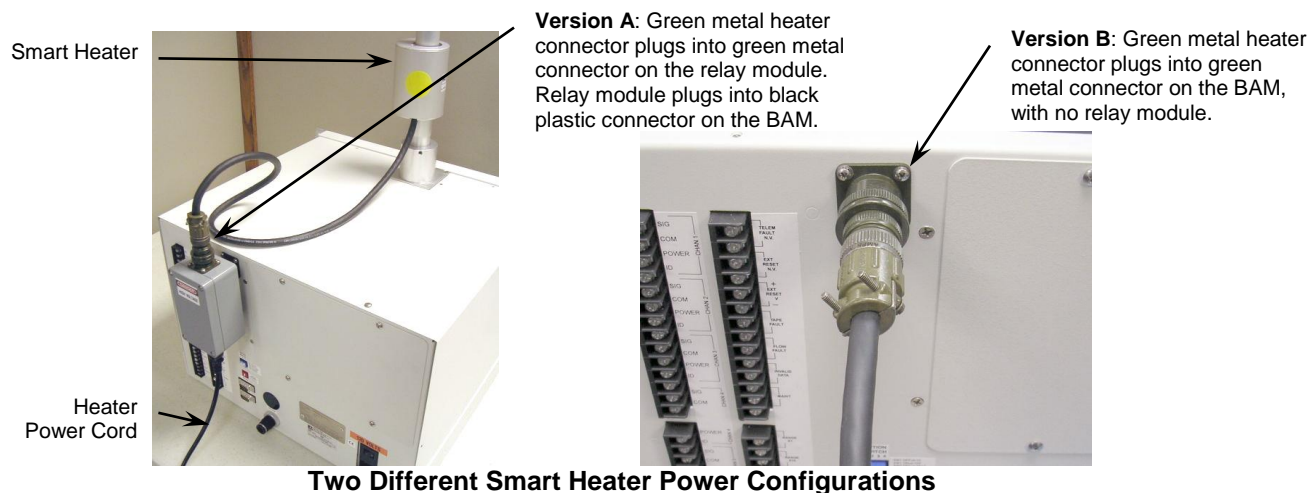pically fastened (about 90 degrees apart) to the inlet tube with a supplied hose clamp. The bottom ends of the struts should be fastened to the roof with lag bolts (not supplied). Some installations may require different methods or hardware for supporting the inlet tube. Support the tube in the best manner available. The BX-902/903 mini shelters do not require inlet tube supports.

8. **Temperature Sensor Installation:** BAM-1020 units are supplied with a BX-592 (temperature only) or BX-596 (AT/BP) sensor, which attaches to the inlet tube above the roof. The sensor cable must route into the shelter to be attached to the BAM. Use a waterproof cable entry point or weatherhead if your shelter has one. The BX-902/903

mini shelters have a cable entry on the side. Route the cable into the shelter in the best manner available. In some cases you may need to simply drill a 3/8" hole through the roof a few inches away from the inlet tube, route the cable through the hole and caulk it to prevent leaks. The BX-596 sensor 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.

Connect the cable to the terminals on the back of the BAM as follows. Additional optional Met One auto ID sensors may be connected to channels 1 through 5 to log other meteorological parameters. Details on these optional sensor connections are given in Section 10.2 of this manual.

<table>
<tr><th colspan="2">BX-596 AT/BP Sensor</th></tr>
<tr><th>Wire Color</th><th>Terminal Name</th></tr>
<tr><td>Yellow</td><td>Channel 6 SIG</td></tr>
<tr><td>Black/Shield</td><td>Channel 6 COM</td></tr>
<tr><td>Red</td><td>Channel 6 POWER</td></tr>
<tr><td>Green</td><td>Channel 6 ID</td></tr>
<tr><td>White</td><td>Channel **7** SIG</td></tr>
</table>

<table>
<tr><th colspan="2">BX-592 AT Sensor</th></tr>
<tr><th>Wire Color</th><th>Terminal Name</th></tr>
<tr><td>Yellow or White</td><td>Channel 6 SIG</td></tr>
<tr><td>Black/Shield</td><td>Channel 6 COM</td></tr>
<tr><td>Red</td><td>Channel 6 POWER</td></tr>
<tr><td>Green</td><td>Channel 6 ID</td></tr>
</table>

9. **Inlet Separator Heads:** For PM_{10} monitoring, the BX-802 Size-Selective Inlet is installed directly onto the inlet tube with no cyclone. To configure the BAM-1020 as a $PM_{2.5}$ FEM monitor, install the $PM_{2.5}$ Very Sharp Cut Cyclone beneath the PM_{10} head as shown below. Use o-ring lubricant as needed. Note: Foreign $PM_{2.5}$ configurations may use an SCC cyclone instead of a VSCC cyclone.

10. **Inlet Tube Grounding:** The two ¼"-20 set screws located in the inlet receiver of the BAM should create a ground connection for the inlet tube to prevent static electricity from building up on the inlet tube under certain atmospheric conditions. This is also 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 multimeter to measure the resistance between this spot and the "CHASSIS" ground connection on the back of the BAM. It should measure only 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.

11. **Pump Location and Installation:** The best location for the vacuum pump is often simply on the floor under the rack or bench, but it may be located up to 25 feet away if desired. It may be preferable to locate the pump so that noise is minimized if the unit is in an area where personnel are present. If the pump is to be enclosed, ensure that it will not overheat. The Gast pumps have a thermal shutdown inside which may trip if overheating occurs. Route the clear 10mm air tubing from the pump to the back of the BAM unit, and insert it firmly into the compression fittings on both ends. The tubing should be cut to the proper length and the excess tubing saved.

The pump is supplied with a 2-conductor 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 black ferrite filter goes toward the

BAM. The cable has no polarity, so 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.

There are two pump types available for the BAM-1020. The Gast rotary vane pumps are louder and draw considerably more power than the Medo linear piston pumps, but have better vacuum capacity, especially at higher altitude or in 50 Hz applications. The Medo pumps are smaller, quieter, and more efficient, but aren't recommended for 50 Hz use.

12. **Optional External Data Logger Connections:**   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 (not supplied). Polarity must be observed. The logger input must be correctly scaled in order to log the voltage accurately! Information on configuring this analog output is provided in Section 8 of this manual. A current loop output is also available.

Newer data loggers often interface to the BAM-1020 using the digital serial ports for better accuracy. Information about this is also found in Section 8. Met One can also supply additional technical bulletins on the subject.

The BAM-1020 has a variety of other telemetry I/O relays, error relays, and serial data connections located on the back of the unit as shown below. These items are described in Section 8 and Section 9 of this manual.

BX-802
PM₁₀ Head

BX-808
BGI VSCC™
PM₂.₅ Cyclone
(optional)

BX-596
AT/BP Sensor
(or BX-592)

8112
Inlet Tube
8' standard

**Inlet Support
Struts**

**BX-801
Roof Flange**

**Enclosure
Roof**

**BX-827 or 830
Smart Heater**
with insulation

BAM-1020
With Medo
vacuum pump or
equivalent

Mounting
Bench or Rack

adds
14.0"

adds
19.0"

2 Meters
6.5 feet

5' typical

**Pipe Insulation
(recommended)**

8" min. clearance
3 to 4 feet typical

2"

BAM 1020

MET ONE INSTRUMENTS

Typical BAM-1020 Installation in a walk-in shelter

BX-802
PM₁₀ Head

BX-808
BGI VSCC™
PM₂.₅ Cyclone
(optional)

BX-596
AT/BP Sensor
(or BX-592)

27" Inlet Tube

8119 Inlet
Seal

BX-827 or 830
Smart Heater
with insulation

Mounting
Rack

BX-902 or 903
Environmental
Enclosure

BX-126
Vacuum Pump
or equivalent

adds
14.0"

adds
19.0"

27" typical
Inlet tube

2"

15.5"

-Total Height-
6.6 ft (2.0 meters)
without cyclone

7.0 ft (2.1 meters)
with cyclone

BAM 1020

MET ONE INSTRUMENTS

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

5" min. rear clearance

C_L

TOP

16"

Lifting Notes:
The main unit weighs slightly over 50 lbs, with the center of mass near the front of the unit. Lift by the rack rails or by the bottom corner bracket. Observe proper lifting and carrying techniques.

74mm (2 15/16 ") from front face of BAM

71mm (2 13/16 ") from front of rack

14mm (9/16") from center

14.25"

12.25"

9.25"

3.5"

BAM 1020

MET ONE INSTRUMENTS

FRONT

120 VOLTS

BACK

17"

19"
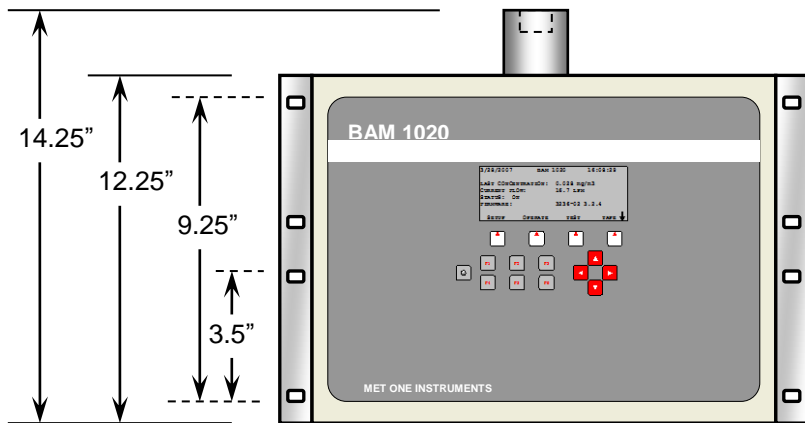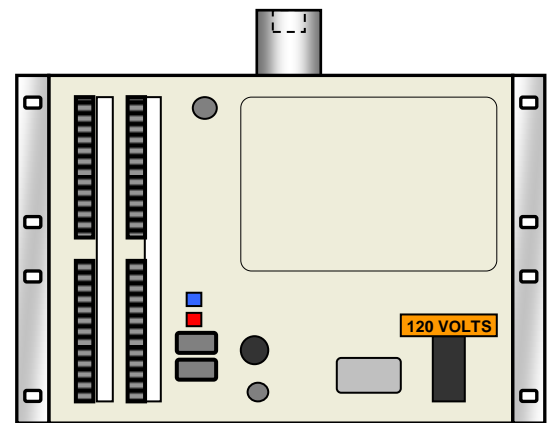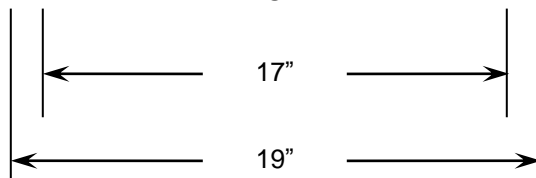
BAM-1020 mounting dimensions

SIGNAL
COMMON — CHAN 1
POWER
ID

SIGNAL
COMMON — CHAN 2
POWER
ID

SIGNAL
COMMON — CHAN 3
POWER
ID

SIGNAL
COMMON — CHAN 4

TELEMETRY
FAULT
NO VOLTAGE

EXTERNAL
RESET
NO VOLTAGE

+
EXTERNAL
RESET VOLTAGE
-

TAPE
FAULT

FLOW
FAULT

INVALID
DATA

MAINTENANCE

SMART
HEATER

POWER
ID — CHAN 5
SIGNAL
COMMON
POWER
ID

SIGNAL
COMMON — CHAN 6
POWER
ID

SIGNAL
COMMON — CHAN 7
POWER
ID

RELAY 1 NC

COMMON

COMMON

RELAY 1 NO

PUMP
CONTROL

POWER
FAIL

+
VOLTAGE
OUTPUT
-

CHASSIS
GROUNDS

+
CURRENT
OUTPUT
-

OPTION SWITCH
1 2 3 4

SW1	OFF= 0-1V
SW1	ON= 0-10V
SW2	OFF= 0-16mA
SW2	ON= 4-20mA

RS232 POLARITY
C1 NORMAL
C2 REVERSE

RS-232

PRINTER

REPORT POLARITY
C1 NORMAL
C2 REVERSE

REPORT

COM 3

ETHERNET

BAM-1020 Rear Panel Connections

2.6 BAM-1020 Power and Electrical Service

The BAM-1020 uses internal 120V AC motors for the tape control system, so the power supply is factory-wired to run on **either 110-120V or 220-240V, and either 50Hz or 60Hz**. The external vacuum pump and inlet heater are also AC powered and voltage-specific, and should match the voltage setting of the BAM. Note: The pump power cord is hardwired, and may need to be replaced or adapted to match local outlet types outside of North America.

⚠️ *Warning: Your shelter and/or electrical service must be wired for the correct voltage and frequency in accordance with local electrical codes. Running the BAM-1020, vacuum pump, or inlet heater on incorrect line voltage or frequency will cause improper operation.*

The current draw of the system varies considerably depending on optional accessories and environmental conditions. A dedicated 15 Amp electrical circuit is generally adequate to run a single complete BAM-1020 system, unless a large air conditioner is on the same circuit. Consult a qualified electrician if unsure. A summary of some worst-case loads is given below:

Model	Description	Amps	Wattage
BAM-1020	BAM-1020 only, 120V, worst case with tape transport motors running.	0.17A	20W
BX-126	Medo Linear Piston Pump, 120V, 60Hz, at 16.7 L/min through clean tape.	1.25A	150W
BX-127	Medo Linear Piston Pump, 230V, 50Hz, at 16.7 L/min through clean tape.*	0.55A	125W
BX-121	Gast Rotary Vane Pump, 120V, 60Hz, at 16.7 L/min through clean tape.	4.44A	530W
BX-122	Gast Rotary Vane Pump, 230V, 50Hz, at 16.7 L/min through clean tape.	2.30A	530W
BX-827	Smart Inlet Heater, 120V, 60Hz, running at 100% high RH duty cycle.	0.85A	100W
BX-830	Smart Inlet Heater, 230V, 50Hz, running at 100% high RH duty cycle.	0.76A	175W
BX-902B	Shelter One Mini Shelter, 120V, worst case with shelter heater ON	4.2A	500W
BX-903	Ekto Mini Shelter, 120V, 2000 BTU air conditioner.	7.4A	586W
BX-904/906	Ekto Mini Shelter, 120V, 4000 BTU air conditioner.	13.5A	1172W

Notes:
- The BAM transport motors only run for a few seconds each per hour. Quiescent BAM current is 0.1A.
- The vacuum pump runs for either 42 or 50 minutes per hour. Startup inrush current is higher.
- *The BX-127 Medo pump is not recommended for 50Hz applications due to marginal vacuum capacity.
- Smart Heater wattage drops to idle at 20% (120V) or 6% (230V) when filter RH is below 35%.
- The BX-902B shelter heater is usually off whenever shelter temp is over 40 degrees F, and can be disabled.
- Values are based on measurements or best available information. Additional information is available from Service.

Fuses: There are two 5x20mm, 3.15A, 250V fuses located inside the BAM power switch module on the back of the BAM. They can be accessed by prying open the top of the small cover surrounding the switch. The power cord <u>must be removed</u> in order to open this cover.

Power Outages and Battery Backup: Any momentary AC power outages will reset the BAM CPU and prevent data collection for the sample hour. The BAM may be plugged into a PC-style uninterruptible power supply (UPS) battery back-up unit to prevent this. A UPS of at least 300 Watts is usually sufficient. The vacuum pump does not need to be connected to the UPS, because the BAM can compensate for short pump flow outages of less than 1 minute duration. If the pump is to be backed up, then a much larger UPS wattage is required.

Chassis Ground: Connect one of the terminals marked "CHASSIS" on the back of the BAM to an earth ground point, using the green/yellow ground wire supplied with the unit. A copper earth-ground rod is recommended. The chassis ground is primarily for added RFI/EMI noise immunity. The BAM-1020 also uses the standard electrical safety ground in the power cord.

3   INITIAL SETUP OF YOUR BAM-1020

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. Some of the topics in this section will direct you to other sections of this manual for more detailed information. It is assumed that the unit is already installed and sited as described in Section 2. In some cases it is useful to first set up the BAM-1020 unit on a test bench before deployment or installation in order to explore the functions of the unit and perform setups. The following steps for starting up your unit are described in this section:

1. **Power on and warm up the unit.**
2. **Familiarize yourself with the user interface.**
3. **Load a roll of filter tape.**
4. **Perform a Self-Test.**
5. **Set the real-time clock, and review your SETUP parameters.**
6. **Perform a leak check and a flow check.**
7. **Return to the top-level menu and wait for automatic start at the top of the hour.**
8. **View the OPERATE menus during the cycle.**

3.1 Power Up

The BAM-1020 power switch is located on the back of the unit 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 unit will take about 30 seconds to boot up the touch screen display module, after which the main menu screen should appear as shown below. The unit will probably flash an error indicating that there is no filter tape installed.

3.2 Warm-up Period

The BAM-1020 must warm up for at least one hour before valid concentration data can be obtained. 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.

3.3 Using the Touch Screen Display and the Main Menu

When the BAM-1020 is powered up it will display the main menu (top level menu) on the graphic touch screen display as shown below. This menu is the starting point for all functions of the BAM-1020 user interface. The time and date are shown at the top of the main screen. The latest concentration value is shown in the circle at the left side. If an alarm is present, it will be displayed in the center of the display where it is easily visible.

The display module used in the BX-970 option is a full-function touch screen PC. Menu navigation is done through graphic buttons on the display. The OPERATE, SETUP, and

TEST menus can all be accessed by pressing the buttons at the bottom of the main screen. The ABOUT screen can be accessed to view the firmware revisions and related information. The OPERATE menu allows data and current operating parameters to be viewed and does not interrupt the measurement cycle. The TEST and SETUP menus require stopping the measurement cycle (if running) and will show a warning screen when entered.

Most menu navigation buttons will appear at the bottom edge of the display. Settings parameters will appear as editable fields in the center area of the display. If a numeric input is required for a setting change, then a ten-key number keypad field will pop up.
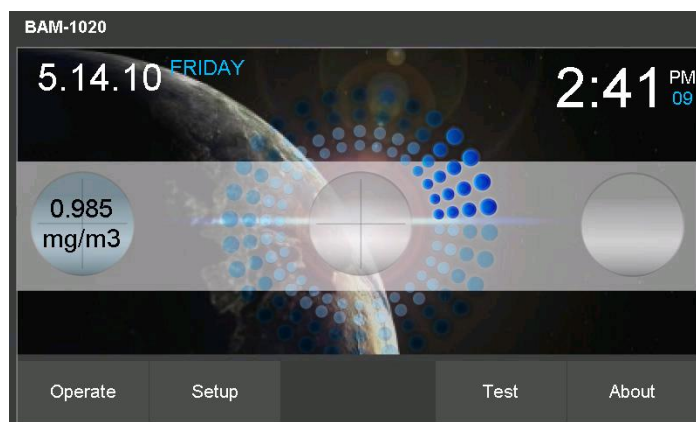

The BAM-1020 Touch Screen and Main Menu

3.4 Filter Tape Loading

A roll of Met One glass fiber filter tape must be loaded into the BAM-1020 for sampling. A roll of tape will last more than 60 days under normal operation. It is important to have spare rolls available to avoid data interruptions. Some agencies save and archive the used filter tape, although the used sample spots are not protected from contamination, and are not marked to indicate the sample hour or site. Chemical analysis may be affected by the binder agent in the tape. Used filter tape should never be "flipped over" or re-used! This will result in measurement problems. Loading a roll of filter tape into the BAM-1020 is a simple matter using the following steps:

1. Turn on the BAM-1020 and enter the OPERATE > LOAD TAPE menu as shown below. The unit should automatically raise the sample nozzle.

2. Lift the rubber pinch roller assembly and latch it in the UP position, and unscrew and remove the two clear plastic reel covers.

3. An empty core tube **MUST** be installed on the left (take-up) reel hub. This provides a surface for the used tape to spool upon. 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 the previous roll. Never fasten the filter tape to the aluminum hub.

4. 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 adhesive cellophane tape or equivalent.

5. Rotate the tape roll by hand to remove excess slack, then install the clear plastic reel covers. The covers must be tight in order to properly clamp the tape in place and prevent slipping.

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

7. **Unlatch and lower the pinch roller assembly onto the tape. The BAM-1020 cannot automatically lower the rollers, and the unit will not operate if the pinch rollers are left latched in the up position!**

8. Press the TENSION button. The BAM-1020 will set the tape to the correct tension and alert you if there was an error with the process. The Forward/Backward buttons can be used to manually feed the tape. Feed the tape forward several times to that a completer turn of tape is wound around the take up reel, then exit the menu.
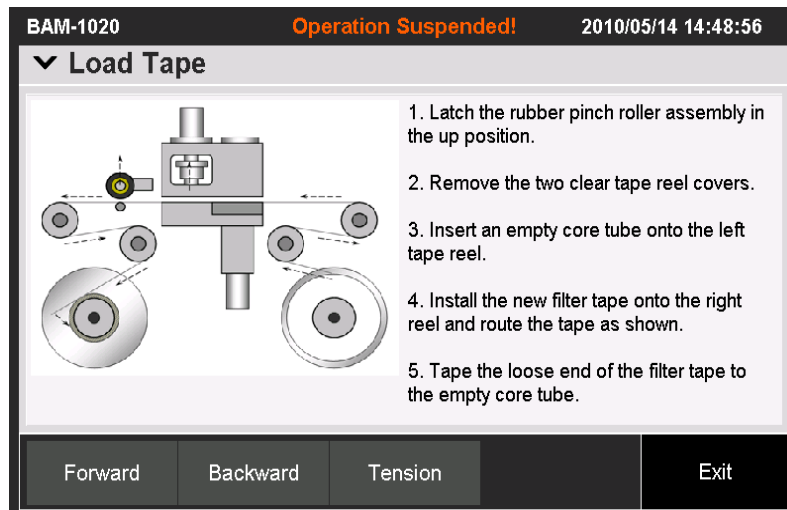
BAM-1020 Filter Tape Loading Screen

3.5 Self-Test Function

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 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 test menus are also available in the BAM, and those are described in the troubleshooting Section 7.

The self-test feature is located in the TEST > SELF TEST menu. Press the START button to start the test. The tests will take a couple of minutes, and the BAM-1020 will display the results of each tested item with a **PASS** or a **FAIL** tag. Press EXIT when finished.
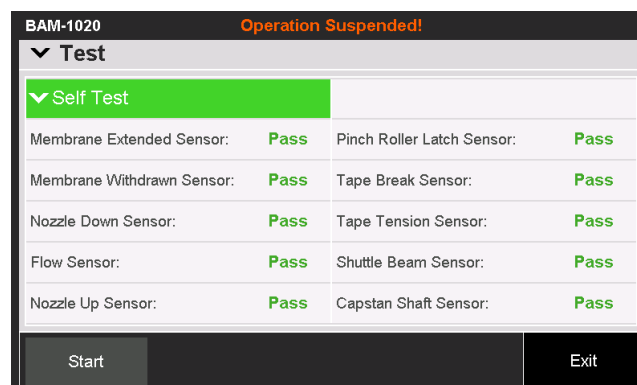
Self-Test Screen

Membrane Extended Sensor: The unit will attempt to extend the reference membrane, and will check the motion with a photo interrupter.

Membrane Withdrawn Sensor: The unit will attempt to withdraw the reference membrane, and will check the motion with a photo interrupter.

Nozzle Down Sensor: 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 nozzle o-ring maintenance is necessary.

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

Nozzle Up Sensor: 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.

Pinch Roller Latch Sensor: This will pass if the photo interrupter senses that the pinch rollers are unlatched (down) as in normal operation. It will fail if the roller assembly is latched in the up position. The tape cannot advance if the rollers are up!

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

Tape Tension Sensor: The unit will tension the filter tape, and then check the condition of the tensioner photo interrupters.

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

Capstan Shaft Sensor: The unit will rotate the capstan shaft forward and backwards and will check if the photo interrupter sees the shaft rotating. The Capstan shaft and rubber pinch rollers are what moves the filter tape back and forth.

3.6 Initial SETUP Settings Considerations

The BAM-1020 comes pre-programmed with a wide array of default values for the settings which govern the measurement and calibration. You will need to review the setup menus in Section 6 of this manual and decide if any values need to be changed. At the very least, review the following parameters:

1. Set the system clock in the SETTINGS > SET CLOCK menu. The BAM-1020 clock may drift as much as two minutes per month. It is important to check the clock at least once per month to ensure the samples are performed at the correct times.

2. Review the SAMPLE, FLOW, and HEATER screens in the SETTINGS menu.

3. The CONFIGURATION field in the SETTINGS > SAMPLE menu is a fast way to set up the unit with most of the correct settings. Set the Field to PM2.5 FEM or PM10 FEM, and the unit will automatically set all of the rest of the sampling parameters to the required values for correct FEM operation. If you set the CONFIGURATION to CUSTOM, then you can manually set each setup parameter as desired.

3.7 Initial Leak Check and Flow Check

The BAM-1020 comes with factory-set flow calibration parameters which will allow the unit to accurately control the 16.7 L/min sample flow system right out of the box. However, due to minor variations between different types of flow transfer standards, it is best to calibrate the BAM flow system with your own traceable flow audit standard. Perform leak checks and flow checks/calibrations as described in Section 5. Become comfortable with these processes, as they will be performed on a routine basis.
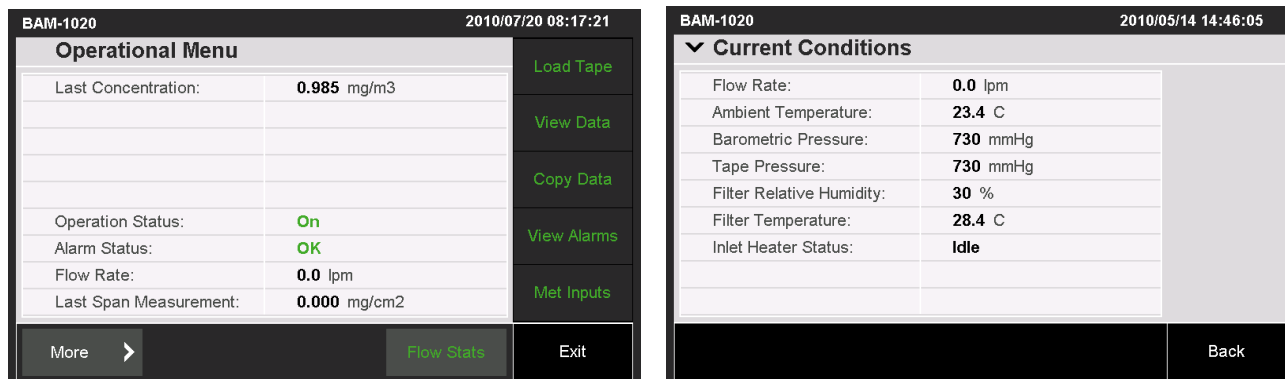
3.8 Starting a Measurement Cycle

When the preceding setup steps of Section 3 have been completed, exit out to the main top level menu. The screen should display no errors. If so, the unit will start at the top (beginning) of the next hour, and will continuously operate until commanded to stop. The unit will stop if the operator enters any of the SETTINGS or TEST menus, or if a non-correctable error is encountered, such as broken filter tape or failed air flow. **Make sure the rubber pinch rollers are lowered. The BAM will not operate if they are latched in the up position!**

3.9 The OPERATE Menu System

The OPERATE button can be pressed at any time during the sample cycle to enter the Operational Menu screen as shown below. This menu allows the user to view the current status of the measurement cycle and the alarm status, as well as the last hourly concentration, span, and flow values. The MORE button can be pressed to access the current operational conditions as shown.

The green buttons on the right side allow access to the data log memory and additional met and flow values as described in the following sections. All of these menus can be accessed without interrupting the sample cycle, except for the Load Tape sub-menu.

BAM-1020		2010/07/20 08:17:21	
Operational Menu			Load Tape
Last Concentration:	**0.985** mg/m3		View Data
			Copy Data
Operation Status:	**On**		
Alarm Status:	**OK**		View Alarms
Flow Rate:	**0.0** lpm		
Last Span Measurement:	**0.000** mg/cm2		Met Inputs
More ❯		Flow Stats	Exit

BAM-1020		2010/05/14 14:46:05
⌄ **Current Conditions**		
Flow Rate:	**0.0** lpm	
Ambient Temperature:	**23.4** C	
Barometric Pressure:	**730** mmHg	
Tape Pressure:	**730** mmHg	
Filter Relative Humidity:	**30** %	
Filter Temperature:	**28.4** C	
Inlet Heater Status:	**Idle**	
		Back

The OPERATE Menus

3.10 The VIEW DATA and VIEW ALARMS Screens

The OPERATE > VIEW DATA and VIEW ALARMS screens allow the user to view previous BAM-1020 data and alarms in memory. The data is sorted by day and by hour. The Previous Day and Next Day buttons are used to select the day. The Previous and Next buttons select which hour of the day is viewed. Each hourly record contains the format shown below. Conc

is the hourly concentration, and Qtot is the hourly flow sample volume. The six met sensor channels also appear even if some of the met channels are unused.

The alarm screen shows the alarm events in date/time order. If numerous alarms are recorded, the Next/Prev buttons can be used to scroll through the pages.

BAM-1020		2010/05/14 14:50:20	
∨ Data Log	Event Time: 2010/05/14 14:49:00		
Channel	Name	Reading	Units
I1	Conc	0.985	mg/m3
I2	Qtot	0.000	m3
1	BP	525.3	mmHg
2	WS	0.0	MPS
3	Conc	-0.015	mg/m3
4	RH	30	%
5	FT	28.4	C
6	AT	23.4	C
Previous	Next	Previous Day	Next Day	Exit

BAM-1020	2010/05/14 14:51:23
∨ Alarm Log	
04-16-10 13:54:32, Maintenance	
05-14-10 14:22:01, Power Fail	
05-14-10 14:42:26, Maintenance	
Prev Next	Exit

The OPERATE > VIEW DATA and OPERATE > VIEW ALARMS Screens

3.11 The MET INPUTS Screen

The OPERATE > MET INPUTS screen allows the user to view the current parameters being logged in the six meteorological sensor inputs in the BAM-1020 internal data logger. Any auto-ID met sensors attached to the back of the BAM, such as the ambient temperature sensor, will appear here. Unused channels appear even if no sensor is connected. The display can be toggled between engineering units or raw voltages. The internal I1 and I2 channels cannot be configured by the user.

BAM-1020		2010/05/14 14:52:20	
∨ Met Inputs			
Channel	Name	Reading	Units
I1	Conc	0.985	mg/m3
I2	Qtot	0.000	m3
1	BP	525.3	mmHg
2	WS	0.0	MPS
3	Conc	-0.015	mg/m3
4	RH	30	%
5	FT	28.4	C
6	AT	23.3	C
Engr Units	Volt Units		Exit

THE OPERATE > MET INPUTS Screen

3.12 The Flow Statistics Screen

The OPERATE > FLOW STATS screens are shown below. This screen can be accessed during the sample cycle, and displays the real-time flow statistics for the current measurement cycle. The MORE button can be pressed to view the current, min, max, and average temperature and pressure values.

The FLOW STATISTICS Screens

3.13 The Copy Data Screen – Copying Data to a USB Flash Drive

The OPERATE > COPY DATA screens are shown below. This screen is used to copy BAM-1020 data to a USB flash drive. **A USB drive mush be inserted into the top USB port on the display module inside of the front door**.

The screen allows the option of selecting ALL or STANDARD files. The STANDARD file set includes the data log, error log, and settings files only. The ALL file set includes the standard files, along with the flow statistics and 5-minute flow files. The PERIOD setting fields can be set to MONTHS or ALL. If set to MONTHS, the user can then select how many months worth of data to collect, backward from the present date. After the desired file set and period are selected, press the COPY button at the bottom of the screen to copy the data to the drive. A status screen will appear during the transfer.


The COPY DATA Screens

4 THE MEASUREMENT CYCLE

This section describes the measurement and timing cycle of the BAM-1020 instrument. A clear understanding of the measurement is helpful for the effective operation and maintenance of the unit. For advanced information on the underlying theory and mathematics of the measurement see Theory of Operation, Section 11.
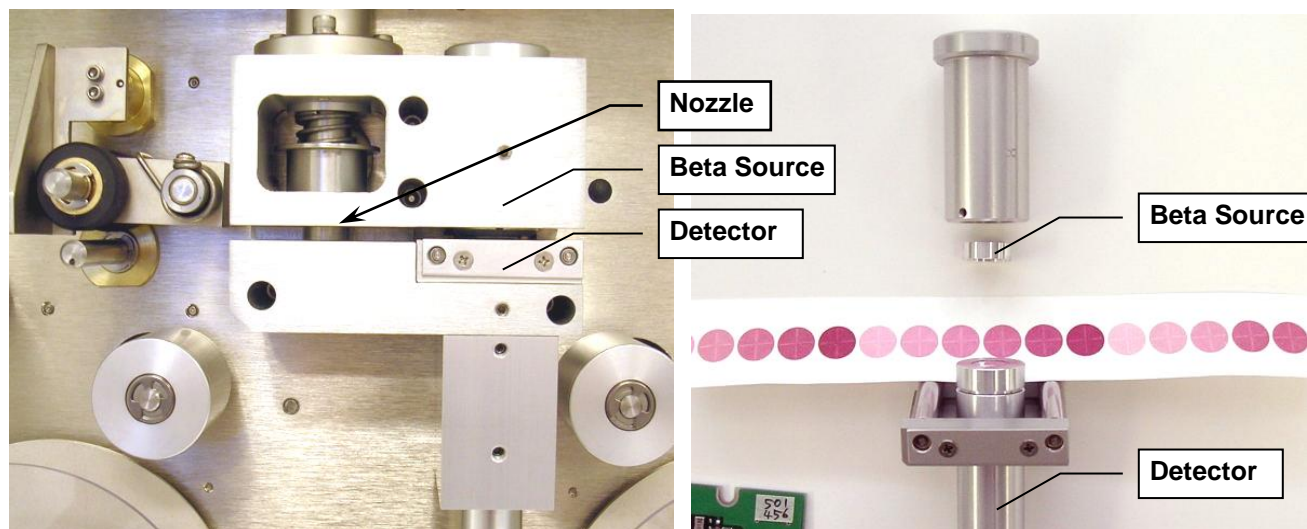
BAM-1020 Sample and Measurement Stations

4.1 The One-Hour Cycle Timeline

The BAM-1020 is almost always configured to operate on 1-hour cycles. The unit has a real-time clock which controls the cycle timing. You will see from the following timeline that the unit makes an 8-minute beta measurement at the beginning and the end of each hour, with a 42 minute air sample period in between, for a total of 58 minutes. The other two minutes of the hour are used for tape and nozzle movements during the cycle. This timeline applies if the unit is set for a COUNT TIME of 8 minutes, which is required for all EPA and EU designated $PM_{2.5}$ configurations.

Units sold for PM_{10} operation only do not have the option of 8-minute counts, only 4 minutes. In this case, the beta counts at the beginning and end of the hour are only 4 minutes long, with a 50 minute air sample in between. Again, the total adds up to 58 minutes. **Note:** This cycle will be slightly altered if the unit is operated in the special Early Cycle mode with an external datalogger. See Section 8.

1. **Minute 00:**   The beginning of an hour. The BAM-1020 immediately advances the filter tape forward one "window" to the next fresh, unused spot on the tape. This takes a few seconds. The new spot is positioned between the beta source and the detector, and the BAM begins counting beta particles through this clean spot for exactly eight minutes. (I_0)

2. **Minute 08:**   The BAM-1020 stops counting beta particles through the clean spot (I_0), and moves the tape exactly four windows forward, positioning that same spot directly under the nozzle. This takes a few seconds. The unit then lowers the nozzle onto the filter tape and turns the vacuum pump on, pulling particulate-laden air through the filter tape on which I_0 was just measured, for 42 minutes at 16.7 liters per minute.

3. **Minute 50:** The BAM-1020 turns the vacuum pump off, raises the nozzle, and moves the filter tape backwards exactly four windows. This takes a few seconds, and puts the spot that was just loaded with particulate back between the beta source and the detector. The BAM begins counting beta particles through the now dirty spot of tape for exactly eight minutes (I_3).

4. **Minute 58:** The BAM-1020 stops counting beta particles through the dirty spot (I_3). The unit uses the I_0 and I_3 counts to calculate the mass of the deposited particulate on the spot, and uses the total volume of air sampled to calculate the concentration of the particulate in milligrams or micrograms per cubic meter of air. The BAM then sits idle and waits a few moments for any remaining time in the hour to expire.

5. **Minute 60:** The beginning of the next hour. The BAM-1020 instantly records the just-calculated concentration value to memory and sets the analog output voltage to represent the previous hour's concentration. The unit advances a new fresh spot of tape to the beta measurement area and the whole cycle starts over…

4.2 Automatic Span Checks During The Cycle

While the vacuum pump is on and pulling air through the filter tape as described above, the BAM-1020 doesn't have anything else to do, so it performs an automatic check of its calibration (a span check), and checks for instrument drift caused by varying external parameters such as temperature, barometric pressure, and relative humidity. No span corrections are made. This check is performed every hour automatically as follows:

1. **Minute 08:** The BAM-1020 has just finished moving the clean spot to the nozzle and turned the pump on. There is another clean spot of filter tape upstream four windows, between the beta source and the detector. This same spot will stay there for the entire time the pump is on (usually 42 minutes), as the tape cannot move with the nozzle down. The BAM begins counting the beta particles through this spot for exactly eight minutes (I_1).

2. **Minute 16:** The BAM-1020 stops counting beta particles through this spot (I_1), and extends the Reference Membrane between the beta source and the detector, directly above the spot of filter tape that was just measured. The Reference Membrane is an extremely thin film of clear Mylar held in a metal tongue. The membrane usually has a mass of about .800 mg. The BAM starts counting beta particles for eight minutes again, this time through the membrane *and* the filter tape spot at the same time (I_2).

3. **Minute 24:** The BAM-1020 stops counting beta particles through the membrane (I_2), withdraws the membrane assembly, and calculates the mass of the membrane **"m"**, as if it were particulate on the filter tape spot.

4. **Minute 42:**   (Eight minutes before the pump stops) The BAM-1020 counts the beta particles through the same spot again (without the membrane) for another eight minutes (called $I_{1'}$ or I_1 prime). This checks the ability of the unit to hold a constant output when measuring blank filter tape, and is not otherwise used.

The mass density *"m"* (mg/cm^2) of the reference membrane calculated during this automatic process is compared to the known mass of the membrane; the *"ABS"* value. During factory calibration, the actual mass of each individual span foil is determined and saved as the **ABS** value of the BAM in which it is installed. Each hourly measurement of **m** must match the **ABS**

value within ±5%. If not, the unit records a "D" alarm for that hour's data. Typically, the hourly value of *m* is within just a few micrograms of the expected value. This span check provides a method of internal diagnostics for the measurement system, and for the monitoring of external variables such as temperature variations or pressure changes. The **ABS** value is unique to each BAM-1020, and can be found on the calibration sheet. Most membrane alarms are caused by a dirty membrane foil.

4.3 Sample Period Description

The sample period is the time when the vacuum pump is pulling dust-laden air through the BAM-1020. As the air enters the inlet, it first passes through the external PM_{10} head which has a screen to keep out insects and debris, and uses inertia to separate out and trap particle larger than 10 microns in size. The air then immediately passes through the optional $PM_{2.5}$ Very Sharp Cut Cyclone (BGI VSCC™) which further separates out and traps particles larger than 2.5 microns in size. Older non-designated $PM_{2.5}$ configurations may use a regular SCC cyclone.

The air then goes down the inlet and through the filter tape, where the remaining particles are deposited. After the sample period is completed and the particulate spot is measured, there is almost always a clearly visible spot of dirt on the filter tape where the particulate was deposited. The BAM-1020 will put the spots very close together on the tape. At exactly midnight, the BAM will skip one spot, leaving a blank spot on the tape. This is a visual aid which separates daily entries on the tape.

5 FLOW SYSTEM and FLOW CALIBRATIONS

5.1 Flow System Diagram

The BAM-1020 airflow control system is very simple and effective, consisting of only a few components. Proper operation of the flow system is critical in order to obtain accurate concentration data. Flow calibrations or audits require a traceable reference flow meter. The Bios Defender 520 or BGI deltaCal® brands are recommended. These include flow, temperature, and pressure standards in one simple unit. If FRM filter samplers or other instruments are to be collocated with the BAM, then the flow of all instruments should must be calibrated with the same standards.

The BAM-1020 is designed to operate with an airflow rate of 16.7 liters per minute (L/min or lpm). This is because size-selective inlets such as the EPA PM_{10} inlet head and $PM_{2.5}$ cyclones use the inertia of the aerosol particles as they flow through the inlet in order to sort out and trap particles above a certain size or "cut point" so that they won't be measured by the instrument. If the airflow is too high, then particles that should get through will instead be trapped, and the concentration may measure too low. If the airflow is too low, then particles that should be trapped are instead allowed through, and the concentration may measure too high. Periodic airflow audits must be performed to ensure that the BAM-1020 maintains the flow within spec. The EPA-specified range is **±5% (±0.83 L/min)** of the 16.7 L/min design value, and **±4% (±0.67 L/min)** of NIST traceable flow standards. However, the BAM-1020 is designed to maintain the flow with an accuracy of better than ±2% (0.33 L/min).
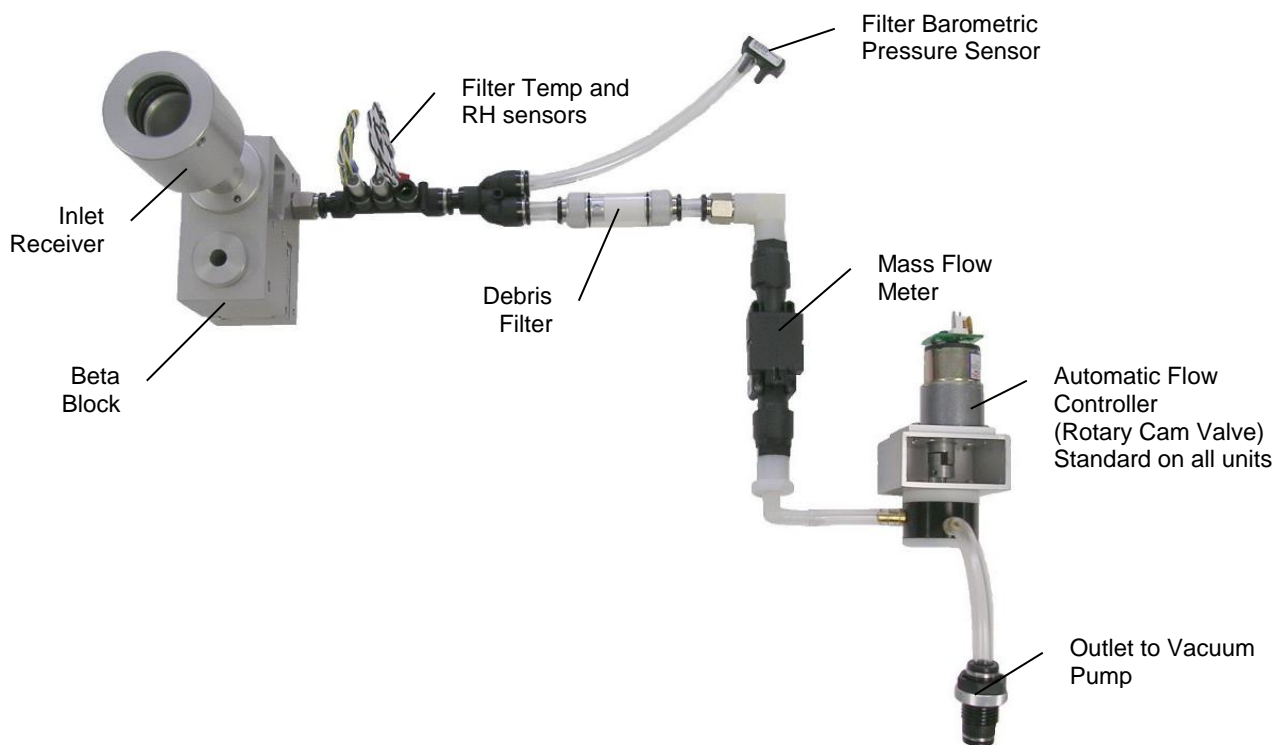
Complete BAM-1020 Flow Control System

As shown in the diagram above, all BAM-1020 units have a mass airflow sensor and a barometric pressure sensor. The BAM-1020 is also equipped with an ambient temperature sensor model BX-592 or BX-596. All units except some early PM$_{10}$ models have an automatic flow controller.

5.2 Flow Control Types – Standard or Actual Flow

BAM-1020 units with firmware revision 3.0 or later (after 2006) have both a FLOW TYPE and a CONCENTRATION TYPE setting. Both can be set to either STANDARD or ACTUAL (see Sections 6.1, 6.2). The unit is capable of controlling the flow using either standard or actual temperature/pressure conditions, and can independently report the particulate concentrations based on either a standard or actual volume of sampled air.

ACTUAL Flow:

Actual flow (sometimes called "volumetric" or "local" flow) is the most accurate flow control method, and is required for all PM$_{2.5}$ monitoring. The local ambient temperature and barometric pressure are always used to calculate the flow, and the flow is continually adjusted to compensate for any changes. The FLOW TYPE is set to ACTUAL so that the BAM will perform actual flow control, and the CONCENTRATION TYPE is set to ACTUAL so that the BAM will report the concentration based on the actual sample volume.

STANDARD Flow:

Standard flow control is used when no ambient temperature sensor is available. The flow is calculated with the assumption that the barometric pressure is 760 mmHg (one atmosphere), and the ambient temperature is 25 degrees C, regardless of the actual local temperature and pressure. Some countries specify a standard temperature of 0 or 20C. At low altitudes and moderate temperature, standard flow will be very close to the actual flow rate. However, at high altitudes the difference between standard and actual flow will be large due to much lower barometric pressure, so standard flow control is not recommended.

PM$_{10}$ data is almost always reported in <u>standard</u> conditions. However, the cut-point of PM$_{10}$ inlets are rated at an <u>actual</u> 16.7 L/min flow rate. For this reason, PM$_{10}$ BAMs should be set with a FLOW TYPE of ACTUAL and a CONCENTRATION TYPE of STANDARD. The unit will perform correct *actual* flow control, but will calculate and store *standard* flow volumes and will calculate and store the particulate concentrations based on the *standard* volume.

METERED Flow: (obsolete)

Metered flow control was used for early discount PM$_{10}$ BAM-1020 units with a manual airflow valve. These had no automatic flow controller, and usually no temperature sensor, so the unit could not compensate for flow variations due to temperature, pressure, or filter loading. The flow volume and concentration were stored in EPA (25C) standard conditions. Metered flow type is no longer used on production BAM-1020 units.

5.3 About Leak Checks, Nozzle Cleaning, and Flow Checks

The three critical aspects of BAM-1020 flow system maintenance are routine *leak checks, nozzle and vane cleaning, and flow checks or calibrations*. Agencies who routinely verify these three aspects almost always obtain high-quality concentration data from the unit. The

minimum service interval is two months, which is the interval for replacing the filter tape. However, many agencies opt to perform leak checks, nozzle/vane cleaning, and flow audits on a monthly basis, and this service interval is recommended by Met One whenever possible. Complete flow system maintenance typically requires less than 10 minutes to perform.

The best order for the monthly flow system checks is:

1. **As-found leak check.**
2. **Nozzle and vane cleaning.**
3. **As-left leak check.** (If a leak was corrected)
4. **Three-point flow check/audit and calibration if required.**

If an air leak is found in a BAM-1020 system, it is almost certain to occur at the interface between the nozzle and the filter tape due to debris buildup. There is normally an insignificant amount of leakage at the tape interface, but an excessive leak lets an unknown portion of the 16.7 L/min sample flow to enter the system at the leak point instead of the inlet. This could cause the total volume of air sampled through the inlet to be incorrect, and the resulting concentration data could be unpredictably biased. **The BAM-1020 has no way of automatically detecting a leak at the tape/nozzle interface because the airflow sensor is located downstream of the filter tape. Allowing a significant leak to persist may result in concentration data being invalidated!** Routine leak checks and nozzle cleaning prevent any significant leaks from forming. Performing an as-found leak check before cleaning the nozzle or performing any service is a key method for validating previous data.

Even if the leak check value is found to be within acceptable bounds, the nozzle and vane should still be cleaned anyway to ensure continued leak-free operation.

5.4 Leak Check Procedure

Perform the following steps to check for leaks in the BAM-1020 system:

1. Enter the TEST > LEAK CHECK menu on the BAM. This will stop the operation cycle of the unit.

2. **(Optional)** Some users perform an as-found flow check/audit before performing any further service. If so, install your flow reference on the inlet, and check the 16.7 flow point in the TEST > FLOW CHECKS screen. Record the as-found flow rate, but do not calibrate any of the flow parameters until the leak checks and nozzle cleaning are finished.

3. Remove the PM_{10} head from the inlet tube and install a BX-305 or equivalent leak test valve onto the inlet tube. If a $PM_{2.5}$ cyclone is used, install the leak check valve on top

of the cyclone, since the cyclone is a possible source of leaks and should be tested. Turn the valve to the OFF position to prevent any air from entering the inlet tube.

4. Press the PUMP ON button. The standard flow rate shown on the BAM display should stabilize at less than **1.0 L/min** in about 20 seconds. Record the as-found results. If the leak flow value is greater than 1.0 L/min, then there may be a vary small amount of leakage in the system. If the leak value is greater than 1.5 L/min, then there may be a more significant leak.

5. If a leak is indicated, resolve it. First attempt the leak check again with the PM$_{2.5}$ cyclone removed (if used). Then clean the nozzle and vane as described below and perform the check again. When the leak is resolved and the leak check value is less then 1.0 L/min, record the as-left leak value.

6. Turn the pump off and remove the leak test valve. Go on to the nozzle and vane cleaning and the flow tests as described below.

Interpreting Leak Test Results:

- A properly functioning BAM-1020 with a clean nozzle and vane will often have a leak value well under the 1.0 L/min limit, such as about 0.5 L/min. The exact "best case" leak value for a particular unit varies depending on the type of pump used and the local altitude.

- The reason for the 1.0 L/min leak flow allowance is due to the test conditions. With the inlet closed, the vacuum in the system is many times greater than during normal sampling. If the leak flow during this test is less than 1.0 L/min, there cannot be a significant leak during normal operation.

- Some agencies choose to adopt tighter tolerances for the leak test criteria, such as requiring a leak value of 0.5 L/min or less after the nozzle and vane are cleaned.

- The typical threshold where data invalidation would be considered, is as-found leak values of greater than 1.5 L/min. Again, some agencies adopt tighter standards, such as invalidating all data back to the last known-good leak check, if the as-found leak value is greater than 1.0 L/min.

- The leak flow value may take a minute or two to stabilize if an inlet tube longer than 8 feet is used.

Advanced Leak Checks: If a leak is found which persists after the nozzle and vane are cleaned, then the source of the leak can be further isolated using a rubber shim, such as part 7440 supplied in the optional BX-308 tool kit. The filter tape can be removed and the shim inserted with the hole centered under the nozzle to eliminate the effects of leakage through the filter tape during the leak check. The shim can also be turned around and the solid side positioned under the nozzle in order to isolate leaks downstream of the vane. Troubleshooting Section 7.5 contains additional tips for resolving leaks in the flow system.
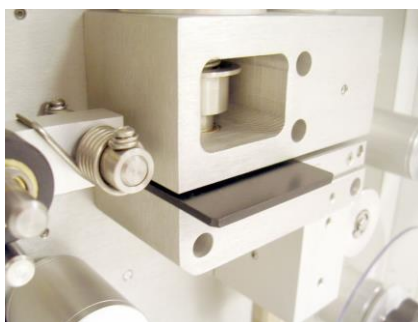
7440 Leak Isolation Shim

5.5 Nozzle and Vane Cleaning Procedure

The nozzle and tape support vane (located under the nozzle) must be cleaned regularly to prevent leaks. The cleaning must be done at least when the filter tape is changed, though monthly cleaning is highly recommended. Some sites will require more frequent cleaning as determined by the site administrator. The worst environment for debris buildup seems to be in humid, hot areas, because the filter tape fibers more easily adhere to the nozzle and vane. The fibers can build up and dry out into a hard mass which can create flow leaks or punch small holes in the filter tape. This can cause measurement errors. Use the following steps to clean the nozzle and vane parts:

1. Latch up the tape pinch rollers, and raise the nozzle in the TEST > LEAK CHECK menu. Slide the filter tape out of the slot in the beta block nozzle area. It is not necessary to completely remove the filter tape from the unit.

2. With the nozzle up, use a small flashlight to inspect the vane. Any debris will usually be visible. Clean the vane surface with a cotton-tipped applicator and isopropyl alcohol. Hardened deposits may have to be carefully scraped off with the wooden end of the applicator. Take care not to damage the vane!

3. Lower the nozzle in the TEST > LEAK CHECK menu. Lift the nozzle with your finger and insert another wet cotton applicator between the nozzle and the vane. Let the nozzle press down onto the swab with it's spring pressure. Use your thumb to rotate the nozzle while keeping the swab in place. A few rotations should clean the nozzle lip.

4. Repeat the nozzle cleaning until the swabs come out clean, then inspect the nozzle lip and vane again, looking for any burrs which may cause tape damage.
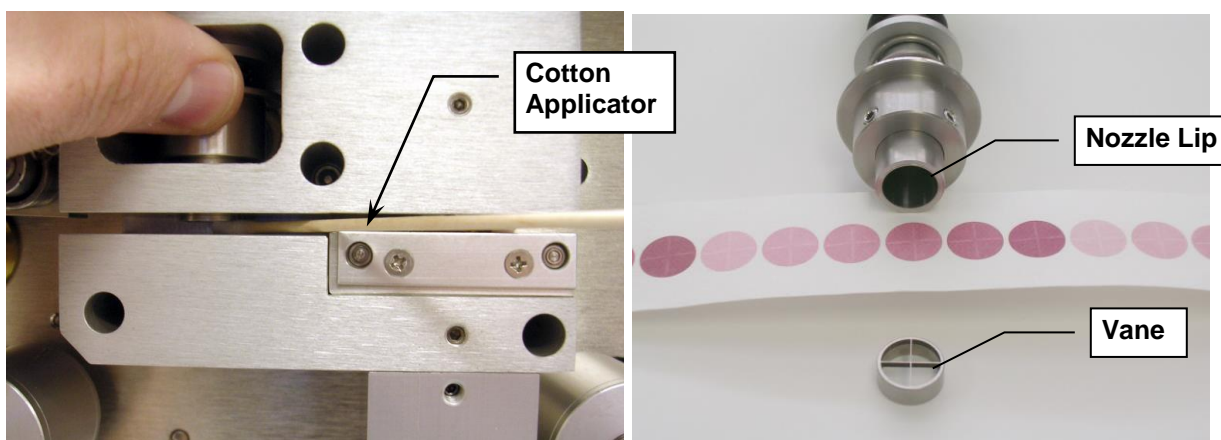
Nozzle and Vane Cleaning, and Disassembled View

The figure below shows the difference between good and bad filter tape spots. The tape on the left is from a properly operated BAM-1020 with a clean nozzle and vane. The dust spots have crisp edges, are perfectly round, and are evenly distributed.

The tape on the right is from a unit which has a leak. A spot of debris has built up on the vane, and is punching a pin-hole at the edge of each spot. These holes can allow beta particles to get through un-attenuated which negatively affects accuracy. The spots also show a "halo" effect due to air leaking in around the edge because the nozzle is not sealing correctly. These faults are easily corrected and prevented by keeping the nozzle and vane clean.
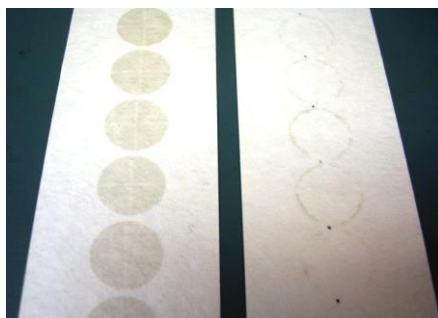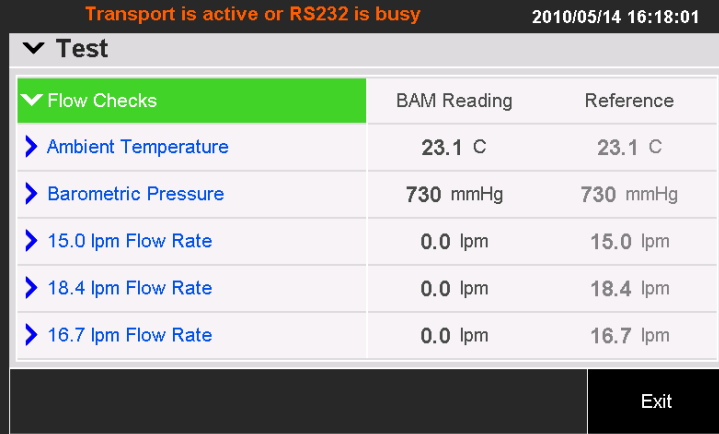

BAM-1020 hourly filter tape spots

5.6 Field Calibration of the Flow System – Actual Flow Mode

Flow calibrations, checks, or audits on any BAM-1020 set for actual flow control are very fast and easy. An ambient temperature sensor must be connected to input channel 6. Perform a leak check and nozzle cleaning before doing any flow calibrations. The FLOW TYPE setting must be set to ACTUAL in the SETTINGS > FLOW menu. See Section 6.2. **Note:** *If the BAM is set to STANDARD flow type, the flow calibration screen will still appear, but the flow calibrations will not take effect.*

The TEST > FLOW CHECKS calibration screen is shown below. The "BAM Reading" column displays what the BAM-1020 measures for each parameter. The "Reference" column is where you can enter the correct values from your traceable reference standard device. The current selected parameter can be changed by pressing the blue text button of the desired parameter. When a parameter is selected, the Reference field will become active and a CALIBRATE and a DEFAULT button will appear at the bottom of the screen. No calibration changes are made to the selected parameter unless the CALIBRATE or DEFAULT key is pressed. The ambient temperature and pressure are always calibrated before the flow, because the BAM uses these parameters to calculate the air flow rate in actual mode.

	BAM Reading	Reference
Transport is active or RS232 is busy		2010/05/14 16:18:01
⌄ **Test**		
⌄ Flow Checks	BAM Reading	Reference
❯ Ambient Temperature	**23.1** C	23.1 C
❯ Barometric Pressure	**730** mmHg	730 mmHg
❯ 15.0 lpm Flow Rate	**0.0** lpm	15.0 lpm
❯ 18.4 lpm Flow Rate	**0.0** lpm	18.4 lpm
❯ 16.7 lpm Flow Rate	**0.0** lpm	16.7 lpm
		Exit

Flow Calibration Screen

1. Enter the TEST > FLOW CHECKS menu as shown above. The nozzle will lower automatically when this screen is entered.

2. (Optional Audit Only) To perform a simple flow "check" or "audit" in which no BAM calibrations are to be changed, simply select the "Ambient Temperature", "Barometric Pressure", and "16.7 lpm Flow Rate" parameters one at a time. Compare the BAM Reading column values to your standard device for each parameter, and record the results. No calibrations are altered if the CALIBRATE or DEFAULT keys are not pressed. If calibration is required, go on to step 3.

3. Select the Ambient Temperature parameter. The Reference value will become active. Measure the ambient temperature with your reference standard device positioned near the BAM-1020 ambient temperature probe. Press the Reference button on the screen, and a keypad will appear. Use the keypad to enter the value from your reference standard and press the OK button. The Reference field should now contain the correct value. Press the CALIBRATE button to calibrate the BAM Reading to match.

4. Select the Barometric Pressure parameter. Enter the barometric pressure value from your reference standard into the Reference field using the same process as temperature, then press the CALIBRATE button calibrate the BAM reading to match.

5. After the temperature and pressure readings are both correct, remove the PM$_{10}$ head from the inlet tube and install your reference flow meter onto the inlet in it's place. Select the "15.0 lpm Flow Rate" button. The pump will turn on automatically. *Allow the unit to regulate the flow until the BAM Reading stabilizes at the target flow rate.* Select the Reference field for the flow point and enter the flow value from your standard device into the Reference field using the pop-up keypad and press OK. Then press the SET button at the bottom of the screen. Note: *The BAM flow reading will not change to match the Reference value until after you have entered all three flow calibration points, since it is done on a slope.*

6. Select the "18.4 lpm Flow Rate" button. Allow the flow to stabilize again, then enter the value from your standard into the Reference field in the same manner and press the SET button. Note: If the BAM-1020 is unable to achieve flow regulation at the 18.4 L/min point, this could be an early indication that the pump needs to be serviced.

7. Select the "16.7 lpm Flow Rate" button. Allow the flow to stabilize again, then enter the value from your standard device into the Reference field in the same manner and press the CALIBRATE button.

8. After this third flow point is calibrated, the BAM Reading for the 16.7 lpm Flow Rate will change to show the corrected flow, then the BAM-1020 will quickly re-regulate the flow to 16.7 L/min based on the new calibration. The BAM-1020 flow reading should now match your flow standard device at 16.7 ± 0.1 L/min. Exit the calibration menu.

Resetting Flow Calibrations:
If the BAM-1020 flow, temperature, or pressure readings do not correctly change to match your standard device during the above calibration process, or if multiple calibrations are required in order to get a good match, then the BAM flow calibrations may need to be reset. This case has sometimes been observed during the first flow calibration after a BAM-1020 firmware update.

Select a parameter and press the DEFAULT button to clear out all previous calibration factors from that parameter and replace them with the original factory calibration factor. Default all of the AT, BP, and flow parameters, then try again to calibrate them to your standards. You may also need to reset the filter RH and filter temperature sensor calibrations. The default factory calibration factors should be very close to the correct values.

5.7 Field Calibration of the Flow System – Standard Flow Mode

All BAM-1020 units configured for PM$_{2.5}$, and almost all units configured for PM$_{10}$ with firmware 3.0 and later, are set with a FLOW TYPE of ACTUAL, and must simply be calibrated as described above in Section 5.6.

If the operational FLOW TYPE must be set to STANDARD for some special reason, then the easiest way to calibrate the flow is to temporarily change the FLOW TYPE from STANDARD to ACTUAL in the SETTINGS > FLOW menu, then perform a normal actual flow audit or calibration as described above. If this method is used, be sure to set the unit back to STANDARD flow type when finished. This works as long as the BAM is equipped with an ambient temperature sensor on input channel six.

6 SETTINGS MENU DESCRIPTIONS

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 section describes the SETTINGS menu in detail, and should be reviewed when the instrument is put into service to ensure desired operation. Once set, most of the values in the SETTINGS menus will not need to be changed by the site operator. The setup values will not be lost if the unit is unplugged or powered down.

WARNING: Some of the settings in the SETTINGS menus are unit-specific calibration constants which must not be changed, or the accuracy and proper operation of the unit may be affected. Entering the SETTINGS menu system requires stopping the sample cycle.

Press the SETTINGS button on the main menu to enter the setup menu as shown below. The default **password of 1234** is required. The Setup Menu provides a choice of operations. Press the blue text button of the desired sub-menu on the touch screen display.

The SETTINGS Menu

6.1 SAMPLE Setup Screen – Range, Sample, and Timing Settings

The SETTINGS > SAMPLE screen is used to set the BAM-1020 sample timing, range/offsets, and some other important settings. Review each of these settings carefully. The SAMPLE screen is shown below. The settings are edited by pressing the button showing the desired parameter. The value for that parameter is then edited by either selecting the desired setting from a pop-up pick-list, or by entering a new value with the pop-up numeric keypad. Press the SAVE button when finished.
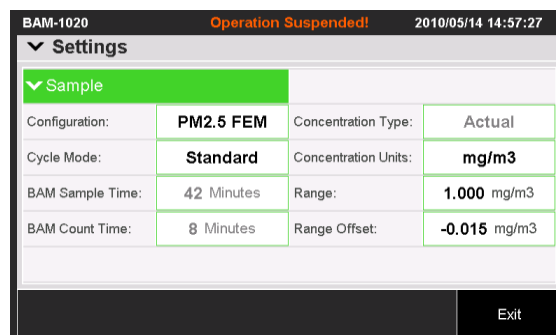
The SETTINGS > SAMPLE Screen

Configuration: This single setting allows the user to quickly preset all of the required settings for EPA designated FEM monitoring by simply setting up the desired configuration type. This will automatically set the BAM sample time, count time, flow type, concentration type, and flow rate settings. The possible configuration values are listed below:

Configuration	Description
PM2.5 FEM	Sets the required settings for PM2.5 FEM monitoring.
PM10 FEM	Sets the required settings for PM10 FEM monitoring.
COARSE PM2.5	Sets the unit as the PM2.5 slave unit in a coarse paired set.
COARSE PM10	Sets the unit as the PM10 master unit in a coarse paired set.
CUSTOM	Allows the user to set all sample settings manually.

Cycle Mode: The Cycle Mode can be set to STANDARD or EARLY. If you are not using the analog output voltage of the BAM-1020, leave this set to STANDARD. The Cycle Mode setting must be reviewed and understood if the analog output is being used. See Section 8.2.

BAM Sample Time: This value sets the amount of minutes per sample hour that the vacuum pump is ON. See Section 4.1 for a description of the hourly cycle. The BAM Sample Time must be set in response to the Count Time value, since current versions of the BAM-1020 allow the option of setting the count time to 4 or 8 minutes. *If the unit is used for PM$_{2.5}$ FEM or EU PM$_{2.5}$ monitoring, the BAM Sample must be set to 42 minutes with 8-minute count time.* PM$_{10}$ monitors are usually set for 50 minute sample time with 4 minute count time, but may be set for 42/8 if the firmware allows the count time to be set to 8 minutes.

BAM Count Time	BAM Sample Time	Used for
4 min	50 min	PM$_{10}$ monitoring, units without a count time setting.
8 min	42 min	All PM$_{2.5}$ FEM, PM-coarse, EU PM$_{2.5}$ monitoring.

The BAM Sample Time setting has a range of 0-200 minutes for custom applications. If set for shorter period, such as 15 minutes, the pump will only sample for 15 minutes and then wait until the end of the hour before beginning a new cycle. This may not leave time for the membrane span check. Only one pump cycle per hour is allowed, regardless of duration. Setting the BAM Sample value too long may cause the total measurement cycle to overlap into the next hour, so that the unit only collects the concentration every second hour. This is usually undesirable. Contact the Service department before setting this to anything but 42 or 50 minutes.

BAM Count Time: This is the amount of time the unit takes to perform the I$_0$ and I$_3$ counts at the beginning and the end of the sample hour. *When used for PM$_{2.5}$ FEM, EU PM$_{2.5}$, or PM$_{10-2.5}$ (coarse) monitoring, the COUNT TIME must be set to 8 minutes.*

Older revisions of the BAM-1020 firmware before Rev 3.2 were always fixed at 4 minute count times only, and some newer units (those sold for PM$_{10}$ use only) are also fixed at 4 minutes. However, if the BAM is equipped with firmware which allows the 8-minute count time, it may be used for PM$_{10}$ as well. See the BAM Sample setting description above, and Section 4.1. The unit will prompt you to change the BAM Sample time setting if you change the Count Time to an incompatible value.

Concentration Type:	This sets the way that the concentration values are reported, and can be set to either ACTUAL or STANDARD. *The Concentration Type must be set to ACTUAL for all PM$_{2.5}$ monitoring, and is almost always set to STANDARD for PM$_{10}$ monitoring.* If set to ACTUAL, then the concentration is calculated and reported based on the volume of the air at local ambient conditions. An ambient temperature sensor is required. If set to STANDARD, the concentration is calculated and reported based on the standard values for temperature and pressure (760 mmHg and usually 25C), even if a temperature sensor is available. See Section 5.2.

Concentration Units:	This setting determines the concentration units which the BAM-1020 displays and stores in memory. This can be set to ug/m3 (micrograms) or mg/m3 (milligrams) per cubic meter. Older revisions of firmware were fixed at mg/m3 only, and this is still the default setting. **Note:** 1.000 mg = 1000 μg.

Range:	The Range setting sets the full-scale range of the concentration measurement system, including the digital system and the analog voltage output. The Range value is rarely ever changed from the default setting of 1.000 mg, with a default Range Offset (lower limit of the range) of -0.015 mg. This means that the BAM measures a maximum full-scale range of -0.015 mg + 1.000 mg = 0.985 mg by default. The table below shows some examples of how the Range and Range Offset setting interact to produce the concentration data outputs.

Offset Setting	Range Setting	Resulting Digital Data Range	Resulting Analog Output Range
-0.015 mg	1.000 mg	-0.015 to 0.985 mg	0-1V = -0.015 to 0.985 mg
-0.005 mg	1.000 mg	-0.005 to 0.995 mg	0-1V = -0.005 to 0.995 mg
-0.015 mg	0.200 mg	-0.015 to 0.185 mg	0-1V = -0.015 to 0.185 mg
0.000 mg	1.000 mg	0.000 to 1.000 mg	0-1V = 0.000 to 1.000 mg
-0.015 mg	2.000 mg	-0.015 to 1.985 mg	0-1V = -0.015 to 1.985 mg

In special cases, the Range value may be set to 0.100, 0.200, 0.250, 0.500, 2.000, 5.000, or 10.000 mg. *It is absolutely critical to understand this setting if an external datalogger is used to log the BAM-1020 analog output, since the data logger must be set to scale the analog voltage correctly. See Section 8.* The only reason to ever set the Range to a lower value such as 0.200 mg, would be to improve the resolution of the analog output if you are sure the concentrations will never exceed 200 micrograms. This is because the 0-1 volt output has a ±.001 volt tolerance, which can introduce up to a 1 microgram error if the Range is set to 1.000 mg, but only a 0.2 microgram error if the Range is set to 0.200 mg.

High Concentrations: The Range setting may be set higher than 1.000 mg in high concentration areas. It is very unlikely that PM$_{2.5}$ levels will exceed 1000 μg without first clogging the BAM filter tape, but some PM$_{10}$ areas can see dust loading that exceeds 1000 μg without clogging the tape spot. *However, setting the Range to 5.000 or 10.000 mg reduces the digital resolution of the BAM-1020 in low concentrations, so don't use these two range settings unless necessary.*

Note: Changing the range setting will affect past data already stored to memory. Always download any old data before changing settings, then clear the memory. Firmware version 3.2.4 or later will require you to clear the memory before letting you change this setting.

Range Offset: The Range Offset value is used to set the lower end of the BAM-1020 measurement range, and is sometimes simply called the "offset". It can be set to values of -0.015, -0.005, or 0.000 mg. The factory default value for Range Offset is -0.015 mg. This shifts the range of the BAM-1020 down slightly so that it can read from -0.015 to 0.985 mg (with the default range of 1.000 mg). This simply allows the unit to measure slightly negative concentration numbers near zero, which is necessary to differentiate between normal noise and a failure such as punctured filter tape.

The default Range Offset on older units was -0.005 mg, and the value may still be set to -0.005 to work with data logging systems structured around the old setting. Some BAM users set the Range Offset value to 0.000 to avoid confusion, but this is not usually recommended, because it will not allow you to see the true zero noise floor of the unit during the zero filter test, and it can cause an artificial positive bias in low concentration PM$_{2.5}$ monitoring.

This value also affects the analog output, so that 0 to 1.000 volts equals -0.015 to 0.985 mg, instead of 0.000 to 1.000 mg. This is because the voltage output cannot go negative. You must take this scaling into account if an external data logger is recording the BAM-1020 analog output voltage.

Note: The OFFSET value is often misunderstood, and should not be confused with the BKGD (zero correction factor) value. Be sure you understand all three of these settings!

Note: Changing the offset setting will affect past data already stored to memory. Always download any old data before changing settings, then clear the memory. Firmware version 3.2.4 or later will require you to clear the memory before letting you change this setting.

6.2   FLOW Setup Screen

The SETTINGS > FLOW screen allows the user to set the airflow for the BAM-1020. Note: The Flow Rate and Flow Type settings can only be changed if the Configuration setting is set to CUSTOM.
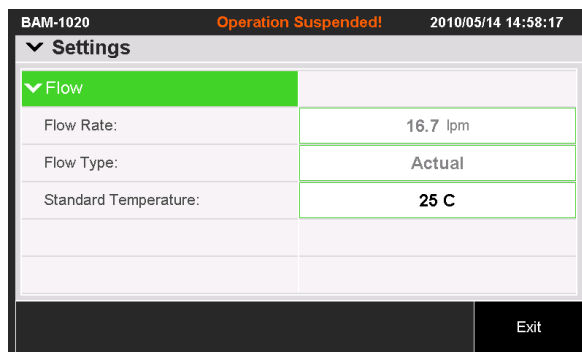
The SETTINGS > FLOW Screen

Flow Rate: This sets the air flow rate for the BAM-1020, and the unit will continuously regulate the flow to this value during sampling. The Flow Rate is always set for **16.7 liters per minute**, as this is required for all PM$_{2.5}$ and PM$_{10}$ monitoring. The only time this might be changed temporarily is if a site operator was testing the ability of the pump and flow controller to regulate the flow at different levels for troubleshooting purposes. The range of the setting is 10 to 20 L/min.

Flow Type: This setting selects the flow control scheme used by the BAM-1020. The options are ACTUAL or STANDARD. This is an important parameter to understand. At sea-level and moderate temperatures the difference between actual and standard flow will be minimal, but at high elevations or varied temperatures the flow rate can be greatly affected by this setting. **Section 5.2 contains a detailed description of each of these flow types**, and should be studied to ensure proper operation of the unit.

The Flow Type must be set to ACTUAL on all PM$_{2.5}$ and PM$_{10-2.5}$ (coarse) units. The flow is controlled based on actual, local ambient temperature and pressure conditions. ACTUAL flow type is also recommended for all newer PM$_{10}$ units with firmware revision 3.0 or later, since the separate Concentration Type setting can be set to STANDARD for standard PM$_{10}$ reporting, even though the flow is controlled volumetrically. Actual flow requires an ambient temperature sensor.

If the Flow Type is set to STANDARD on a unit with revision 3.0 or later firmware, the BAM-1020 will control the flow based on standard temperature and pressure values, even if a temperature sensor is connected. This is rarely used because the inlet heads and cyclones are rated for actual cut-points. Older PM$_{10}$ units with firmware 2.58 and earlier (which did not have a separate Concentration Type setting) had the Flow Type set to STNADARD, which controlled both flow type and concentration reporting. However, if a temperature sensor was available, these older units automatically performed <u>actual</u> flow control.

Standard Temperature: This is the value of standard air temperature, used only for standard flow control or standard concentration calculations. In the U.S. the value of standard temperature is always 25 degrees C as mandated by the U.S. EPA. Some other countries use a standard temperature value of 0C or 20C.

6.3   CALIBRATION Setup Screen – Factory Calibration Settings

The SETTINGS > CALIBRATION screen is where the factory-determined calibration parameters for the BAM-1020 are stored. These values are unit-specific, and can also be found on the calibration certificate for the BAM-1020. Most of these settings will never be changed without specific information from Met One Instruments. It is good practice to periodically audit the calibration values to verify that they have not been altered.

BAM-1020	Operation Suspended!	2010/05/14 14:59:11
∨ Settings		

∨ Calibration	
Cv (Flow Sensor Coefficient of Variablity):	0.980
Qo (Flow Sensor Zero Correction):	0.000
ABS (Span Membrane Expected Mass):	0.813
μsw (Factory Mu Switch Setting):	0.306
K (Factory Slope Correction):	0.980
BKGD (Background Offset Correction):	-0.0016

	Exit

The SETTINGS > CALIBRATION Screen

Cv: This value is a factory-set scaling slope for the internal mass flow sensor. The value of Cv is never altered except when performing a flow calibration on old units without an

automatic flow controller. All newer units with flow controllers and ambient temperature sensors never need to have this value altered, because the flow calibrations are done in the TEST > FLOW CALIBRATIONS screen.

Qo: This value is the factory-set zero correction offset for the internal mass flow sensor, and is almost always simply zero. Qo is usually never changed by the user except when troubleshooting a leak check failure if the BAM flow display does not drop to 0.0 L/min when the pump tubing is disconnected from the unit.

ABS: The ABS value is the factory-set expected mass of the reference membrane foil used during the automatic hourly span check. This expected value is compared to the measured value each hour (see section 4.2). Each unit's ABS value is different, but is typically near 0.800 mg/cm^2. **The ABS value is never changed by the operator unless the span membrane foil is replaced due to damage.**

μsw: This is called the Mu-switch value, and is the factory-set mass absorption coefficient used by the BAM-1020 in the concentration calculations. The value varies for different units, but is typically near 0.305. **Warning: This is a unit-specific calibration value which may significantly affect the accuracy of the unit. Never change this value without specific instruction from Met One Instruments.**

K: The K-factor is the factory-set calibration slope correction (multiplier) for the BAM-1020 concentrations. The K-factor value is determined by dynamic testing of the BAM-1020 in the factory smoke chamber. This will always be a value between 0.9 to 1.1. All of the stored and displayed data contains this correction. **Warning: This is a unit-specific calibration value which may significantly affect the accuracy of the unit. Never change this value without specific instruction from Met One Instruments.**
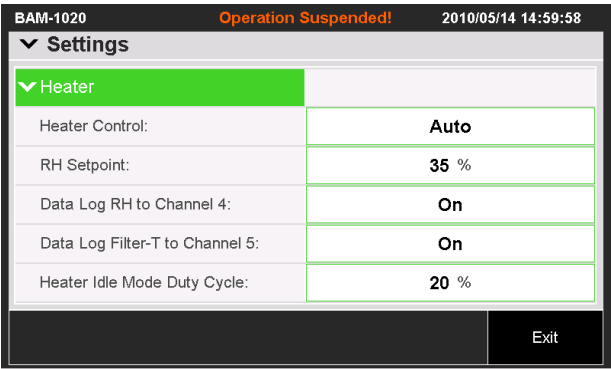
BKGD: The BKGD (background) value is the zero correction (offset) for the BAM-1020 concentrations. This is determined by running the unit for at least 72 hours with a zero filter on the inlet. The concentration values over this time are averaged, and the BKGD is the negative of this average. All of the stored and displayed data contains this offset correction. The BKGD value is typically between 0.000 and -0.005 mg/m^3. Met One supplies the BAM-1020 units with a factory-set BKGD value. All PM$_{2.5}$ units are also supplied with a BX-302 zero filter kit which allows the user to audit the background value and set it for local conditions. **Warning: This is a calibration value which may significantly affect the accuracy of the unit.**

Note: The BKGD value is a true data offset, and is not to be confused with the Range Offset value in the SETTINGS > SAMPLE menu. See section 6.1.

6.4   HEATER Setup Screen – RH Control Settings

The SETTINGS > HEATER screen is used to configure the settings used by the BAM-1020 to control the Smart Inlet Heater. The BAM uses an RH and temperature sensor located below the filter tape in the sample air stream to monitor the conditions of the air as it is being sampled. If the sample relative humidity is excessive (above about 50%), the particulate on the filter tape can begin to absorb moisture and the measured mass will increase. The effect

gets worse as the sample RH increases. The Smart Heater minimizes this effect by actively heating the inlet tube to lower the humidity.

BAM-1020	Operation Suspended!	2010/05/14 14:59:58

∨ Settings

∨ Heater	
Heater Control:	**Auto**
RH Setpoint:	**35** %
Data Log RH to Channel 4:	**On**
Data Log Filter-T to Channel 5:	**On**
Heater Idle Mode Duty Cycle:	**20** %
	Exit

The SETTINGS > HEATER Screen

Heater Control: This setting selects which operation mode the Smart Inlet Heater is used in, and can be set to AUTO or MANUAL. This value must be set to AUTO for all PM$_{2.5}$, PM$_{10}$ and PM$_{10-2.5}$ monitoring. When set to AUTO, the Smart Heater can use the filter RH and/or temperature sensors to control the inlet tube heating. The Smart Heater will be automatically turned on full power whenever the humidity of the sample stream exceeds the RH Setpoint (usually 35%). When the RH falls back below the set point, the heater turns down to a low power heat mode which simulates the older style wrap-around heaters. If set to MANUAL, the unit will simply turn the heater on to full power regardless of filter conditions. Manual mode is not used.

RH Setpoint: This is the relative humidity level that the filter will be regulated at or below by the inlet heater. This value must be set to **35%** for all PM$_{2.5}$ FEM units. The value is set to 45% for European PM$_{2.5}$ units, and may be either 35% or 45% for PM$_{10}$ units. The RH Setpoint can be set from 10% to 99% for special applications only.

Data Log RH to Channel 4:   If ON is selected, the filter RH values will be logged on met channel 4 of the BAM-1020. Always select ON if you do not have any external sensors attached to channel 4.
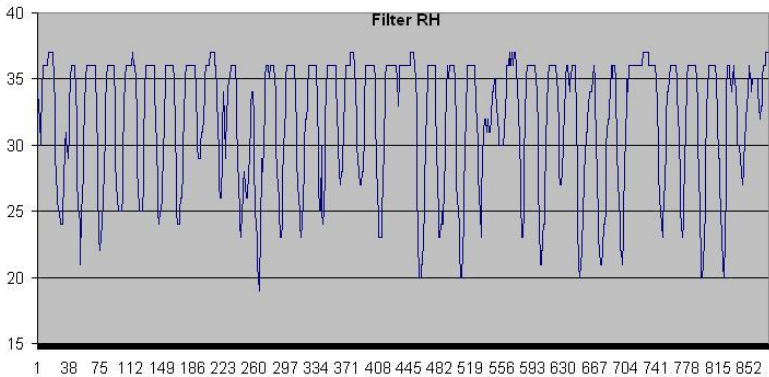
Properly Regulated Channel 4 Hourly Filter RH Graph

Data Log Filter T to Channel 5: If ON is selected, the filter temperature values will be logged on met channel 5 of the BAM-1020, as long as no other external sensors are attached to channel 5. The filter temperature is not used for heater control, but some BAM-1020 users log it for informational purposes.

The filter temperature in the BAM is always higher than ambient temperature due to the inlet heater and shelter effects. Volatile organic compounds (VOCs) may be lost from the sample if the filter temperature is excessive. However, the BAM-1020 changes the filter spot every hour, and the classic 5 degree C filter Delta-T limit does not apply to the BAM-1020. In cold climates, the BAM-1020 Delta-T values can be very large. Excessive filter RH has a far greater adverse effect on the concentration measurement than filter temperature.

Heater Idle Mode Duty Cycle: This is the idle mode setting for the inlet heater. Whenever the filter RH is below the setpoint, the heater will be set to this percentage of its full wattage (200W). The default is 20% (40W). This setting may be set lower for use in mini shelters where minimal heating is desired.

6.5   ADVANCED Setup Screen

Many of the settings in the ADVANCED setup screen are rarely changed.

The SETTINGS > ADVANCED Screen

Station Number: This is a station identification number. This number has a range of 001-254, and will be included in the data reports. When used in a network, every BAM-1020 should be given a different station number. Default value is 01.

RS-232 Baud Rate: This allows you to set the baud rate of the RS-232 serial port. The available values are 300, 600, 1200, 2400, 4800, 9600, 19200, and 38400 baud. The default setting is 9600 baud. The BAM-1020 must be set to 9600 baud during flash firmware upgrades, but may be set faster for data collection. The fixed handshaking settings of 8 data bits, no parity, and 1 stop bit cannot be edited.

Met Sample Average: This value is the averaging period for the built-in met sensor data logger. It sets how often the data array is averaged and written to memory, and can be set to 1,5,15, or 60 minutes. For example, if an optional wind speed sensor is attached to the BAM, the Met Sample period could be set to 1 or 5 minutes. This value applies to all parameters and sensors attached to the unit, except for the dust concentration data which is always an hourly average regardless of this setting.

Warning: This setting will affect how long the memory will last before getting full!
There are **4369 records** available in the BAM memory. The default Met Sample period of 60 minutes (1 record per hour) will result in 182 days' worth of memory capacity, but a 1 minute average period would fill up these memory records in only 3 days. When the memory gets full

the unit over-writes the oldest data. Leave the Met Sample period set at the default value of 60 minutes unless a faster average is required for a particular met sensor application.

MET SAMPLE	Data Capacity
60 min	182 days
15 min	45 days
5 min	15 days
1 min	3 days

AP Filter Pressure Drop: Pressure-drop limit. This is the maximum amount of increase in pressure drop which is allowed to occur at the filter tape due to heavy dust loading, before the "P" alarm will be generated. Setting the AP higher will allow more dust to accumulate before the sample is terminated, but may cause flow regulation problems. See the Pressure-drop alarm description in Section 7.2. The default setting of **150** mmHg is correct for most applications using the standard Medo or Gast pumps. Larger pumps can accommodate a higher AP setting and higher dust loads while still being able to regulate the sample flow. The setting range is 0-500 mmHg.

Telemetry Fault Input Polarity: This sets the polarity of the Telemetry Fault Relay input. This can be set to Normal Open or Normal Closed. Almost never used.

External Reset Input Polarity: This tells the BAM-1020 the incoming polarity of an external clock reset signal, if used. This signal is used to synchronize the BAM clock to an external data logger. This can be set to Normal Open or Normal Closed. Almost all dataloggers use normal open polarity for the signal.

MORE > Span Check: (Not Shown in screen shot above) This setting determines how often the BAM-1020 performs the automatic span membrane check. If the value is set to 1 HR, the BAM measures and displays the span each hour as normal. If this value is set to 24 HR, then the BAM will only perform the span check once during the sample hour beginning at midnight, or during any sample hour following a power failure. The resulting value will be displayed throughout the rest of the day. If this value is set to OFF, the span check will be disabled entirely. **Note:** This setting does not appear in any firmware before V4.3.0, where the setting is invisible and fixed at hourly.

6.6 MET INPUTS Setup Screen for External Met Sensors

The SETTINGS > MET INPUTS menu is where configurations and setup parameters are located for the six analog input channels used to log external meteorological sensors. Each channel must be configured to accept the sensor before data can be acquired. Description for the parameters are provided below. There is a separate configurable setup screen for each of the six external sensor inputs in the menu. There are also two internal channels (I1 concentration and I2 flow volume) which can be viewed but not modified.

Met One BX-500 series meteorological sensors have an Auto ID feature which allows the BAM to automatically recognize the sensor and enter all of the setup parameters for any channel the sensor is attached to. The six channels can also be manually configured for other sensors. Almost any meteorological sensor with a voltage output range of 1.0 or 2.5 volts can be scaled and logged by the BAM-1020.

The SETTINGS > MET INPUTS Screen

Channel: Selects the channel to be viewed. Select channel 1 through 6.

Name: This is the parameter name. You can select the parameter and an ASCII character set will appear on the touch screen.

Units: This is the measurement units label for the channel. You can select the parameter and an ASCII character set will appear on the touch screen.

Multiplier: This is really the measurement range or the span of the sensor. If a baro sensor has a range of 525 to 825 mmHg, then the MULT would be 300 (mmHg). If a RH sensor has a range of 0 to 100%, then the MULT would simply be 100 (%).

Precision: This is the precision field, which sets the number of available decimal places for the Multiplier and Offset parameters. Can be set to 0, 1, 2, or 3.

Full Scale: This is the full-scale voltage output of the sensor. The maximum voltage range that can be supplied by the sensor. This value is usually going to be either 1.000 or 2.500 volts. 2.500 is the maximum setting for this field.

Auto ID: This field can be set to either ON or OFF. If AUTO ID is OFF, the user can enter their own setup parameters for the channel. AUTO ID mode is used with 500 series sensors, and must be set to ON in order for the unit to recognize the sensor automatically. **NOTE:** Any manually set parameters for that channel will be lost when enabling AUTO ID mode. **Channel 6 must be set to AUTO ID for all units equipped with an ambient temperature sensor.**

Offset: This is the range offset value, or the measurement value that the sensor represents at 0.000V output. For example, If an AT sensor has a 0-1V output representing -50 to +50C. So the MULT range is 100 (C) and the offset is -50, because 0.000V from the sensor represents -50C.

Vector: This value sets the averaging method. Set this to OFF for all sensors except for wind direction, which uses vector calculations.

Inverse Slope: This setting allows the channel to recognize a sensor with an inverse slope. This is always set to OFF except for use with thermistor temperature sensors with resistance-only outputs.

6.7 CLOCK Setup Screen

The SETTINGS > SET CLOCK screen allows for the setting the time and date. Time is a 24-hour clock only. Set the clock by selecting one of the parameters, then entering a new value using the pop-up numeric keypad. Press the SAVE button when finished. The BAM-1020 clock may drift as much as a minute or two per month. The lithium battery backup keeps the clock running during power-down. Met One recommends checking the clock monthly to ensure correct sample timing.

SETTINGS > CLOCK Screen

6.8 PASSWORD Setup Screen

The SETTINGS > PASSWORD screen allows the program administrator to change the password required to enter many of the TEST or SETTINGS menus. The password prevents untrained users from accidentally changing critical settings or calibrations on the unit. The password can be any four-digit numeric value. **The default password is always "1234"**. Met One does not recommend changing the default password unless necessary. Contact the Met One Service department for instructions if the password is lost or forgotten.

6.9 CLEAR MEMORY Setup Screen

The SETTINGS > CLEAR MEMORY screen is used to erase the data log or alarm log memory. Press the Clear Data or Clear Alarm button. The BAM will display a warning screen asking if you are sure that you want to clear the memory. The "Data Log Memory" field shows how much memory is left before the unit will start to over-write the oldest data records.

The SETTINGS > CLEAR MEMORY Screen

6.10 UPDATE PROGRAM Setup Screen

The SETTINGS > UPDATE PROGRAM screen is used to flash update the touch panel PC module software. A factory-supplied USB flash drive with the new program must be inserted

into the **bottom USB port** on the display module inside the front door. Then the OK button is pressed to upload the new software. This must only be done if instructed by Met One.

6.11 QUERY Setup Screen

The SETTINGS > QUERY screen allows the user to configure a custom digital data array for the Query Output, or for the European BH Bayern-Hessen protocol. The user can select exactly which data parameters appear in the array, and in what exact order they appear. The custom array can be as simple as a single concentration value, or it can be very comprehensive including some parameters that are not even available in any of the standard data files, such as the hourly span membrane check value. The setup of this custom array does not affect any of the standard BAM data arrays. A separate technical document for the Bayern-Hessen protocol functions is also available. See Section 9.9 for instructions about how to retrieve the Query output files. **Note:** The first releases of the touch screen BAM firmware prior to rev 4.2.0 did not support the Query or BH data array.

Touch the **N:** field to set how many values to include in the array, starting with position 1. Up to 18 parameters can be included.

Each position in the array can then be changed to any desired parameter using the touch screen for each field. In the example above, 18 parameters are included, and the shown parameters were selected for each of the 18 positions in the array. The available parameters are listed in the table below. **Note:** Some of the parameters shaded below will only appear as available in the pick list if the BAM-1020 is set to perform as part of a PM-coarse pair. See Section 6.1.

Parameter	Description
CONC	Concentration value for the last sample period.
PM10	PM10 concentration from the master unit in a PM-coarse pair. This parameter is only available in the master unit of a coarse set.
Q_STD	Sample flow volume in cubic meters at standard conditions.
Q_ACT	Sample flow volume in cubic meters at actual AT/BP conditions.
REF	Reference span membrane mass measurement in mg/cm2.
FLOW	Real time flow or average flow for the last sample.
CV	Flow coefficient of variability for the last sample period. (Standard deviation divided by the mean)
AT	Average ambient temperature for the sample period.
BP	Average barometric pressure for the sample period.
ANALOG 1	Average of analog met sensor channel 1 (user defined channel).
ANALOG 2	Average of analog met sensor channel 2 (user defined channel).
ANALOG 3	Average of analog met sensor channel 3 (user defined channel).
ANALOG 4	Average of analog met sensor channel 4 (usually filter RH).

ANALOG 5	Average of analog met sensor channel 5 (user defined channel).
ANALOG 6	Average of analog met sensor channel 6 (almost always AT).
TIME	Date and Time stamp for the sample period. Ignored for BH protocol.
ERRORS	Decimal error codes of the 12 major error categories.
PM10s	PM10 concentration using standard conditions. Used in PM-coarse systems where the coarse PM10 value is in actual conditions, but the standard PM10 value is also needed for regular PM10 reporting requirements. This parameter is only available in the PM10 master unit of a coarse set.
PM2.5	PM2.5 concentration from the slave unit in a PM-coarse pair. This parameter is only available in the master unit of a coarse set.
PMc	PM-coarse (PM10 - PM2.5) concentration value. This parameter is only available in the master unit of a coarse set.
STAB	Diagnostic Stability measurement. Available in 3236-77 EU firmware only.

6.12 REPORTS Setup Screen

The SETTINGS > REPORTS screen is used to set some advanced data array features.

Daily Range: Determines which sample hours are included in the legacy BAM daily text reports. The two possible choices are:

00:00 to 23:00 (old default setting) or **01:00 to 24:00** (correct newer setting)

The BAM-1020 time stamp is the <u>end</u> of the sample hour, not the beginning, so the 01:00 data point is for air sampled between midnight and 1:00 am. Always select 01:00 to 24:00. The 00:00 to 23:00 setting is only included for a few agencies who may have a data collection system built around the old setting.

Report PM10 Standard: Determines if the EPA standard PM_{10} concentration appears in the regular BAM-1020 data arrays, along with the actual PM_{10} concentration, when the BAM is set as the PM_{10} master unit in a PM-coarse pair. This is because the PM-coarse method uses actual conditions for all PM_{10}, $PM_{2.5}$, and coarse calculations, but classic PM_{10} is reported in standard conditions. The setting allows the master BAM to report a regular PM_{10} standard value in addition to the actual values.

BAM-1020	Operation Suspended!	2011/01/24 17:11:02
⌄ Settings		
⌄ Reports		
Daily Range:	00:00 - 23:00	
Report PM10 Standard:	Yes	
	Exit	

7 MAINTENANCE, DIAGNOSTICS and TROUBLESHOOTING

This section provides information about routine maintenance, identifying errors and alarms, and performing diagnostic tests if a problem is encountered on the BAM-1020. The TEST menu functions are also described in this section.

Met One Instruments also publishes a comprehensive array of technical bulletins that cover advanced information about less-common subsystem troubleshooting, upgrades, and repairs that are too detailed to be included in this manual. These are available in the "BAM Users" section of our website, or by e-mail request from the Technical Service department.

7.1 Met One Recommended Periodic Maintenance Table

The following table shows the recommended interval for the regular BAM-1020 maintenance, field check, and service tasks. Special tools are not required for any of the routine BAM service tasks on less than yearly intervals. Met One recommends the BX-308 and BX-344 kits for non-routine service and repairs such as nozzle removal and detector tests. Complete instructions are included.

Maintenance Item	Period
Nozzle and vane cleaning.	**Monthly**
Leak check.	**Monthly**
Flow system check/audit.	**Monthly**
Clean capstan shaft and pinch roller tires.	**Monthly**
Clean PM10 inlet particle trap and PM2.5 cyclone particle trap.	**Monthly**
Download and save digital data log and error log.	**Monthly**
Compare BAM-1020 digital data to external analog datalogger data, if used.	**Monthly**
Check or set BAM real-time clock.	**Monthly**
Replace filter tape roll.	**2 Months**
Run the SELF TEST function.	**2 Months**
Download and verify BAM-1020 settings file.	**Quarterly**
Complete flow system calibration.	**Quarterly**
Completely disassemble and clean PM10 inlet and PM2.5 cyclone.	**Quarterly**
Replace or clean pump muffler.	**6 months**
Test filter RH and filter temperature sensors.	**6 months**
Test smart heater function.	**6 months**
Perform 72 hour BKGD test (BX-302 zero filter).	**12 months**
Clean internal debris filter.	**12 Months**
Remove and check membrane span foil.	**12 Months**
Beta detector count rate and dark count test.	**12 Months**
Clean vertical inlet tube (BX-344 cleaning kit).	**12 months**
Test analog DAC output, if used.	**12 Months**
Replace lithium battery if necessary.	**12 Months**
Rebuild vacuum pump.	**24 months**
Replace nozzle o-ring.	**24 months**
Replace pump tubing, if necessary.	**24 Months**
Factory recalibration is not required except for units sent for major repairs.	**---**

7.2 BAM-1020 Error and Alarm Descriptions

The following table describes the BAM-1020 error and alarm codes. Errors are grouped into twelve categories. If an error or alarm occurs, it will appear at the end of the hourly digital data array as a simple "1" bit in one of the twelve error bit positions. This allows data collection systems to easily identify errors. See Section 9 for data examples. Errors and alarms are also stored in the separate BAM digital error log file, which contains more detail about the specific sub-category cause of the alarm.

Note: *In general, any error which prevents the BAM-1020 from making a valid, accurate hourly concentration measurement will also cause the digital concentration value to be stored as a full-scale value (usually 0.985 mg) in order to indicate invalid data.* In most cases, critical errors will also force the analog output to full-scale (1.00V). The rules for which errors cause invalid data and full-scale values have varied slightly with past revisions of firmware. The following descriptions explain these conditions in as much detail as possible. If an error occurs in your unit which does not seem to agree with this description, please note your firmware revision and contact Technical Service.

| Code	Error/Alarm Type	Error/Alarm Description
E	**External Reset** or **Interface Reset**	This alarm indicates that an external datalogger sent a clock synchronization signal to the BAM on the EXT RESET input, but the BAM was unable to reset it's clock, because it occurred outside of the allowable time window. Hourly clock reset signals will be ignored by the BAM from minutes 5-54 (standard cycle) or minutes 0-49 (early mode). See Section 8.2.The alarm will also be generated if the synch signal occurs within the acceptable window near the end of the hour, but before the BAM has finished the previous concentration calculation. The digital error log will indicate which of these two has conditions occurred. If an external clock reset event is successful, then no alarm is logged. These alarms do not prevent the BAM from storing a valid data record for the sample hour.
		Manually set the BAM-1020 clock to match the datalogger clock initially. This should cause subsequent clock synch events to succeed. Make sure the BAM lithium battery is functional.
U	**Telemetry Fault** or **Interface Fault**	This alarm indicates that an external datalogger has sent an error signal to the BAM-1020 on the TELEM FAULT input, indicating that the logger unit has encountered a problem. This feature is almost never used. These alarms do not prevent the BAM from storing a valid data record for the sample hour.
M	**Maintenance Alarm**	This alarm almost always indicates that the sample cycle was stopped because someone entered a SETUP or TEST menu for calibration or testing purposes. Maintenance flags always cause the digital concentration value to go full-scale for that hour, because the sample cycle was not finished.
I	**Internal Error** or **Coarse Link Down**	The "I" error is rare, and indicates that an error occurred in the BAM concentration, mass, span, or stability calculation which prevented the generation of a valid concentration value. The digital error log will indicate which of these calculations has failed. The concentration value is set to full-scale due to invalid data. This may indicate a problem in the digital circuitry.
		In BAM-1020 units configured as the PM_{10} master unit in a PM-coarse pair, the "I" alarm indicates that the digital link between the two units is down, and the master unit could not obtain the $PM_{2.5}$ value from the slave unit and thus could not calculate a coarse value. The coarse and $PM_{2.5}$ values will be full-scale.

L	**Power Failure or Processor Reset**	This error occurs if AC input power is lost even momentarily, or if the power switch is turned off. Frequent "L" errors usually indicate poor quality AC power. If frequent power errors occur even when the unit is connected to a UPS backup system, contact Met One for instructions on possible power supply upgrades. Anything that causes the microprocessor to reset will also result in an "L" error, such as low voltage on the 5.25V Vcc system, bad connections on the internal DC power harness, or in rare cases electrical interference. All power failure errors cause the digital concentration value to go full-scale.
R	**Reference Error or Membrane Timeout**	This error indicates that the span reference membrane assembly may not be mechanically extending or withdrawing properly. The error is generated if photo sensors S2 and S3 never change state after 15 seconds despite drive commands to the membrane motor. The digital error log will indicate which photosensor timed out. It may be a simple sensor/flag alignment problem that can be identified and corrected using the TEST > TRANSPORT menu. However, if the span foil assembly is stalled in a partially extended position, it could block the beta signal and prevent valid data collection.
N	**Nozzle Error or Delta-T Alarm**	This error indicates that the nozzle motor is not operating correctly. The error is triggered if photo sensors S4 and S5 never change state within 12 seconds, despite drive commands to nozzle motor. The concentration value is set to full-scale if the nozzle motor or sensors have failed. The digital error log will indicate which photosensor timed out. **Important Note:** The nozzle sensors watch the motor cam rotation, not the actual action of the nozzle itself, so it is technically possible for the nozzle to become stuck in the UP position even if the motor and sensors indicate no error. This could result in a massive flow leak and useless data with no errors or alarms being generated! Proper maintenance of the nozzle o-ring and proper inlet alignment prevent this. Due to a limited number of discrete alarms, the "N" alarm is also used to indicate that the Delta-Temperature set-point was exceeded by more than 1 degree, if Delta-T control is enabled. In this case the alarm is used to simply as a flag, and valid concentrations are still stored. Delta-T control is disabled in almost all applications. Download the error log file to tell if the alarm is from a nozzle failure or simply a Delta-T event. Note: Delta T control is not used with the BX-970 touch screen option.
F	**Flow Error**	Critical flow errors result in the sample being terminated and/or the concentration data being set to full-scale. Minor flow alarms occur if a parameter was out of bounds, but the sample was not stopped and concentration data is still stored. The digital error log contains the exact sub-category which generated the alarm: • **Flow Failure** - Flow > 10% out of regulation for more than 1 minute. • **5% out-of-regulation** - Flow > 5% out of regulation for more than 5 minutes. • **AT Disconnected** - Missing or incorrectly connected AT sensor. • **AT Failure** – One minute average of the AT sensor was within 1 degree of the sensor min or max range. May occur in extreme cold or hot environments. • **Internal or External BP Failure** – One minute average of the barometric pressure sensor exceeded the min or max range of the BP sensor. • **Q Total** – Total hourly flow volume was zero. • **Average** – Hourly average flow was outside of the FRh and FRL parameters as set in the SETUP > ERRORS screen. • **Self-Test** – Self test flow rate less than 10 L/min. • **Pump Off Failure** - Flow sensor indicates >5 L/min with the pump turned off. Flow errors can occur due to a fault with the flow controller or flow sensor, or if the vacuum pump is wearing out or has a clogged muffler. See the troubleshooting section below.

P	**Pressure Drop Alarm** or **Delta-Pressure Alarm**	This error indicates that the pressure drop across the filter tape has exceeded the limit set by the "ΔP" value due to heavy particulate loading plugging the tape pores. Current firmware will stop the sample early when this occurs, and make the concentration calculation based on the partial volume, then wait for the next hour. This feature is designed to stop the sample early if the vacuum capacity of the pump is about to be exceeded, before flow errors occur. Firmware before Rev 3.6.3 would not stop the sample for the "P" alarm, and subsequent flow errors could occur due very high concentration dust loading. The pump cycle must run for at least 5 minutes before a pressure drop alarm event can occur. See Section 6.5.
D	**Deviant Membrane Density Alarm** or **BAM CAL alarm**	This error indicates that the reference membrane span check measurement (**m)** for that hour was out of agreement with the expected value (**ABS**) by more than ±5%. These alarms are usually caused by a dirty or damaged membrane foil, which must be inspected. If the foil is clean and undamaged, the alarm could indicate that the beta detector tube itself is noisy or beginning to wear out, or that the membrane holder is not extending and withdrawing fully. These alarms do not prevent the BAM from storing a valid concentration for the sample hour because the dust mass is a completely separate measurement, but the alarm must be investigated and resolved in order to ensure proper beta detector operation. Note: If the ABS value is less than 0.500 mg, then the alarm criteria is ±25μg, not ±5%, This feature is not used.
C	**Count Error** or **Data Error**	This error indicates that the beta particle counting system is not operating properly, and is activated if the beta count rate falls below 10,000 counts during any of the mass, membrane, or stability measurements. The 4-minute beta count rate through clean filter tape is usually more than 800,000 counts. This rare error occurs if the beta detector, high voltage, or digital counter has failed, or if the beta signal is physically obstructed. This alarm sets the concentration value to full-scale.

The sub-category "count, failed" occurs if the beta counter is still counting 10 seconds after the scheduled end of any count period, indicating a digital fault. |
| **T** | **Tape System Error** or **Filter Tape Error** | The tape error usually indicates that the filter tape is has run out or broken. It occurs if the right spring-loaded tensioner (tape roller nearest to the detector) is at the far left limit of its travel. In this case, tape break photosensor S6 is ON continuously, despite drive commands to the tape reel motors and the capstan motor. The tape error is also generated if the pinch rollers are latched in the up position when a new sample hour starts, preventing the cycle.

Note: *Firmware revision 3.6 and later will cause the concentration value to go to full-scale due to a tape error, because the cycle cannot be performed with broken tape. All previous firmware revisions did not set the concentration to full-scale, but instead repeated the last valid concentration value until the tape was replaced. This older method was confusing, and was changed due to user requests.*

In rarer cases, a tape error may also be generated due to a failure in the tape control electromechanical system. In current firmware there are several possible sub-categories for this error which will appear in the digital error log:

- Tape, Latch – Pinch rollers latched up at cycle start.
- Tape, Shuttle – Shuttle photosensor not responding to shuttle move.
- Tape, Forward/Backward – Tape supply motor or take-up motor not responding.
- Tape, Tension/Un-tension – Tensioner photosensor not responding.
- Tape, Capstan – Capstan motor or capstan photosensors not responding.
- Tape, Self-Test – Shuttle beam did not respond during self-test.
- Tape, Break – Broken or empty tape.

Tape errors caused by failures other than broken tape or latched pinch rollers can usually be identified using the TEST > TRANSPORT menu to manually operate the motors and photosensors. See Section 7.16. Tape errors can be caused by grit in the shuttle ball slide. Contact tech service if the left/right shuttle action is not smooth. |

7.3   Correlating BAM-1020 Data to FRM Sampler Data

The BAM-1020 instrument is designed and calibrated specifically to provide average concentration data that matches 24-hour gravimetric analysis filter samplers, including EPA Federal Reference Method (FRM) type samplers. It is very common for BAM-1020 units to be at least temporarily collocated with filter samplers for instrument validation or acceptance testing purposes.

The primary correlation analysis method is a linear regression between 24-hour averages of the BAM-1020 data and daily gravimetric filter weight data points for the same days as shown below. The combined slope and offset values of the BAM-1020 regression should usually be within bounds as shown in the polygon.
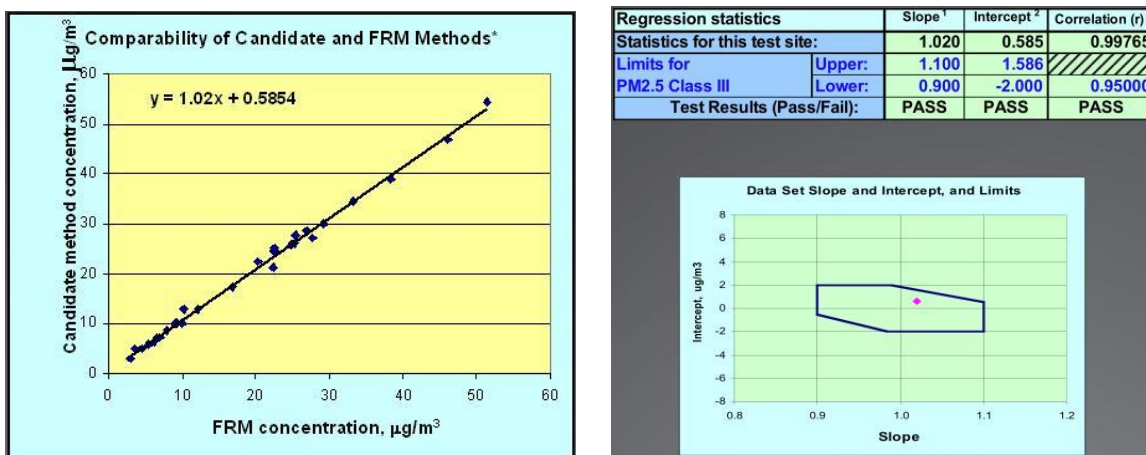
BAM-1020 linear regression and dot-within-matrix polygon plots (from EPA template)

There are several considerations which must be taken into account in order to obtain good correlation results when BAM-1020 units are compared to filter samplers:

- **Background Offset Correction:** If the BAM-1020 correlation shows an offset (additive bias) compared to the FRM, then the background offset correction (BKGD) value may need to be audited by running the unit with the zero filter. See Sections 7.7 and 6.3. This is a required test during deployment of a $PM_{2.5}$ FEM BAM-1020. The background value is a true data offset, so if it's not correct then correlation offsets can also be out of bounds.

- **Critical Maintenance:** The BAM-1020 leak check, nozzle cleaning, and flow checks must all be within bounds during comparison tests. These can result in inconsistent positive or negative data biases if neglected.

- **Flow Calibrations:** The BAM-1020 and the filter samplers should be calibrated using the same AT, BP and flow standards whenever possible.

- **RH Control:** High humidity on the BAM-1020 filter dust spots can cause the BAM mass values to measure too high, resulting in high slopes (multiplicative bias). Make sure that the filter RH sensor is not improperly calibrated (section 7.9) and verify the smart inlet heater setup values. The Channel 4 filter RH data from the BAM should show proper regulation below 35% or 45% RH.

- **Strict Collocation:** The BAM-1020 and filter sampler inlets must be strictly collocated during comparison tests! The inlets must be at the same height and within 1 and 4 meters spacing. See Section 2.3.

- **Analog Voltage and Scaling Errors:** The BAM-1020 digital data should be used for comparison tests whenever possible. If analog output voltage must be used, then the operator must verify that the BAM voltage output is accurate, and that the datalogger is scaled to record the voltage correctly. If the logger is scaled incorrectly, then a significant data offset between the BAM and the sampler will result. See Sections 6.1, 7.13, and 8.1.

- **Filter Handling:** The samples from the filter sampler unit must be handled, collected, and analyzed correctly in order to get good correlations to the BAM-1020. Single-event samplers tend to match the BAM better than sequential samplers where the samples are left in the field longer. Careful and correct filter handling will often prevent slope biases caused by volatile compounds on the filter samples.

- **Daily Data Sets:** In most cases, the 24 hourly BAM data points used for the daily BAM averages should be the same 24 hours that the actual filter sample was run.

- **Limited Data Set Effects in Low Concentration PM$_{2.5}$:** In some areas where the daily concentration averages are always within a very tight range (such as always between 5 and 10 micrograms of PM$_{2.5}$) it can be difficult to trend an accurate slope in the linear regression if there are not enough data points. This is almost like trying to make a slope through a single point. This can appear as a slope bias in the BAM correlations when there may really be no problem. The solution is to continue to add data points to the data set until even just a couple of slightly higher data points are obtained.

7.4 Power Up Problems and Electrical Safety Considerations

The BAM-1020 must be at a state where it can be powered on before any other testing or diagnosis can be performed:

- Make sure that the unit is plugged into the correct AC voltage. The unit is internally wired for either 110/120V or 220/240V. The digital, analog, and user interface systems are powered from a universal-input power supply, so these should work even if the line voltage is not correct. The filter tape, nozzle, and span check control motors all run on AC voltage and will not operate correctly if the line voltage is incorrect.

- Check the two fuses (3.15A, 250V) inside the power switch housing. The power cord MUST be removed before the fuse door can be opened, or you will break it. Pry open the top edge of the power switch housing cover to access the fuses. See Section 2.6.

- It is possible for the display contrast to be set so lightly that it looks like the display is OFF when it is really ON. Try pressing and holding the contrast key on the front door for a few seconds while the unit scrolls through the contrast settings. In rare cases the display may fail completely. If the unit "beeps" when you press the keys, it is ON.

- If the above checks do not resolve the power-up problem, then there could be a failed power supply or other significant problem inside the unit. Contact Met One for further

instructions. Do not attempt to open or repair the power supply assembly unless qualified.

⚠️ *Warning! The BAM-1020 uses hazardous live voltages which can cause electrocution if electrical safety precautions are not strictly followed during service or repair of the machine. The BAM-1020 is designed to provide protection from hazardous voltages during normal operation. If the equipment is modified or used in a manner not specified by the manufacturer, protection provided by the equipment may be impaired.*

Hazardous voltages are present in the following areas:

- **Power Supply AC:** The main power supply is located inside the BAM-1020, inside the power supply sub-enclosure labeled "DANGER HIGH VOLTAGE". The power supply enclosure contains the main AC-to-DC converter and the motor driver board for the transport motors, all of which contain live AC line voltage when the unit is powered up. Do not open the power supply sub-enclosure lid without unplugging the BAM-1020 power cord.

- **Detector Negative High Voltage DC:** The 3150 circuit board is inside the BAM-1020, mounted vertically on the outside of the power supply sub-enclosure, and covered with a clear plastic safety shield. This circuit board generates a dangerous negative DC bias voltage for the beta detector of between -800 and-1200 volts. Do not remove the clear cover or touch the board without unplugging the BAM-1020. Do not touch the large green capacitor or the detector preamp board with the BAM-1020 turned on.

- **Pump AC:** The vacuum pump is powered by AC line voltage, and has its own power cord. Do not open the electrical junction box on the side of the pump, or touch the enclosed solid-state relay without first unplugging the pump power cord.

- **Inlet Heater AC:** The inlet heater is powered by AC line voltage. The heater either plugs into an external gray plastic relay enclosure on the back of the BAM (with its own power cord), or it plugs directly into the back of the BAM and takes power from the main power supply, with the relay located under a clear plastic cover on the inside floor of the BAM enclosure. See Section 2.5. Do not open the relay cover or touch the relay while the BAM and/or the relay box is plugged in. Do not remove the cylindrical metal shell from the smart heater module, or touch any of the internal parts while the heater is plugged in. The heater module does not contain any serviceable parts inside the metal shell.

7.5 Basic Problem and Cause/Solution Table

The following table contains information on some of the more common BAM-1020 problems which may be encountered, and some steps to identify and remedy the problems. Met One welcomes customer suggestions for new items to include in this section of future manual revisions. If the solution cannot be found in the following table, then contact one of our expert service technicians for help in resolving your problem.

Problem:	The BAM won't start a measurement cycle.
Cause/Solution:	• The unit is programmed not to start a sample cycle until the beginning of an hour. Make sure the clock is set correctly. • The unit will wait until the beginning of a new hour before it starts, even if the operation mode is set to ON. • Don't expect the pump to turn on until the clean tape count is finished, about 8 minutes after the start of the hour. • The unit cannot start if the pinch rollers are latched UP! The unit cannot lower them. • Make sure the filter tape is installed correctly. • The unit will never start a cycle if the display is left in a TEST or SETUP menu! The main screen or OPERATE menu must be displayed. • The unit will usually display an error if it cannot start a new sample cycle.

Problem:	The analog output voltage and/or digital concentration reading are full-scale.
Cause/Solution:	• The unit will force the analog and digital concentration values to full-scale (usually 0.985mg) to indicate that an error has prevented the collection of a valid hourly data point, or that the hourly cycle was interrupted. Download the digital error log to identify the cause. The current hourly record after power-up will also be full-scale.

Problem:	The BAM hourly concentration is reading negative values.
Cause/Solution:	• It is possible for the unit to occasionally read negative numbers if the actual ambient particulate concentration is below the detection limit of the BAM-1020, such as below 3 micrograms. This is because the BAM has a noise band of several micrograms. This should not happen often. • If the unit is reading negative numbers hour after hour, it may be punching holes in the filter tape. These holes can be very small. This is almost always caused by debris on the nozzle or vane. Clean the parts. • The BKGD zero correction offset value may have been incorrectly entered, or may need to be audited. Met One supplies the BX-302 zero filter kit for auditing the zero average and noise floor of the unit. Set the BKGD value to 0.000 during the test. • Look for sources of electrical noise, such as bad grounding. Any source of noise will show up in the zero filter test. • Verify that the inlet tube is grounded to the chassis of the BAM-1020.

Problem:	The airflow rate is too low and won't adjust up to 16.7 L/min.
Cause/Solution:	• The gray plastic pump mufflers on the Medo pumps may clog up after several months. Replace it or drill a hole in the end of it for a temporary fix. The brass mufflers on Gast pumps can often be cleaned. • Some users replace the pump muffler with a 30 inch length of air tubing. This will not clog and reduces the pump noise as well as the mufflers do. • The vacuum pump may need to be rebuilt after about 2 years. Medo pumps slowly loose flow capacity as the pump wears out. Eventually, the flow capacity drops below 16.7 lpm when it needs to be rebuilt. • Checking the 18.4 L/min point during the regular 3-point flow audits verifies the pump capacity. • Check the inlet and PM heads for obstructions.

Problem:	The airflow is stuck at a particular rate, and will not change.
Cause/Solution:	• The flow controller unit on some older units can become stuck. If your flow controller does not have a small circuit board mounted directly on the motor, it needs to be upgraded. Contact the Service dept. • Perform the 3-point flow audit in the TEST > FLOW screen. The BAM should try to regulate to these flow values. If the flow does not change, the flow controller may not be working. • Unplug the pump power while performing a 3-point flow check. With the pump off, you should be able to clearly hear the flow controller pulse at 1-second intervals as it rotates and attempts to regulate the flow. If not, the flow controller is not working or the circuit board output is not working. • If the flow regulates lower, but not higher than 16.7 lpm, the pump is probably worn out, or there is a leak.

Problem:	The nozzle gets stuck in the UP position, or won't press down onto the tape fully.
Cause/Solution:	• With the nozzle in the down position, lift the nozzle up and down with your thumb and determine if it feels sticky or gritty. • The nozzle o-ring eventually breaks down and needs to be replaced. See Section 7.6 for instructions. • The brass nozzle bushings may have grit in them. See Section 7.6. Remove the nozzle and clean the parts. A shim kit is required for nozzle reassembly. • A stuck nozzle is sometimes caused by a misaligned inlet tube. Make sure it is straight up and perpendicular to the top of the unit.

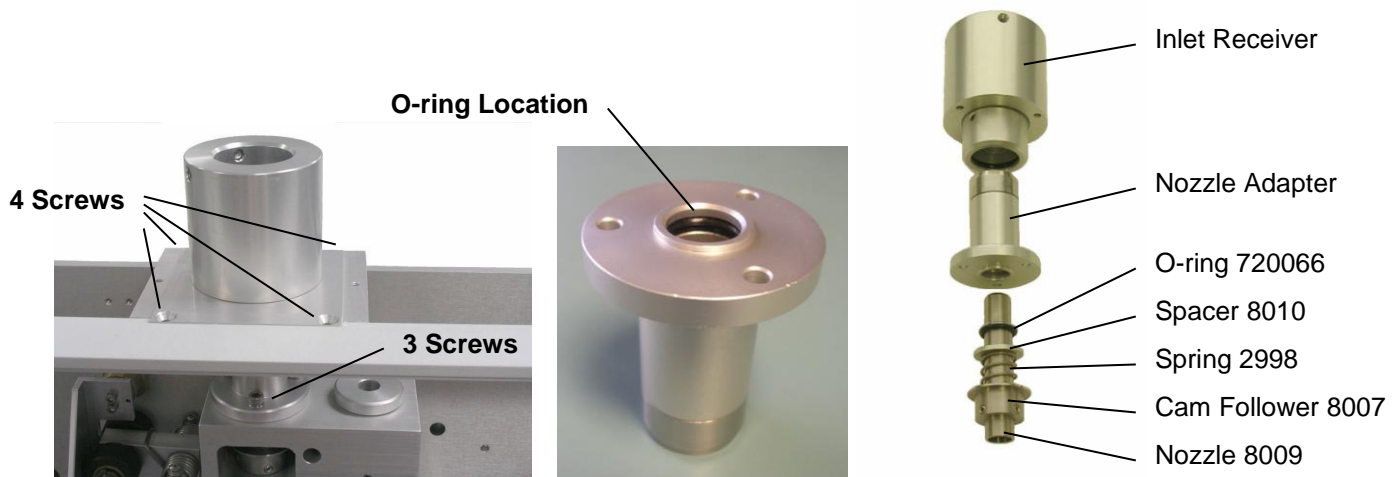| Problem:	The unit has flow leaks, even after cleaning the nozzle and vane.
Cause/Solution:	• The nozzle may be sticking as described above. Verify that the nozzle up/down motion is smooth and complete. If the nozzle feels sticky or gritty, it will not seal properly. • Check the o-rings on the sharp-cut cyclone (if used). These frequently leak. • Check the zero of the flow sensor in the BAM: Perform another leak check, but disconnect the tubing between the pump and the BAM, so there can be no air flow through the unit. Verify that the flow reading on the BAM reads less than 0.2 L/min. If not, the flow sensor Q_0 zero offset setting may need to be adjusted in the SETUP > CALIBRATION menu. The Q_0 setting is usually very close to zero. • Check for bad o-rings on the BAM inlet tube receiver. • Remove the BAM case cover and inspect all air fittings inside the BAM. These are compression fittings, and must be fully inserted to prevent leaks. • Inspect the internal and external flow system for split or cracked air tubing.

Problem:	The unit logs frequent "L" Power Failure errors.
Cause/Solution:	• The 5 volt DC power supply output must be set to 5.25 volts. Contact the Service dept for instructions to check or adjust this. • The CHASSIS terminal needs to be connected to a good earth ground. • Try plugging the BAM into a computer-style UPS. • Even a split second power failure will cause an "L" error. This will interrupt the sample cycle until the top of the next hour. • Local high power RF fields must be avoided if possible. • Some vintages of the DC power supply used in the BAM can be prone to oxidization on the harness pins which can cause the unit to reset frequently. Upgrade parts may be available for certain units. Current power supplies have the output harness wires soldered to the supply. Contact the Service department. • Rarely, some older 220 volt units can experience resets caused by the Smart Heater control wiring inside the BAM. Contact the Service department.

Problem:	The BAM data shows repeated concentration values hour after hour.
Cause/Solution:	• Certain error flags, such as the "T" (tape broken) flag will cause the BAM to repeat the last known good concentration value until the error is resolved. Check the error log to identify any errors for those hours. This only occurs on firmware before R3.6. • If the RANGE setting on the BAM is set higher than 2.000mg, them the resolution of the A/D system is reduced to 2 micrograms. If the ambient air concentrations do not vary much over several hours, then the BAM data may show repeated values due to lost resolution. Leave the RANGE set to 1.000mg unless very high concentrations are expected.

Problem:	Frequent "D" membrane density errors.
Cause/Solution:	• This usually indicates the membrane foil surface is dirty or damaged. It can be cleaned with water rinse. Damaged membranes must be replaced. • The membrane assembly may not be fully extending or retracting properly, which causes the metal part of the assembly to partially or completely block the beta particles. Check the membrane motion. • Verify that the ABS expected membrane mass matches the calibration certificate.

Problem:	The clock settings are lost when the unit is powered down.
Cause/Solution:	• It is normal for the clock to drift as much as 1 minute per month. • The BR2032 lithium battery on the 3230 circuit board may need to be replaced after about 10 years on units built before 2008. • Units built after 2008 may need the lithium battery replaced every 1-2 years.

Problem:	The filter tape keeps breaking during normal operation.
Cause/Solution:	• The photo sensors which watch the tape transport motion may be out of alignment. Check the photo sensors as described by section 7.16. • This is sometimes caused by misalignment of the "SHUTTLE" photo sensor or the interrupter flag on the end of shuttle beam inside the BAM.

Problem:	The display shows "MISSING TEMP PROBE" message.
Cause/Solution:	• The unit requires a BX-596 or BX-592 ambient temperature sensor if either the CONC TYPE or FLOW TYPE are set to ACTUAL. If no sensor is attached to channel 6 of the BAM, this message will appear. • If the Auto ID line from the temperature sensor is not working, the BAM will not ID the sensor, causing the alarm. • BAM-1020 units with firmware part 3236-2 (PM10 only) cannot identify the BX-596.

## 7.6   *Nozzle Component Service and O-ring Replacement*

The BAM-1020 sample nozzle system needs periodic inspection and service in order to prevent flow leaks. The primary indicator is if the nozzle up/down motion feels sticky or gritty when performing the normal monthly nozzle cleaning, or if the nozzle fails to fully seal against the tape when lowered, causing leakage. The nozzle o-ring may need to be replaced approximately every two years during continuous operation. This is a simple matter and no special tools are required. Instructions for o-ring replacement are below.

The sample nozzle may also be easily removed from the unit for further cleaning or rebuild. This requires a set of brass adjustment shims to set the spring tension during reassembly. The standard BX-308 BAM tool kit contains all of the required tools and instructions. The BX-310 kit includes the two shims only.

O-ring Location

4 Screws

3 Screws

Inlet Receiver

Nozzle Adapter

O-ring 720066

Spacer 8010

Spring 2998

Cam Follower 8007

Nozzle 8009

1. Remove the filter tape and the main BAM-1020 case cover. The sample nozzle <u>must be in the down position</u>. Lower it using the TEST > LEAK CHECK menu if needed. Lift the nozzle up and down against its spring with your thumb and note the action feel.

2. Remove the four screws (two flat head Philips, two 9/64" hex) that fasten the square inlet receiver bracket to the BAM chassis. Lift the assembly off of the BAM. It is not necessary to remove the bracket from the inlet receiver cylinder.

3. Remove the three 9/64" hex screws that fasten the nozzle adapter to the top of the beta block. A T-handle hex wrench is easiest. The nozzle adapter can now be lifted off of the top of the nozzle, revealing the o-ring location. Clean the top of the nozzle.

4. Remove the o-ring from the groove. Thoroughly clean the o-ring groove and the inside if the nozzle adapter using alcohol and cotton-tipped applicators, then install the new o-ring and lubricate it with silicone grease.

5. Check the nozzle up/down action again before reassembly. If the nozzle action feels smooth, then reinstall the nozzle adapter and inlet receiver assemblies. Check the nozzle action after each step of reassembly to identify any binding or sticking. Perform a normal leak check when finished.

6. **Optional further disassembly (shim set required):** If the nozzle action feels feel sticky or gritty with the nozzle adapter removed, then the nozzle needs to be removed and the nozzle and bushings cleaned. Loosen the two (or three) set screws in the cam follower with a 5/64" hex wrench. The nozzle can now be lifted out of the bushings. The cam follower, spring, and spacer can be removed from the front of the block.

7. Clean the nozzle inside and out, and inspect the nozzle face for any burrs or defects. Clean the two brass bushing bores with a cotton-tipped applicator. This is also a good time to clean and inspect the tape support vane since the nozzle is out of the way. The bushings do not need to be lubricated. Reinstall the cam follower, spring, and spacer, and align them with the bushing bores.

8. Lower the nozzle down through the bore. The two brass shims must be positioned as shown before the set screws are tightened to retain the nozzle. The square shim must be under the nozzle face. The slotted shim goes under the cam follower. Tighten the set screws evenly, only a little at a time to avoid distorting or binding the nozzle.

9. Remove the shims and check the up/down action of the nozzle before reassembling the nozzle adapter and inlet receiver. It must feel smooth and even after each step of reassembly. If the nozzle still binds or sticks, then contact technical service.
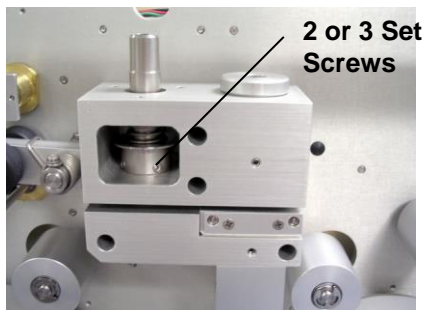
Nozzle Removal
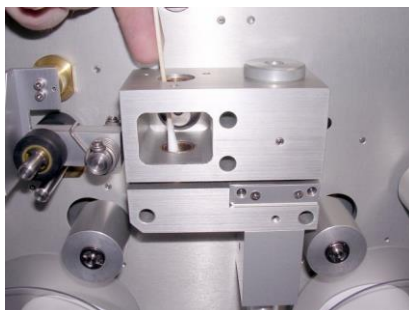
Cleaning the Bushings

Using Shims for Reassembly

7.7 Performing the 72-Hour Zero Filter Background Test

All BAM-1020 units configured as EPA FEM or EU 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.

The primary purpose of the test is to fine-tune the Background Offset (BKGD) value in the BAM-1020 to compensate for minor variations in local site conditions, such as grounding, radon, or RFI characteristics. This results in optimum accuracy at lower concentrations typical of PM$_{2.5}$ levels, and appropriate offsets when compared to FRM filter samplers. A secondary purpose of the test is to provide information about the hourly noise level and detection limit of the BAM-1020 being tested. *Any source of noise that will affect your concentration values, such as leaks, bad grounding, RFI/EMI, a failing beta detector, or improper shelter temperature control, will also be visible on the zero filter test results*.

The Background (BKGD) value is an offset correction factor for all concentration data collected by the BAM-1020 (see section 6.1). This value is factory calibrated for each unit under laboratory conditions using the same type of zero filter. The factory BKGD value is found on the calibration certificate, and may be left as-is for PM$_{10}$ monitoring.

Note: For best results, the zero test should not be performed during a period of rapidly changing barometric pressure. The shelter room temperature must be within the specified range, and as stable as possible. See Section 2.2. This will prevent any rapid changes in air density between the beta source and detector from being measured as additional mass noise or background shift.

The BAM-1020 must be fully installed in the shelter at its permanent sampling site, and it must be fully configured with all of 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. If this is not possible, then the first day of zero data may simply be ignored during data analysis. A leak check and flow check should be performed before proceeding on to the following steps for the zero background test:

1. The BKGD value is located in the SETTINGS > CALIBRATION menu. **Record the existing BKGD value, then change it to 0.0000**. Save and exit back to the main menu.

2. Remove the PM_{10} inlet and $PM_{2.5}$ cyclone. Install the BX-302 zero filter assembly onto the top of the inlet tube as shown below. If there is any chance of precipitation, install the included plastic fitting and short length of tubing to keep rain out of the filter inlet. **Note:** It is completely acceptable to install the zero filter inside the BAM shelter (just above the smart heater) using a short inlet tube. This helps prevent condensation inside the zero filter which can adversely affect the zero test in humid conditions.

3. Allow the BAM-1020 to sample for at least 72 hours, not counting the warm-up period. The unit should operate just like it would for regular $PM_{2.5}$ or PM_{10} monitoring, only with the zero filter installed instead of the PM_{10} inlet and cyclone.

4. After at least 72 hours of operation, download the test data from the unit and import it into a spreadsheet for analysis. The error log should not contain any error flags during the test period. Data collected during the warm-up period may be discarded because the first few hourly data points after power-up are typically noisy. The remaining data will be used for analysis. *Note: Met One has a free Microsoft Excel® template available for the zero test analysis. All calculations and graphs are done automatically*.

5. Calculate the average of the 72 hourly BAM concentrations to four decimal places. **The new BKGD value is simply the negative of this average**. Enter the new BKGD value into the SETTINGS > CALIBRATION menu on the BAM. For example, the average of the data below is 0.0021 mg (2.1 μg), so the BKGD value is -0.0021.

6. Compare the new BKGD value to the previous factory-set BKGD value. The field-set BKGD should typically vary from the factory value by less than 2 μg. Record the test results and any BKGD changes, and keep it with the audit records for the BAM-1020.

7. Remove the BX-302 zero filter and reinstall the PM_{10} and $PM_{2.5}$ inlets. The unit can now be operated normally. The new BKGD value will be automatically applied to all hourly concentration data points in the unit.

Optional zero noise analysis: Graph the hourly concentration data so that the zero noise characteristics of the BAM-1020 from the test are visible. Calculate the standard deviation (σ) of the hourly zero test data (STDEV function in Excel) to four decimal places. The value should be less than 2.4 μg, and can be as low as 1.1 μg on some units. Lower standard deviations mean less noise. This natural noise band is caused by small statistical variations in the beta source output. The hourly detection limit is defined as two-times the hourly standard deviation (2σ). The daily detection limit is defined as 2σ/4.9 and will be less than one microgram. The example below shows a typical low-noise data set from a $PM_{2.5}$ FEM unit. If the standard deviation is more than 2.4 μg, then external noise sources should be investigated. **Note:** Older non-FEM compatible units may not meet these noise specifications.
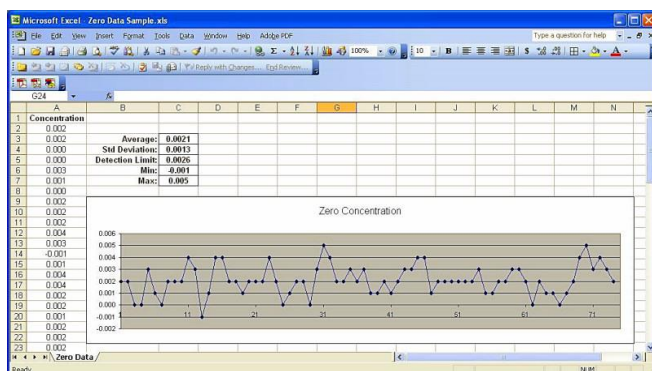

Typical zero background test results   **BX-302 Zero Filter Kit**

7.8   The TEST Menu System – Overview

The following sub-sections provide information for performing diagnostic checks on the BAM-1020 sub-systems using the TEST menus. Most of these tests are used for troubleshooting purposes only, and are not necessary on properly functioning units. The TEST menu system is accessed by the TEST button from the main menu. These screens are used to perform calibrations and audits of various sensors, as well as some advanced diagnostics to resolve failures and errors. The SELF TEST screen function is described in Section 3.5. The FLOW CHECKS and LEAK CHECK procedures are described in Section 5.
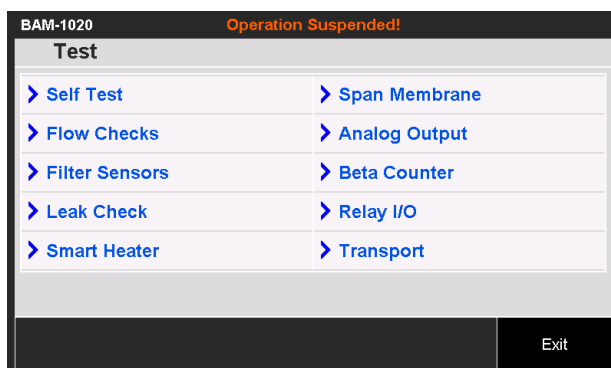
The TEST Menu

7.9   FILTER SENSORS Test Menu – Filter RH and Temp Sensors

The TEST > FILTER SENSORS screen is used to check or calibrate the filter temperature and RH sensors located in the air stream beneath the filter tape. The RH sensor measures the humidity of the sample air to control the Smart Heater system, which turns up or down as needed to maintain the sample near or below the RH setpoint value. The filter RH sensor should match ambient RH within +/- 4% **when properly equilibrated** (see notes below). If the sensor fails, it usually reads something impossible like -25% or 135% RH. The filter temperature sensor is used for data logging purposes only, and should match ambient within +/- 1 deg C when properly equilibrated.
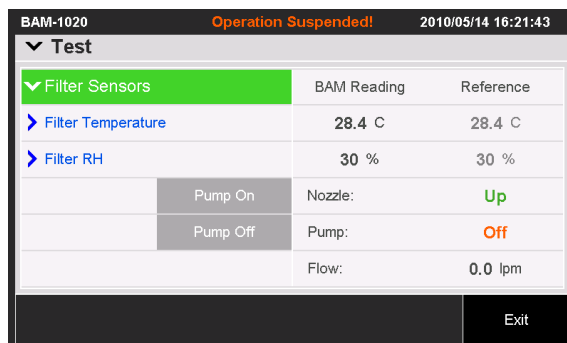
The FILTER SENSORS Test Screen

To calibrate it the sensors, pressing the blue parameter name to select the parameter. The Reference field will become active and CALIBRATE and DEFAULT buttons will appear at the bottom of the screen. Press the Reference value, and the pop-up numeric keypad will appear where you can enter the correct measurement value from your reference device into the field, then press the CALIBRATE button to cause the BAM Reading for the parameter to change to

match your reference. The DEFAULT button can be used to remove all previous field calibrations from the selected sensor and restore the default factory calibration. Do not press the CALIBRATE button after DEFAULT, or whatever value happens to be in the Reference field will be calibrated.

⚠️ **Important Filter Sensor Equilibration Notes:** It is difficult to effectively correlate an ambient RH measurement to the filter RH reading, because the BAM has some self-heating from the Smart Heater which causes the filter RH sensor to measure significantly lower than ambient RH, and the filter temperature sensor measures higher than ambient. For this reason it is usually best to leave the factory default filter sensor calibrations alone, unless you have clear evidence that it needs to be calibrated. *If the filter RH sensor is calibrated without first being fully equilibrated to ambient, it will introduce a large artificial offset.*

For example: The ambient RH is 50%, but the filter RH sensor reads 20% due to inlet heat. If the filter sensor calibration is adjusted to that it matches 50%, this adds a +30% offset to all RH readings. Now the filter RH data values are all 30% too high and it looks like the inlet heater is not functioning and not regulating the sample RH when it actually is. In addition, the inlet heater may run at full power trying to achieve regulation to the setpoint.

To equilibrate the sensors without removing them from the sample stream: Enter the TEST > FILTER SENSORS screen. The BAM will raise the nozzle. Turn the pump on to pull room air past the RH sensor. Unplug the inlet heater and allow the BAM to cool completely to room conditions. This might take an hour or more. Position your RH audit device as close as possible to the BAM sample nozzle during calibration.

To remove the sensors from the flow system for calibration: Unplug the inlet heater and remove the BAM case cover. Remove the black 3-port compression manifold from the flow path. It is located under the nozzle motor and holds the two filter sensors. This is easiest with tool 9627 from the BX-308 tool kit. Leave the sensors plugged into the circuit board. Do not touch the RH sensor element because it is ESD sensitive. Move the sensor manifold away from the BAM so that accurate ambient RH and temperature values can be obtained. Allow the sensors to equilibrate for at least five minutes before calibrating them.

7.10 LEAK CHECK Test Menu – Manual Pump and Nozzle Tests

The TEST > LEAK CHECK screen is used to perform leak checks as described in Section 5. It can also be used to manually force the pump on and off, or to manually move the nozzle. **Note:** *The BAM will regulate the flow to the 16.7 L/min setpoint, but the flow rate shown on this screen is uncorrected and always in standard conditions, even if the BAM operates in actual flow mode.* For this reason, no flow audits should be performed using this screen!
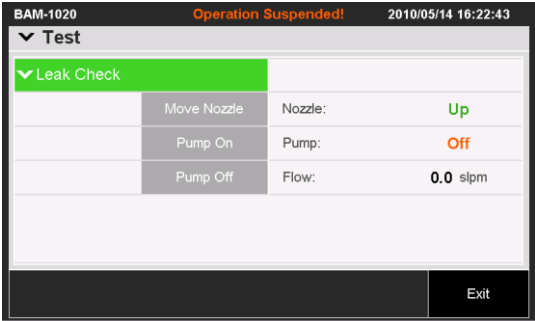
The LEAK CHECK Test Screen

The NOZZLE status value will indicate if the nozzle is currently UP or DOWN. The PUMP status indicates if the pump is turned ON or OFF. The FLOW value is the current flow rate, displayed in standard liters per minute (25C) only.

The MOVE NOZZLE soft key can be used to force the nozzle up or down for testing purposes. Elapsed time is about 5 seconds. If the pump is ON this operation is disabled.

The PUMP ON and PUMP OFF soft keys can be used to turn the vacuum pump on or off. The nozzle will be lowered automatically if PUMP ON is pressed.

7.11 SMART HEATER Test Menu

The TEST > SMART HEATER screen is used to force the Smart Inlet Heater on or off for testing purposes. The Heater Level field can be set to OFF, ON, or IDLE. The ON mode will turn the heater up to full power of 200 watts. The Idle mode will set the heater to low power mode at the default of 40 watts (20%) or whatever the idle mode wattage is set to. The heater takes several minutes to heat up or cool down noticeably.

The pump can be turned ON or OFF in the screen, and the filter RH and temperature sensors can be monitored to test the effects of the heater. The heater automatically turns back off upon exit from the screen.
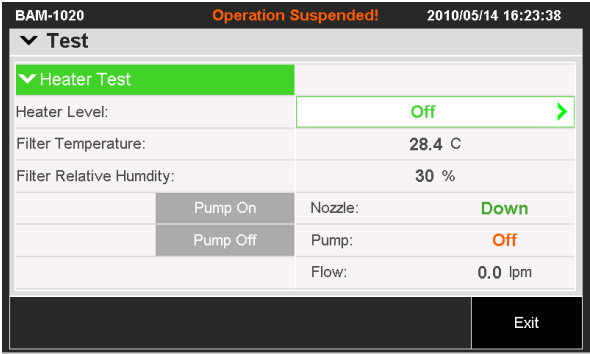
The SMART HEATER TEST Screen

7.12 SPAN MEMBRANE Test Menu – Span Mass Tests

The TEST > SPAN MEMBRANE screen is used to perform tests of the reference membrane span check which occurs automatically every sample cycle. This test can be run if the BAM-1020 has been logging **D** errors. Each BAM-1020 has an individually weighed membrane, and this mass is measured and displayed during this test. Compare the value from this test with the ABS value on the calibration sheet for your unit. The values must match within 5%, and will typically match within just a few micrograms. If not, the most common cause is a dirty membrane foil, which can be carefully cleaned with canned air or clean water rinse. Alcohol is not used because it leaves a film. CD cleaner works well for badly soiled membranes.

Caution: The span membrane foil is a thin sheet of polyester and is fragile. It must be replaced if damaged. Contact the Service department for replacement instructions.

The SPAN MEMBRANE Test Screen

The Membrane Status value indicates if the reference membrane is currently extended or withdrawn from the beta particle path.

The Zero Count (I_1) value is the total 4-minute beta count through the filter tape only.

The Span Count (I_2) value is the total 4-minute beta count through both the filter and the membrane, and is always less the I_0 count.

The Measured Mass value is the measured mass of the foil in milligrams per square centimeter, derived from the two count values.

The START button starts the test cycle. Counting will immediately begin. After 4-minutes the I_1 count will stop, the membrane will extend, and the I_2 count will begin. At the completion of the test, the counting will stop and the mass of the membrane will be calculated. The total elapsed time is about 8.1 minutes per test.

7.13 ANALOG OUTPUT Test Menu – Voltage Output Test

The TEST > ANALOG OUTPUT screen is used to test the function of the analog output voltage and the DAC (digital/analog converter) electronics. Use the SET VOLTAGE OUTPUT value to force the voltage to any value between 0.000 and 1.000 volts (0.100V increments). The corresponding voltage on the VOLT OUT +/- terminals on the back of the BAM-1020 should always match within ±0.001 volts. Use a high-quality voltmeter for these tests. If the actual voltage does not match the value on the screen, contact the service department.

The ANALOG OUTPUT Test Screen

At the bottom of the screen is a display showing the minimum and maximum concentrations based on the current Range and Range Offset values in the BAM (Section 6.1). These represent the zero and one volt concentration outputs. The SET CONCENTRATION OUTPUT field allows the user to force the output voltage to represent a certain concentration.

The BAM will output the correct voltage for that concentration, and the external logger should scale the voltage back to the same concentration shown in the screen. This allows an easy method to ensure that your logger scaling is set correctly.

Note: This function is critical for all users of external analog data loggers. Measure the voltage all of the way to the input of your data logger. Every millivolt of error is a microgram of error!

7.14 BETA COUNTER Test Menu – Beta Detector Tests

The TEST > BETA COUNTER 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 total will stay on the display after the counting is finished, and up to ten 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 START button is pressed to start a new four-minute static count test. The count value on the screen will immediately begin to count rapidly if the detector is operational and unobstructed. Typical four-minute count totals through clean filter tape are between 600,000 and 1,100,000 counts. The count total will be lower if the membrane is extended. After four minutes the counting will stop and wait for the operator to initiate another count or EXIT.

Dark Count Tests: A steel shim such as Met One 7438 can be placed between the beta source and detector to perform a dark count test. The shim blocks all beta particles, and only counts created by noise or cosmic rays will appear. The total four-minute dark count value should be less than 10 counts. If the total is more than 50 counts, contact technical service.

7.15 RELAY OUTPUT Test Menu – Relay I/O Channel Tests

The TEST > RELAY OUTPUT screen is used to test the relay inputs and outputs on the back of the BAM-1020. The two inputs TELEMETRY FAULT and EXTERNAL RESET are tested by applying the appropriate signal to the terminals on the BAM, then verifying that the value on this screen changes to OPEN or CLOSED in response.

The relay outputs TAPE FAULT, FLOW FAULT, INVALID DATA, MAINTENANCE, RELAY 1, and RELAY 2 are tested by turning them ON or OFF using the touch screen, then verifying that the contact closure outputs on the back panel terminals respond accordingly with an Ohm-meter.
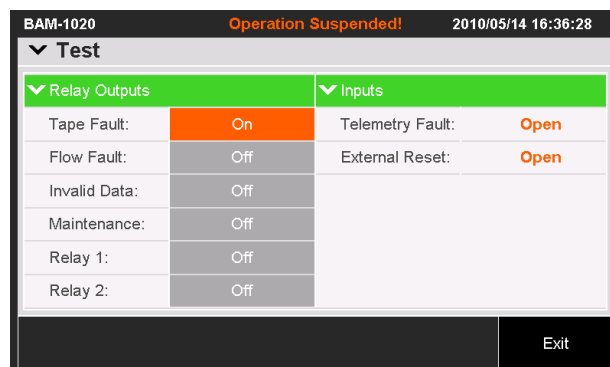
The RELAY OUTPUT Test Screen

7.16 TRANSPORT Test Menu – Motor and Photosensor Tests

The TEST > TRANSPORT menu system is used primarily to test the nine photosensors which monitor all of the mechanical movement in the BAM-1020 tape transport assembly. This is useful if the unit has failed some of the Self-Test parameters. The function of the TRANSPORT sub-menus are described in this section. **Note:** The filter tape should be removed during these tests, because many of these functions will break the tape.
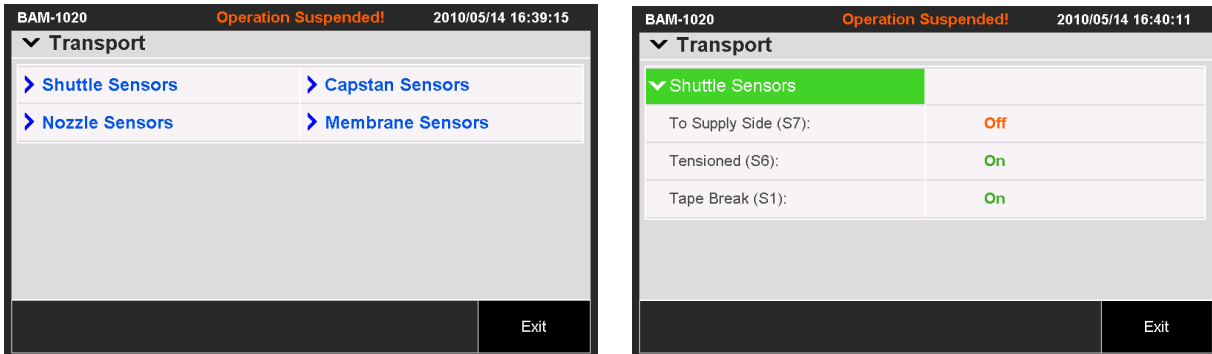
The TRANSPORT TEST Menu

Shuttle Sensors: This screen tests the photosensor which monitors the position of the shuttle beam (the two outer tape rollers that move together). The status of photo sensor S7 should <u>only change to ON when the beam is moved all the way to the right side</u>. The shuttle must be moved by hand for this test. It rides on a ball slide and is not motor-driven.

This screen also tests the photosensors which monitors the position of the right-side spring-loaded tape tensioner. The tensioner must be moved by hand. When the tensioner is in the leftmost position under its spring pressure, both photo sensors S6 and S1 should be OFF. If the tensioner is moved to the middle of its travel, photo sensor S1 should be ON and S6 OFF. When the tensioner is at the rightmost position, S1 and S6 should both be ON. These are the sensors which monitor tape breakage and tape tensioning. The left side tensioner assembly has no photosensors.
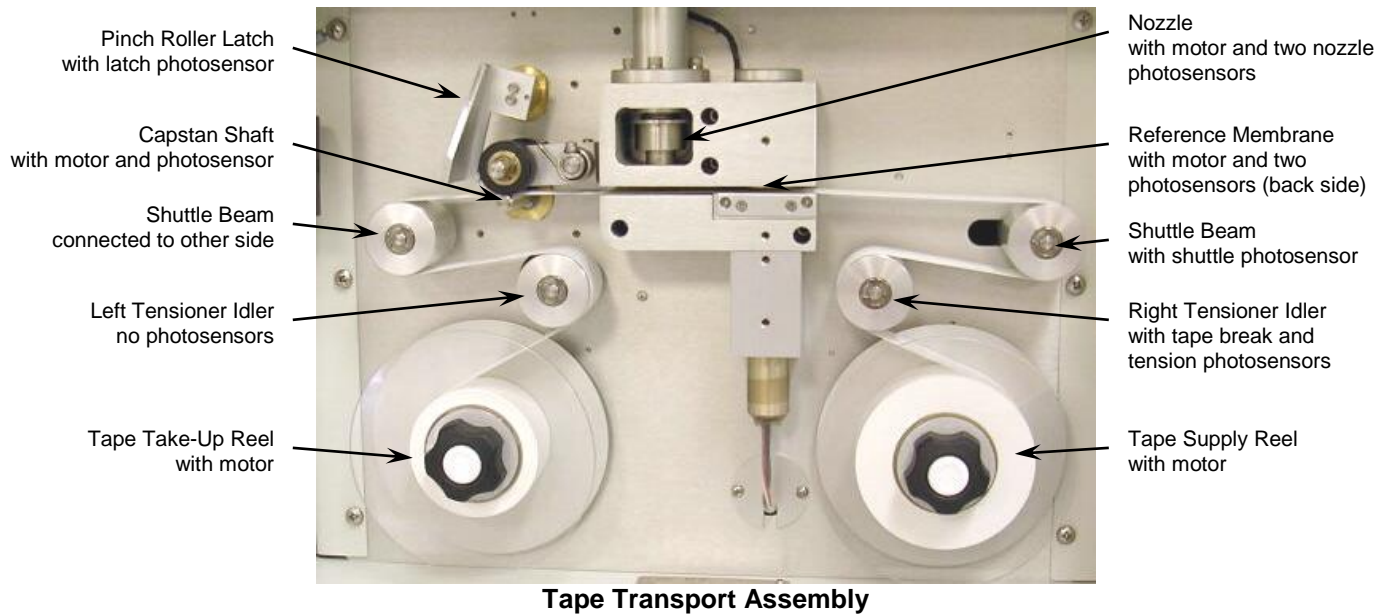
Nozzle Sensors: This screen tests the two nozzle photosensors and the nozzle motor. Use the UP and DOWN buttons to move the nozzle motor, and monitor the status of the S4 and S5 photo sensors on the screen. The two sensor should change states when the nozzle motor is raised or lowered.

Capstan Sensors: This screen tests the photosensor which watch the rotation of the Capstan shaft motor. This is the shaft under the rubber pinch rollers which drives the filter tape forwards and backwards. Press the FORWARD button to rotate the Capstan counter-clockwise, and the BACKWARD button to rotate clockwise. The shaft should turn one-half of a rotation each time. Photo sensor S8 should turn ON to stop the shaft at each half-turn, and will be OFF while the shaft is turning. It is helpful to put an ink mark on the end of the shaft to view the rotation.

This screen also shows the status of the pinch roller latch. If the rollers are latched in the UP position, then S9 should be ON. S9 should turn OFF if the latch is unhooked an lowered.

Membrane Sensors: This screen tests the two photo sensors which monitor the position of the reference membrane assembly. When the EXTEND button is pressed the

membrane should extend and the S2 photo sensor should be ON, and S3 OFF. When the WITHDRAW button is pressed the membrane should withdraw and the S2 photo sensor should be OFF and S3 ON. It takes a few seconds for the membrane to move.

Pinch Roller Latch
with latch photosensor

Capstan Shaft
with motor and photosensor

Shuttle Beam
connected to other side

Left Tensioner Idler
no photosensors

Tape Take-Up Reel
with motor

Nozzle
with motor and two nozzle
photosensors

Reference Membrane
with motor and two
photosensors (back side)

Shuttle Beam
with shuttle photosensor

Right Tensioner Idler
with tape break and
tension photosensors

Tape Supply Reel
with motor

Tape Transport Assembly

8   EXTERNAL DATALOGGER INTERFACE SYSTEM

This section describes the configuration of the BAM-1020 to work with a separate, external datalogger. The BAM-1020 provides an analog concentration output voltage along with a clock synchronization input feature which allows unit to function with many analog dataloggers. The BAM-1020 digital data outputs can also be collected with digital dataloggers or automatic digital data acquisition systems. In any case, the BAM-1020 internal digital data logging system still stores the complete data array, which can be collected periodically.

This section describes the BAM-1020 configurations required for external dataloggers. Consult your datalogger documentation for the specific setup requirements for your model. Met One Instruments can also supply technical bulletins describing sample setup programming for several of the more popular types of datalogger.

8.1   *Analog Concentration Output Signal*

The BAM-1020 analog output type is selectable between voltage output (0-1 or 0-10 volt DC) or isolated current output (4-20 or 0-16 mA). The rear panel dipswitches are used to select the desired output as shown in the table below. The 1-volt voltage output is almost exclusively used for analog data logging applications.

SWITCH	ON	OFF
SW1	0-10 vdc	0-1 vdc
SW2	4-20mA	0-16mA
SW3	Not used	Not used
SW4	Not used	Not used

Important Note: The scale of the output voltage of the BAM-1020 is determined by the RANGE and OFFSET setting. See Section 6.1. In most applications where the OFFSET is set to -0.015, and the RANGE is set to 1.000 mg, the BAM-1020 analog output will be scaled as **0.000v to 1.000v equals -0.015 mg to 0.985 mg.** It is critical that your analog datalogger input is programmed to scale this voltage correctly, or a significant data offset mistake will occur! The BAM digital data should be periodically compared to the analog logger data to ensure correct logger scaling. In addition, the BAM output voltage should be tested as described in Section 7.13 to ensure that the actual voltage output of the BAM matches the expected voltage.

Analog Error Encoding: The analog output is the only voltage channel available between the BAM-1020 and the datalogger, so any errors generated by the BAM are reported using the same voltage signal. The BAM-1020 will set the analog output to its full-scale reading whenever a critical error prevents a valid concentration from being measured. The external datalogger should be programmed to recognize a full-scale reading as an error, and not a valid concentration. This method is used because it is rare for an actual concentration reading to exceed the range of the BAM-1020, and if it does, it should be reported as an invalid data point anyway. The digital data values stored in the BAM are always unaffected and available, if the alarm was non-critical and did not prevent the hourly concentration measurement from occurring.

8.2 Early Cycle Mode Option For Analog Data Collection

During a standard BAM-1020 measurement cycle, the unit waits for the beginning of the new hour before it sets the analog output to represent the just-finished hour's concentration. However, some types of dataloggers must have the concentration value available **before** the new hour starts, or the data will be stored in the wrong hour. The BAM-1020 has a special EARLY cycle mode (in the SETTINGS > SAMPLE menu) which causes the unit to start and finish the measurement a few minutes early in order to output the concentration voltage for the last 5-minutes of the hour which was just sampled. The datalogger must be programmed to read this value during the window. Because of the critical timing involved, the BAM-1020 clock will have to be synchronized to the datalogger clock using the EXT RESET inputs described below. The following describes the timing of the STANDARD and EARLY modes.
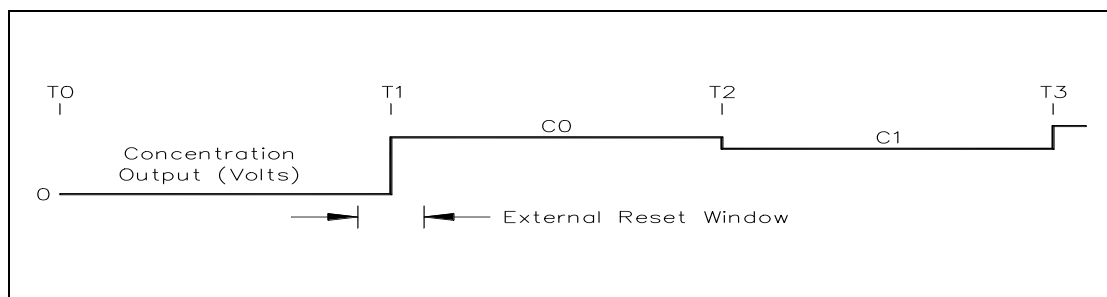
STANDARD Cycle Example
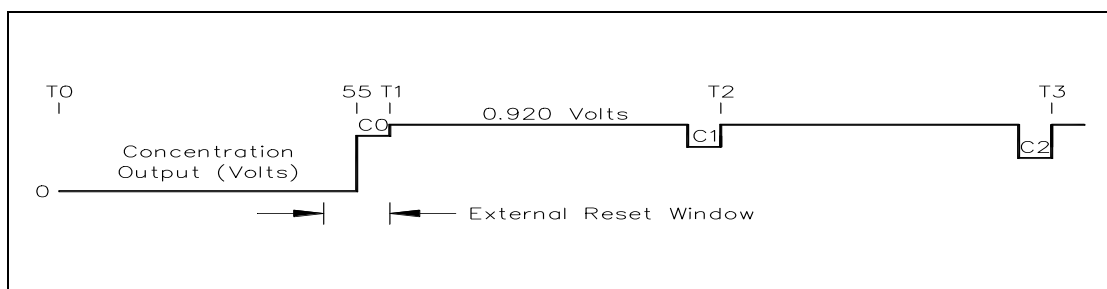
EARLY Cycle Example

Analog Output Levels

C_0 represents the concentration output level measured from time T_0 to T_1, where the T labels represent the top (beginning) of an hour (such as 12:00:00). As you can see, the concentration voltage C_0 for the standard cycle is present for the whole <u>next</u> hour following the measurement. In early mode, the C_0 voltage for the current hour is present for only the <u>last 5 minutes of the hour just-sampled</u> (minute 55 to 60), and all other times the concentration output voltage is fixed at 0.920 volts.

External Reset Windows

An external reset signal may be used to synchronize the BAM-1020 clock to the datalogger. In standard mode the external reset window is plus or minus 5 minutes around the beginning of the hour, but in early mode the external reset window is between minute 50 and 60 only. The BAM clock will not reset if the previous cycle has not finished the I_3 count, and an "E" alarm will be logged. See Section 7.2.

Standard Mode Clock Resets:

Minute 0 to 5:   An external reset signal will change the BAM clock back to the 00:00 of the current hour. If a cycle has already started, it will continue. No error occurs since there is adequate time to complete the cycle.

Minute 5 to 55:   An external reset signal has no effect. The error log will contain the date and time of the "E" alarm reset attempt.

Minute 55 to 60:   If an external reset occurs after a completed cycle (idle condition), then no error occurs. The clock will be set forward to 00:00 of the next hour and a new measurement cycle will start.
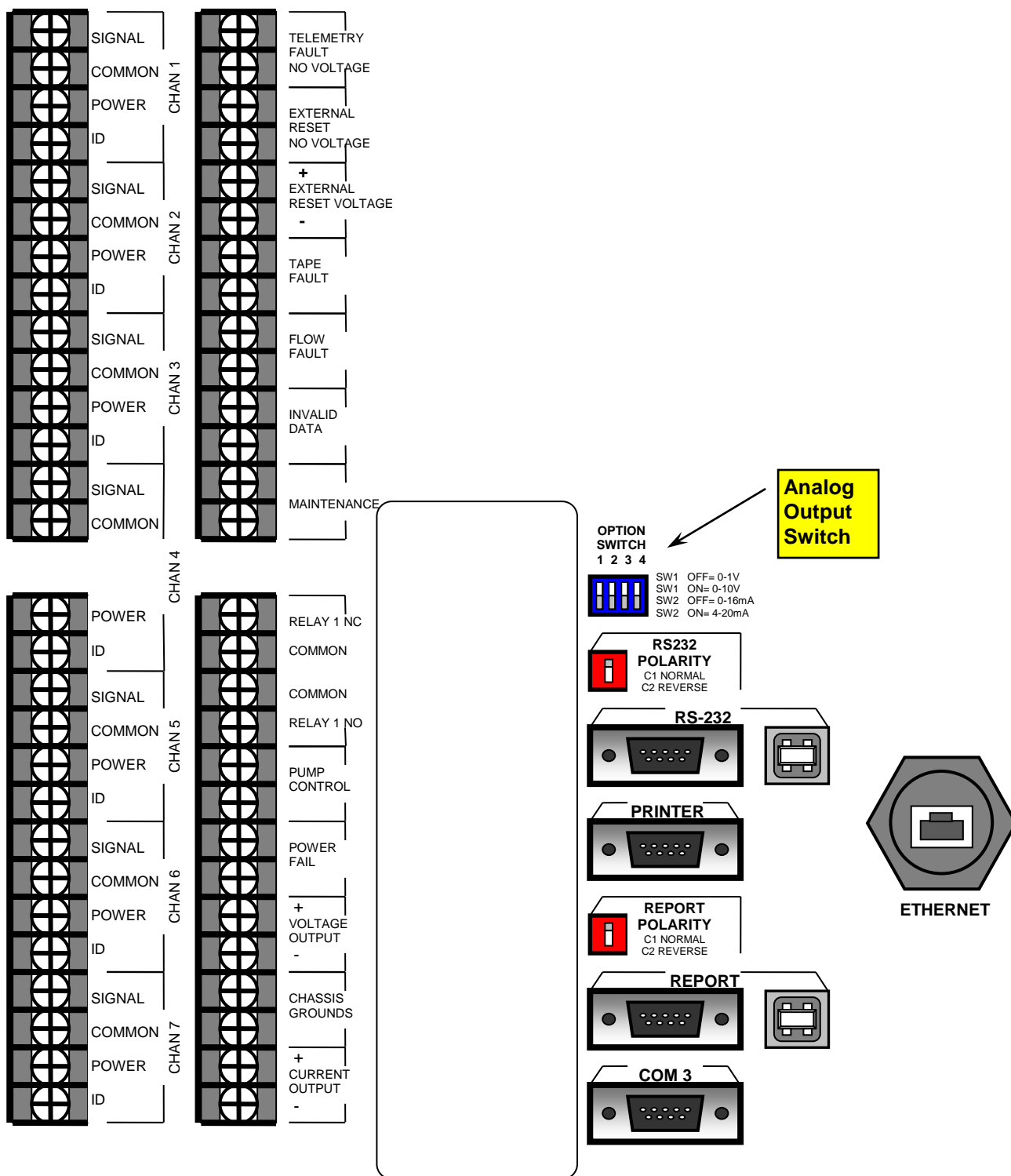
EARLY Mode Clock Resets:

Minute 55 to 60:   The external reset signal changes the clock back to minute 55:00 of the current hour. A new measurement cycle will start at that moment. If a cycle has already started, it will continue. No error occurs since there is adequate time to complete the cycle.

Minute 0 to 50:   The external reset signal has no effect. The error log will contain the date and time of the "E" alarm reset attempt.

Minute 50 to 55:   If an external reset occurs after a completed cycle (idle condition), then no error occurs. The clock will be set forward to minute 55:00 of the current hour and a new measurement cycle will start.

8.3   Telemetry and Error Relays

In addition to the analog output voltage, several input and output relay connections are provided on rear panel of the BAM-1020. These can be connected to an external datalogger as a second method of indicating alarms between the BAM and the logger, but in practice most of these relay telemetry connections are rarely used. The function of each input and output is described below.

Note: A **contact-closure input** to the BAM-1020 is achieved by shorting the two terminals on that particular input together, usually with a relay on the external datalogger. The datalogger should not apply any voltage to the terminals. **Contact-closure outputs** from the BAM-1020 are provided by the unit shorting the two terminals together with an internal relay, without applying any voltage or current to them. The external datalogger must then sense the closure. The contacts are rated at 100VDC, 0.5A max. **Normally-Open** means that the relay contacts are not shorted together unless a certain condition occurs, while **Normally-Closed** means that the relay contacts are shorted until the condition occurs, then they open.

Left column (CHAN 1–4 terminal blocks):

CHAN 1
- SIGNAL
- COMMON
- POWER
- ID

CHAN 2
- SIGNAL
- COMMON
- POWER
- ID

CHAN 3
- SIGNAL
- COMMON
- POWER
- ID

CHAN 4
- SIGNAL
- COMMON

Second column (terminal block):

- TELEMETRY FAULT NO VOLTAGE
- EXTERNAL RESET NO VOLTAGE
- **+** EXTERNAL RESET VOLTAGE **-**
- TAPE FAULT
- FLOW FAULT
- INVALID DATA
- MAINTENANCE

Left column (CHAN 4–7 terminal blocks):

CHAN 4
- POWER
- ID

CHAN 5
- SIGNAL
- COMMON
- POWER
- ID

CHAN 6
- SIGNAL
- COMMON
- POWER
- ID

CHAN 7
- SIGNAL
- COMMON
- POWER
- ID

Right terminal block:

- RELAY 1 NC
- COMMON
- COMMON
- RELAY 1 NO
- PUMP CONTROL
- POWER FAIL
- **+** VOLTAGE OUTPUT **-**
- CHASSIS GROUNDS
- **+** CURRENT OUTPUT **-**

Analog Output Switch

OPTION SWITCH
1 2 3 4

SW1 OFF= 0-1V
SW1 ON= 0-10V
SW2 OFF= 0-16mA
SW2 ON= 4-20mA

RS232 POLARITY
C1 NORMAL
C2 REVERSE

RS-232

PRINTER

REPORT POLARITY
C1 NORMAL
C2 REVERSE

REPORT

COM 3

ETHERNET

BAM-1020 Back Panel and Relay Connections (Extra Report Processor Digital Outputs Shown)

1. **TELEMETRY FAULT NO VOLTAGE**   This input can be used to signal the BAM-1020 that the external telemetry system (datalogger) is not operational. This contact-closure input must be activated for a minimum of 2-seconds. If activated, the BAM will continue to function and will log a "U" error (see section 7.2), and will also activate the INVALID DATA relay output. This input can be set to normally-open or normally-closed in the SETUP > INTERFACE menu. Rarely used.

2. **EXTERNAL RESET NO VOLTAGE**   This input can be used to synchronize the BAM-1020 clock to the external datalogger at the top of the hour, and is often used in EARLY cycle mode. This is a contact-closure input which must be activated for a minimum of 2-seconds. The input can be set to normally-open or normally-closed in the SETTINGS menu.

3. **EXTERNAL RESET VOLTAGE**   This input is the same as above except the input is activated by a TTL logic voltage level instead of a contact-closure. Max 15mA @ 15V or 5mA @ 5V DC. Five-volt logic is typically used for this input.

4. **TAPE FAULT`**   This is a contact-closure output which will be activated whenever a "T" tape error is generated by the BAM (see section 7.2). Polarity is normally-open.

5. **FLOW FAULT**   This is a contact-closure output which will be activated whenever an "F" flow error is generated by the BAM (see section 7.2). Polarity is normally-open.

6. **INVALID DATA**   This is a contact-closure output which will be activated whenever a C, P, N, R, L, I, M, or U error is generated by the BAM (see section 7.2). Polarity is normally-open.

7. **MAINTENANCE**   This is a contact-closure output which will be activated whenever a maintenance "M" flag is generated by the BAM (see section 7.2). Polarity is normally-open.

8. **RELAY 1 NC/NO**   This relay output is used in dual-unit coarse configurations only. The master BAM outputs a clock synch signal to the external reset input of the slave unit using this output.

9. **PUMP CONTROL**   This is the low-voltage output which signals the vacuum pump to turn on or off. There is no polarity on this output because the pump controller has a diode bridge input. Connect the two-wire control cable from the pump to these output terminals.

10. **POWER FAIL**   This is a contact-closure output which will be activated (closed) whenever a power failure or an "L" error occurs in the BAM (see section 7.2).

11. **VOLTAGE OUTPUT**   This is the BAM analog concentration output voltage connection. See section 8.1. Polarity must be observed on this output.

12. **CHASSIS GROUNDS**   These are the earth-ground terminals. These should be attached to a ground rod for best operation of the unit.

13. **CURRENT OUTPUT**   This is used when the analog output is needed in current loop form instead of voltage. Typically only used if there is a long distance between the BAM and the datalogger. Output is selectable between 4-20mA or 0-16mA.

8.4   Interfacing a Digital Datalogger with the BAM-1020

Many BAM-1020 users configure an external digital datalogger to retrieve data from the BAM-1020. This typically requires some programming experience with the particular type of digital logger to be used. Several environmental datalogger manufacturers supply pre-made BAM-1020 drivers for basic data collection applications. All digital files from the BAM-1020 must be obtained through the RS-232 port or the newer REPORT serial port, or in some cases from the PRINTER port. The BAM-1020 digital files are described in Section 9.

The most common method is to program the digital logger to request the last hourly comma-separated data record array from the BAM-1020, once per hour, using the RS-232 or REPORT port. In this case, the logger must establish connection with the BAM by sending three carriage returns (ENTER key), then send the **6 (csv report), 4 (last data)** command string just like you might when downloading the data with a computer and a terminal program as described in Section 9.4. The logger must ignore the BAM menu responses, then receive the hourly data array response and parse out the desired data parameters and store them appropriately. The last concentration value, Qtot flow volume, ambient temperature, pressure, filter RH, and alarm bits are often collected in this manner.

CPU Interruptions: Care is required when collecting data from the classic BAM-1020 RS-232 port. The BAM main CPU cannot multitask, so if the unit is moving any of the filter tape or span membrane motors (especially near the top of each hour) it will ignore any RS-232 serial port commands and interrupt any serial data downloads until the mechanical motion is complete. See Section 4. The best solution when using the classic RS-232 port is to program the digital logger to make a single hourly data request to the BAM near the middle of each hour, such as between minute 25 and minute 50. However, small files such as the last hourly record can be downloaded very quickly, and may be accomplished at almost any time during the hour as long as the timing is carefully controlled. If your datalogger is programmed to digitally request data from the BAM-1020 RS-232 port continuously throughout the hour (such as every minute), then some number of the data requests will certainly be ignored by the BAM due to mechanical interrupts.

The BX-965 Report Processor back panel option was designed to allow easier digital data connectivity with the BAM-1020. The REPORT serial port works exactly like the classic RS-232 port and accesses the same files, except that it has its own CPU and memory and cannot be interrupted or ignored. The REPORT port also has much more data memory capacity. The classic RS-232 port and it's legacy functionality is also still supported on Report Processor back panels as a backup.

Clock Timing With Digital Loggers: Timing must also be considered when collection BAM data with a digital system. If the BAM is operating in standard cycle mode, then the digital concentration data values are updated exactly at the top of the hour. If the digital logger is set to collect the BAM concentration value as soon as it is available, then the clocks should be synchronized to prevent collecting the wrong hourly record.

If the logger must have the BAM concentration before the top of the hour, then the BAM can be set for early cycle mode, and the BAM clock will have to be synchronized to the logger. Some BAM-1020 users leave the BAM in standard cycle mode and set their digital logger to synchronize the BAM clock at minute 59 of the hour. This causes the BAM to be one minute ahead of the logger so that the concentration is available at the top of the logger hour. This method is similar to running in early cycle mode, except that the timing schedule is much easier to understand.

9   DIGITAL COMMUNICATIONS AND DATA RETRIEVAL

This section describes the methods used to retrieve digital data files through the RS-232 serial communications system on the BAM-1020. The unit has one or more two-way RS-232 serial ports which may be used with a computer, laptop, modem, or digital datalogger. The data can be accessed through the serial ports with a terminal program and a simple menu driven interface, or by using the free Comet software that comes with the BAM.
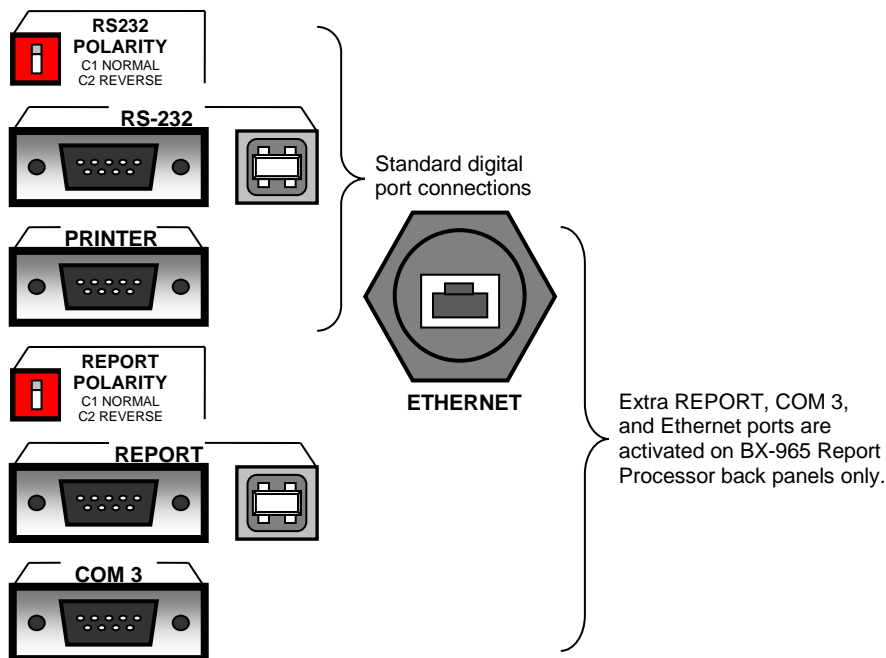
BAM-1020 Back Panel Digital Connections

9.1   Direct Serial Port Connections and Settings

The "RS-232" serial port on the back of the BAM-1020 handles data transfer directly from the BAM CPU, and can be used for less intensive digital collection systems. Units with the newer Report Processor back panel option also have a second REPORT serial port and USB serial converters. The REPORT port has its own file service system which can't be interrupted or ignored by the BAM sample cycle, and should be used whenever available. Both the RS-232 and REPORT ports contain the same data files and are accessed in the same manner. The PRINTER port is output-only and is rarely used. The COM3 port is for connecting two BAMs together in PM-coarse systems only.

Direct Desktop Computer Connections:

The BAM-1020 RS-232 or REPORT port can be directly connected to almost any standard PC that has a COM1 to COM4 serial port available. Connect the port on the back of the BAM-1020 to the COM port connector on the computer with the supplied BAM serial cable (part 400658, female-to-female 9-pin null). **CAUTION:** Do not confuse the parallel printer port or video adapter port on your computer with a serial port.

Direct Laptop Computer Connections:

The BAM-1020 can be connected to most laptop computers. Most older laptops have a regular 9-pin RS-232 serial port, just like a desktop computer. Newer laptops do not usually

have RS-232 ports, so a converter will have to be obtained. The easiest and cheapest type is a USB-to-RS232 serial adapter. Met One recommends the Belkin F5U109, available from Met One or a local electronics store. You will still need the Female-to-Female 9-pin RS-232 cable. Certain laptops occasionally have difficulty communicating through this type of adapter.

Another option is an RS-232 serial PCMCIA card, such as the Quatech SSP-100 which installs in an expansion card slot in the laptop and provides a serial port for the BAM. This type of adapter is very reliable, but more expensive and takes longer to install and configure. See www.quatech.com for more information.

BAM-1020 units with the optional Report Processor back panel have USB data ports which can be connected to the USB port on the laptop with an appropriate cable. Met One can supply drivers for the computer to allow it to communicate with the BAM in this manner. Note: This is exactly the same as using a USB-to-serial converter cable, except that the converter is built into the BAM.

Communication Settings:

The BAM-1020 communicates at 9600 Baud, 8 data bit, no parity, one stop bit. The default 9600 baud rate may be changed to a faster setting for downloading large BAM data files, but in any case, the terminal program baud rate must match the BAM baud setting. **NOTE: The BAM-1020 user interface must be in the main top-level menu or OPERATE menu before any communication can be established through the RS-232 port.** The LCD display and keypad on the BAM-1020 are disabled whenever RS-232 communication with the CPU is in progress. The optional REPORT port does not have these limitations. If unable to communicate, try changing the RS-232 Polarity switch on the back of the BAM-1020. This swaps the polarity of the TX and RX lines (pins 2&3) and functions as a null modem.

9.2 Using Met One Comet Communications Software

Each BAM-1020 is supplied with a free copy of **Comet**™ utility software from Met One Instruments. Comet is a communications terminal program which can retrieve data from the BAM-1020 directly or through a modem. The CD contains complete instructions. The Comet program is very simple and easy to use and can be mastered quickly without having to navigate any of the BAM terminal menus described in section 9.3 and 9.4 below.

Install the program on your computer, then run it from the programs directory. You will have the option to select a previously saved station, or to create a new station. If you want to create a new station, then Comet can auto scan for any BAM units connected to the computer serial ports, or you can manually set up a new station connection. If Comet finds one or more instruments during an auto scan, then you can select the instrument and enter a station name and a phone number if desired. The following window will appear:
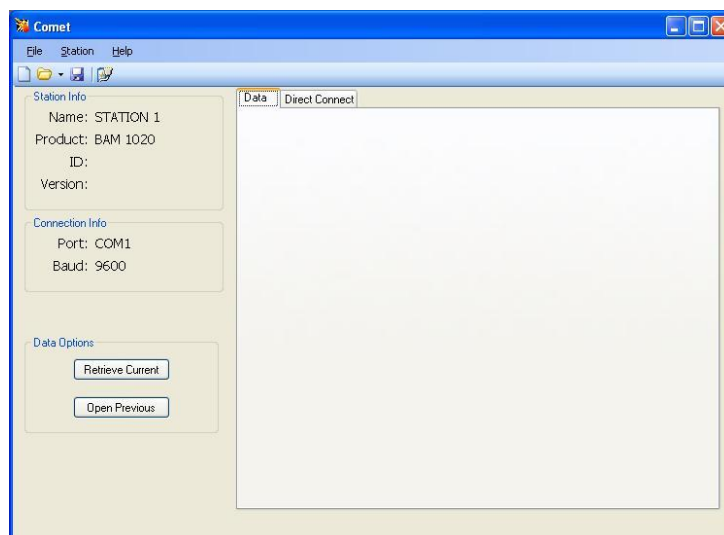
Comet Program Interface

Click the "Retrieve Current" button. A window will appear to select which data files you want to retrieve, and to select if you want all data from the BAM or only new data since last download. Press Retrieve to collect and save the selected files.

In addition, the Comet program has a "Direct Connect" tab which allows you to optionally access the ASCII menu system and data files from the BAM exactly as you would when using a terminal program as described in section 9.4 below.

## 9.3 Downloading Data Using Simple Terminal Programs

The BAM-1020 data can be easily downloaded through the serial ports using HyperTerminal® or other simple terminal programs. Nearly all PCs have the HyperTerminal program already included. The following describes how to set up the program with the BAM-1020:

1. Connect the RS-232 or REPORT port on the back of the BAM to your computer or laptop using the appropriate cable. Connect to the COM1 serial port if available.

2. Open HyperTerminal. (Usually located in the Programs\Accessories\Communications directory). The program will ask you to type a name for the connection. Type "BAM-1020" or a name of your choice, then click "OK".

3. The "Connect To" window will open. Select COM1 (or another port if used) from the drop-down menu in the "Connect Using" field. Click "OK". Note: You can also set up the program to dial the BAM through a modem in this window.

4. The "COM1 Properties" window will open. Set the following values in the drop-down menus, then click "Apply" and "OK".

Bits per second:	**9600**
Data bits:	**8**
Parity:	**None**
Stop bits:	**1**
Flow control:	**None**

5. The main HyperTerminal connection window should now be open. Press the ENTER key three times. The window should respond with an asterisk (*) indicating that the program has established communication with the BAM-1020.

6. Once communication is established, press the **h** key. This should cause the BAM-1020 System Menu to appear on the window as shown below. You can now send any of the ASCII characters in the menu to retrieve the desired files. The menu options are described in the following section.

7. HyperTerminal will only display 100 lines of data in the window. To capture larger files (such as All Data), first select Transfer > Capture Text from the drop-down menu. Select a location for the file, then click the "Start" button. Retrieve the desired files, and HyperTerminal will automatically store them to the text file. Anything that comes through the terminal window will be saved to the file. Click the "Stop" button to stop capturing the text.

8. When you exit HyperTerminal, it will ask if you want to save your connection. Click "Yes" and a file named BAM-1020.ht will be created in the HyperTerminal folder, which will have all of the settings saved. Use this for future communications with the BAM.
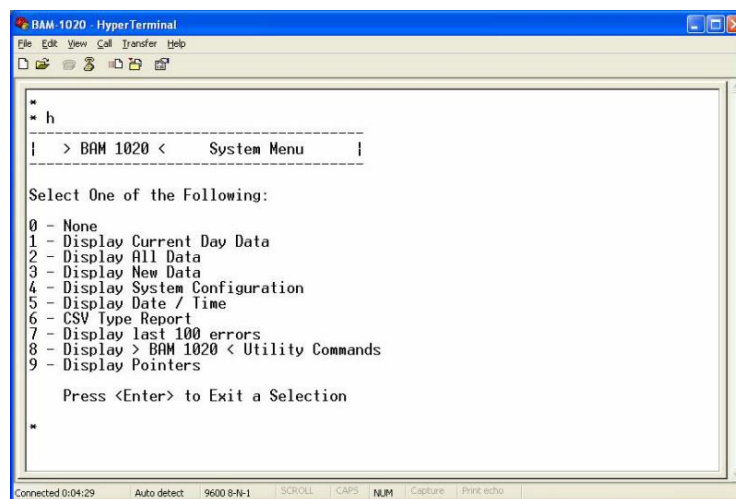
Terminal Window showing BAM-1020 menu

9.4   System Menu and File Descriptions Using a Terminal Program

Once a serial connection between a terminal program and the BAM-1020 has been established as shown above, you will have access to the main BAM-1020 System Menu. Each number 0-9 represents a different data file you can download from the unit. Each file is described below. To get the desired file, simply press the appropriate number on your keyboard. **Note:** After a few minutes, the BAM will stop waiting for a command and you will have to press ENTER three times to reestablish the asterisk command prompt, then send another **"h"** to refresh the menu. If you already know the number of the file you want, you can skip the H menu altogether.

Files 1, 2, and 3:   Current Day Data, All Data, New Data:
These files are simple text views, and are for easy visual checks of the data only, because it is difficult to import these into a spreadsheet for analysis. An example of the data format is shown below. File 1 Current Data is data from the current day only. File 2 All Data is all of the data in the BAM separated into daily blocks. File 3 New Data is all data since the last download, also in daily blocks. A data pointer is set in the BAM indicating where the last download stopped. See Section 9.8.

The first data column is the time, followed by a series of dashes which represent error or alarm bits. If an error occurred, a letter representing the error will appear in this field. For this example, at 7:00 am an **"L"** error (power failure) occurred. Then at 8:00 an **"M"** error was logged, indicating that the operator was performing maintenance that hour.

The next column is the concentration. The Qtot column is total flow volume for the hour. With a flow rate of 16.7 L/min and a sample time of 50 minutes, this value will be about .834 m^3 per hour. With a sample time of 42 minutes this value will be about 0.701 m^3 per hour. The remaining six columns are the six datalogger inputs on the BAM. In this example RH was logged on channel 4, and Ambient Temperature was logged on channel 6. The other four channels had nothing attached, but will appear in the array anyway. The data shown on the unused channels is only noise.

```
Report for 04/22/2005 - Day 112    > BAM 1020 <    Station ID: 1

Channel                  01    02    03    04    05    06
Sensor       Conc  Qtot  WS    no    WS    RH    WS    AT
Units        mg/m3 m3    KPH   V     MPS   %     KPH   C
======================================================
01:00 ------------ 0.010 0.834 019.6 0.012 000.3 00017 132.2 008.7
02:00 ------------ 0.009 0.834 019.9 0.012 000.3 00018 132.1 007.4
03:00 ------------ 0.011 0.834 019.8 0.012 000.3 00018 132.1 006.5
04:00 ------------ 0.011 0.833 020.0 0.012 000.3 00018 132.1 006.1
05:00 ------------ 0.012 0.833 019.8 0.012 000.3 00018 132.1 005.3
06:00 ------------ 0.011 0.834 020.1 0.012 000.3 00018 132.0 005.6
07:00 ----L------ 0.995 0.000 020.3 0.012 000.3 00018 132.0 007.4
08:00 ---M------ 0.995 0.000 019.8 0.012 000.3 00017 132.1 009.4
09:00 ------------ 0.008 0.833 019.9 0.012 000.3 00015 132.2 012.5
10:00 ------------ 0.003 0.834 019.5 0.012 000.3 00014 132.2 016.2
11:00 ------------ 0.007 0.833 019.5 0.012 000.3 00013 132.2 019.7
12:00 ------------ 0.011 0.833 019.5 0.012 000.3 00012 132.0 020.7
13:00 ------------ 0.008 0.833 019.1 0.011 000.3 00010 132.0 021.9
14:00 ------------ 0.010 0.833 019.2 0.011 000.3 00010 131.9 022.3
15:00 ------------ 0.020 0.833 019.1 0.011 000.3 00011 132.0 020.9
16:00 ------------ 0.011 0.834 019.3 0.011 000.3 00012 132.1 018.7
17:00 ------------ 0.010 0.833 019.5 0.012 000.3 00012 132.2 017.9
18:00 ------------ 0.010 0.833 019.4 0.012 000.3 00012 132.1 017.1
19:00 ------------ 0.010 0.834 019.4 0.012 000.3 00014 132.2 015.3
20:00 ------------ 0.007 0.833 019.6 0.012 000.3 00015 132.1 014.4
21:00 ------------ 0.006 0.834 019.5 0.012 000.3 00017 132.1 013.3
22:00 ------------ 0.006 0.834 019.7 0.012 000.3 00021 132.0 011.2
23:00 ------------ 0.005 0.833 019.6 0.012 000.3 00023 132.0 010.0
00:00 ------------ 0.011 0.834 019.9 0.012 000.3 00017 132.2 009.5

Savg         0.009 0.833 019.7 0.012 000.3 00015 132.1 013.2
Vavg         0.000 0.000 000.0 0.000 000.0 00000 000.0 000.0
Data Recovery 100.0 %
```
File 1 Current Day data text file example

File 4: Display System Configuration (BAM Settings File):

This file contains a list of the BAM-1020 settings and calibration values. This is useful for verifying the setup parameters on the BAM-1020, or to send to the factory if service is required. Following is an example of the File 4 settings report. Older revisions of BAM firmware may display a slightly different report format than the one shown below.

```
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,
```

File 4 System Configuration (Settings) file example

File 5: Display Date / Time:

This file command will show the date and time of the BAM-1020 real-time clock.

File 6: CSV Type Report:

The CSV data menu is commonly used for BAM data retrieval through terminal programs. The 6 command will respond with the sub-commands shown below. The data values in each file are separated by commas. This allows the text file to be opened directly by spreadsheets.

This is the recommended data retrieval method. Be sure to capture text when downloading large files if using HyperTerminal. The CSV reports are also often used when BAM data is downloaded by an external digital datalogger. Following is a list of the sub-files available in CSV format. Sub files 5, 6, 7, and 8 are flow diagnostics files and are rarely used.

2 – Display All Data   **(All data records in the BAM)**
3 – Display New Data   **(Data records since last download)**
4 – Display Last Data   **(Previous hour's data only)**
5 – Display All Flow Stats   (All flow stats files)
6 – Display New Flow Stats   (Flow stats since last download)
7 – Display All 5 Min Flow   (5 minute averages of all flow stats)
8 – Display New 5-Min Flow   (5 min averages of flow stats since last download)
9 – Display Error Log   **(Error/alarm log showing sub-categories)**

Example of a CSV report of the "LAST DATA" record (File 6 sub-file 4):

The following example shows a typical CSV download of the file 6,4 last data record from the BAM-1020, such as might be retrieved by an external digital datalogger on an hourly basis. This file download does not reset the data pointer.

1. A series of three carriage returns is sent to the BAM through the serial port. The BAM responds with a single asterisk (*) indicating that communication is established.

2. An ASCII character "6" is sent to the BAM requesting the file 6 CSV menu. The BAM responds with the CSV menu options as shown below, ending with ">".

3. An ASCII character "4" is sent to the BAM, requesting file 4 "Display Last Data". The BAM responds with the Station ID number, then the header info, then the data record.

The data includes date/time stamp, concentration for the last hour (CONC), Flow volume for last hour (Qtot), then all six individual met sensor channels. The labels for these channels will vary, but will always appear in the data array regardless if used or not. 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.

```
* 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

>4 - Display CSV Data
Station,  5
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
01/30/08 16:00,  0.084, 0.834, 0.0,0,0,30,57.0,27.1,0,0,1,0,0,0,0,0,0,0,0,1,
```
Example of CSV last data report

Example of a CSV report of the "NEW DATA" records (File 6 sub-file 3):

The following example shows a typical CSV download of the file 6,3 new data records form the BAM-1020, such as might be done for routine data collection using a local computer or modem. The file contains all of the data record since the last download, and resets the data pointers. See Section 9.8.

1. A series of three carriage returns is sent to the BAM through the serial port. The BAM responds with a single asterisk (*) indicating that communication is established.

2. An ASCII character "6" is sent to the BAM requesting the file 6 CSV menu. The BAM responds with the CSV menu options as shown below, ending with ">".

3. An ASCII character "3" is sent to the BAM, requesting file 3 "Display New Data". The BAM responds with the Station ID number, then the header info, then the data records.

The data starts at the first record since last time it was retrieved. In this example, the MET SAMPLE was set to log the array every 15 minutes.

```
* 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

>3 - Display CSV Data
Station,  5
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, 0.127,0,0,38,1.1,24.6,0,0,0,0,0,0,1,0,0,0,0,
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,
```
Example of CSV new data report

Changing a .txt file to a .csv file: Even though the downloaded data is in comma-separated format, the file is still a text file, and will need to be converted to a .csv file so that it can be opened with a spreadsheet. Delete all of the menu characters from the beginning of the text file, leaving only the data header row and the data records. Make sure that there are no characters after the end of the data either, then save the text file. The file extension can then be changed from .txt to .csv to change the file format into one that can be directly opened by a spreadsheet. Each data parameter should then appear in its own column of the spreadsheet.

CSV Reports of Flow Statistics and 5-Min Flow Files:

The flow statistics fields available in the CSV menu are described below. These files are not available except on BAM units configured as FEM PM$_{2.5}$ units. A BX-596 sensor is required. The flow statistics files are typically used for diagnostics only.

Field	Description
Start	Start time of BAM sample period.
Elapsed	Elapsed BAM sample time.
Flow	Average flow rate for the BAM sample period.
CV	Flow rate coefficient of variance for the BAM sample period.
Volume	Sample volume for the BAM sample period.
Flag	Flow regulation out of range warning flag.
AT	Average ambient temperature for the BAM sample period.
AT Min	Minimum ambient temperature for the BAM sample period.
AT Max	Maximum ambient temperature for the BAM sample period.
BP	Average ambient pressure for the BAM sample period.
BP Min	Minimum ambient pressure for the BAM sample period.
BP Max	Maximum ambient pressure for the BAM sample period.

The 5 minute flow statistics averages are described below. These files are not available except on BAM units configured as FEM PM$_{2.5}$ units. A BX-596 sensor is required.

Field	Description
Time	Event time stamp in seconds since January 1, 1970 00:00:00
Flow	5 Minute average flow rate for the BAM sample period.
AT	5 Minute average ambient temperature for the BAM sample period.
BP	5 Minute average ambient pressure for the BAM sample period.

File 7:   Display Last 100 Errors (Error Log):
This file contains the date, time, and a description of each of the last 100 errors logged by the BAM-1020, in text format. This file reports the 12 main alarm categories only, but not the sub-categories showing the more specific alarm cause. For this reason, the csv error log file should be used instead (file 6 sub-file 9). This file should be downloaded to identify the exact sub-category of any errors or alarms which are not immediately evident.

File 8:   Display BAM-1020 Utility Commands:
This file contains a list of ASCII commands can be sent to the BAM-1020 through the serial port to configure certain parameters or to perform advanced diagnostics. Most of these commands will not be used by the typical operator unless instructed by a factory technician. Some of these commands require a password to access. The password is the same as the F-

key sequence used to enter SETUP screens (default password is **1 2 3 4**). The functions are shown in the table below.

Command	Command Function
a	**Printer Port Output Configuration.** This sets what is output on the printer port. Sending this command will prompt the following sub-menu: 1 – Printer Port (default). 2 – Standard Diagnostic Port. 3 – Factory Diagnostic Port. 4 – Comma Separated Data Output Port.
c	**Clear Data Memory.** This serial command erases all stored data from memory! Password required.
d	**Set Date.** This sets the date on the unit. Password required.
e	**Display Hex EEPROM Setup Values.** This displays the special memory locations where the setup values are stored. Diagnostic only.
f	**Factory Calibration Test.** This is used for factory calibration only!
h	**Display System Menu.** This is the command used to access the data downloading menu options. Become familiar with this command.
i	**Display ID Values.** This command displays the ID codes of the met sensors for diagnostic purposes.
m	**Display Hex Data Memory Values.** This command displays the data memory locations for diagnostic purposes.
p	**Modify Modem Pointer.** Factory use only.
q	**Display Station ID.** This command displays the preset station ID number.
t	**Set Time.** This command sets the time on the unit. Password required.
b	**XMODEM Data Download**. This command allows binary data transfer of the unit memory. Download only. Requires software handshaking. For use with special software only, not terminal programs. Advanced use only.
r	**XMODEM Real-Time Value Download.** This command is only used by special software to scan instantaneous values of sensors, alarms and settings. Requires software handshaking. Advanced use only.
x	**XMODEM EEPROM Value Download.** This command allows quick scanning of non-volatile memory for diagnostic purposed. Advanced use only.
z	**Enable concentration report to PRINTER output.** This command configures the printer port to output a fixed-width concentration report at the end of the sample period. For external loggers. Available in firmware 3.2 or later only.

File 9:   Display Pointers:
This file is a display of the current status of the data storage memory. The current pointer position and number of full memory locations is shown. Rarely used.

9.5   Printer Output Port Functions

The Printer port on the back of the BAM-1020 is an output-only RS-232 serial interface which may be used with a serial printer or as a diagnostic output to a computer. The printer port output can be configured by using the "**a"** utility command through the main RS-232 port. (See section 9.4) The output may be set for data printouts, fixed-width data output, or one of two diagnostic modes. Diagnostic modes are not used except by a factory technician.

A configuration has been added for the printer port which enables it to output a fixed-width concentration report at the end of the sample period, which can be used to interface to a serial data logger. This output is enabled by using the **"z"** utility command through the serial port. The output format is date, time, concentration, and flow volume as shown below.

Format in mg/m3 is: **mm/dd/yy hh:mm:ss,+99.999,+9.999**
Format in μg/m3 is: **mm/dd/yy hh:mm:ss,+999999,+9.999**

If the BAM is set to STANDARD cycle mode, the output will occur at the top of the next hour. For example, if a measurement is made over hour 2, then the format would be:

03/28/07 03:00:00, +00.027,+0.834

If the BAM is set to EARLY cycle mode, the output will occur at minute 55:00 for the current hour. For example, if a measurement is made over hour 2, then the format would be:

03/28/07 02:55:00, +00.027,+0.834

9.6 Modem Option

The Met One Instrument BX-996 modem is recommended for use with the BAM-1020, as it is designed to reliably communicate when other modems may not. If a different modem is used, it must be set in "dumb terminal" mode or equivalent because the BAM does not support handshaking with the modem. Note: the RS-232 Polarity switch on the back of the BAM-1020 may need to be set to REVERSE polarity for communication using the modem.

If you are using one of the Met One Instruments data acquisition programs such as MicroMet Plus, AirPlus, or Comet you need only enter the telephone number of the site in the system setup menu of the program. Multiple telephone numbers can be entered for connection to multiple remote sites. After connection, the data collection is the same as it would be with a direct serial connection to the BAM.

If you are communicating with a terminal program such as HyperTerminal® or ProComm Plus® you will need to define the serial port configuration in the setup of the program. Set the baud rate to 9600, with 8 data bits, no parity, and 1 stop bit. Use the terminal program's internal dialing command sequence to dial up the BAM-1020. Verify the connection to the BAM-1020 by pressing the <Enter> key at least three times until the command prompt asterisk (*) appears. If not, verify the cabling and communications settings. Once connected, the access to the BAM-1020 is the same ASCII menu driven interface as used for the direct PC connection.

9.7 BAM-1020 Firmware Upgrades

The BAM-1020 has a system of one or more firmware (embedded software) programs located in one or more EEPROM chips that control the operation of the unit. There are also several different possible versions of these firmware programs depending on the intended configuration of the unit.

The BAM-1020 CPU board in all units runs at least the main instrument control firmware program (part number 3236-X), which can be updated through the RS-232 port. The optional BX-965 Report Processor back panel board has its own firmware (part number 80353-X), which can be updated through the REPORT port. The optional BX-970 touch screen display has its own software based on Windows CE (part number 80596), which can be updated by installing an update flash drive in a USB port inside the front door on these touch screen units. The following is a basic table of the different firmware programs:

Part Number	Ver/Rev Series	Description
3236-02	V 3.X.X (and earlier)	PM10-only firmware for main CPU. Units without touch screen.
3236-05	V 3.X.X	PM2.5 FEM (USA type) firmware for main CPU. Units without touch screen.
3236-06	V 3.X.X	PM-Coarse FEM firmware for main CPU. Units without touch screen.
3236-07	V 5.X.X	PM10 & PM2.5 EU (Euro type) firmware for main CPU. Units without touch screen.
3236-55	V 4.X.X	PM2.5, PM10, & Coarse FEM (USA type) firmware for main CPU, units with touch screen only.
3236-77	V 5.X.X	PM2.5 & PM10 EU (Euro type) firmware for main CPU, units with touch screen only.
80353-1	V 1.X.X	BX-965 Report Processor firmware, older units with HC11 processor only
80353-3	R 2.X.X	BX-965 Report Processor firmware, units with HC12 processor, all units except touch screen.
80353-4	R 2.X.X	BX-965 Report Processor firmware, for all units with BX-970 touch screen.
80596	V 2.X.X	BX-970 Touch Screen panel PC software.

Warning! The compatibility and interactivity of these various firmware programs is complex. Some firmware versions and/or revisions are incompatible with others, and upgrading one program may require upgrading other programs in order to maintain compatibility. Please contact Met One technical service in order to ensure that you have the correct files before attempting to upgrade any firmware.

The BAM-1020 has the capability for flash firmware upgrades through the serial ports. Flash updates allow the field operator to easily reprogram the main EEPROM firmware to the latest revision through the serial port using the Flash Update Utility. Units which currently run firmware revision 3.0 or later already have a flash compatible EEPROM. If the unit has old revision 2.58 or earlier firmware, then you will need to physically replace the EEPROM chip with a flash compatible chip available from Met One.

You will need a computer or laptop with an RS-232 (9-pin) serial COM port and the standard BAM serial cable that came with the unit. Laptops without a 9-pin COM port will need a reliable USB-to-RS-232 converter, or a USB cable can be used if your BAM has the USB converter port on the back. Do not update the firmware over a modem.

Note: The main BAM-1020 operating system firmware is always updated through the standard RS-232 port only. The Report Processor back panel option has its own EEPROM, its own processor, and its own memory. The Report Processor firmware can be flash updated through the REPORT port, in a similar manner to the main BAM firmware.

Warning! Take great effort to ensure that the power source to the BAM-1020 will not be interrupted during the flash firmware update process! A power interruption may cause the firmware to become inoperative, and the unit will have to be returned to the factory!

Before the flash firmware update:

- Download and save all BAM-1020 data and error logs. These files will be erased from memory during the upgrade process!

- Download the BAM-1020 settings file, or at least record your current settings in the > SAMPLE and CALIBRATION settings screens. Note: If the BAM already has revision 3.2 or later firmware, then none of the settings or calibrations should be affected by the update process.

- Set the BAM baud rate to 9600 for the flash update process.

Flash Update Process:

1. A Met One technician will probably e-mail you a link to the FTP file server site where the current Firmware Update Utility program is located. It will look something like the following:

   http://metoneftp.com/service/Firmware_Upgrades/BAM-1020%20Firmware/BAM%201020%20Firmware%20Installer%20PM2.5%203236-05%20V3.4.3.exe

2. Click on the link or paste it into your internet browser address bar. After a moment the following download window should appear:

   You can run the executable installer program if this is the same computer you plan to use to update the BAM unit, otherwise click "Save" and save the installer to the hard drive or to a removable drive that you can use to transfer the file to the computer you plan to use for the update.

3. Transfer the executable installer file to the appropriate computer if needed, then run the .exe program to extract and install the Firmware Update Utility. The installer will guide you through the installation steps.

4. Connect the COM port of the computer (usually COM 1) to the **RS-232** port on the BAM-1020 with the standard BAM serial cable. The BAM-1020 should be set to 9600 baud in the SETUP menu. The BAM must be powered on and displaying the main menu screen.

5. From the Windows Start menu, go to *Programs/Met One/BAM 1020/BAM 1020 Firmware Installer* to run the Firmware Update Utility program as shown below. Press Y and the Enter key to proceed. The program will then prompt you for the COM port number. Enter the number (usually 1) and press the Enter key to begin the update process.
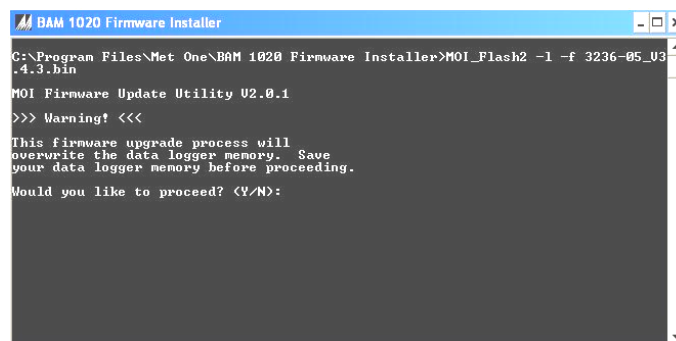
6. Execution time is approximately 12 minutes. Do not disconnect the serial cable or power during this time. The BAM display will show a warning screen during the update. If the main menu is still displayed, then the update is not occurring. Check the

BAM baud rate, serial cable connections, and polarity switch. A "Done!" message will be displayed in the computer window at the end of the update process.

After the flash firmware update:

- Check or set the BAM baud rate back to the desired rate for regular data collection.

- Reset the calibration of the filter temperature and filter RH sensors. Default and then recalibrate the ambient temperature, pressure and flow in the TEST > FLOW CHECKS screen. **Note:** *Sometimes false field calibration values can end up in these parameters as a result of firmware updates, and they must be cleared out for proper BAM operation.*

- Check and verify the settings in the SAMPLE and CALIBRATION settings screens to ensure that they are still correct. It is always good practice to review all settings after any firmware update.

9.8 Resetting the Data Pointer for New Data Collection

The BAM-1020 sets a data pointer when data files are retrieved. The pointer indicates the last data record collected, so that next time "new data" is retrieved, only data back to that pointer is sent. This prevents collecting redundant data and needlessly large files. It is sometimes helpful to be able to manually reset this pointer back to a specific record if it becomes incorrectly set, such as if a modem hangs up in the middle of a download. BAM firmware rev 3.2.6 and later allows the data pointer to be manually reset by sending an escape command through the serial port. Note: The REPORT port on the optional Report Processor back panel uses different pointer reset commands. See the BX-965 manual.

The reset command is **<esc>FH<cr>** where **<esc>** is the esc key. F is the desired file number of **3** (data log file), **6** (flow stats file), or **8** (5-min flow file). H is the number of hours back from current to set the pointer (1 to 9999). **<cr>** is the enter key.

For example, sending **<esc>3 24<cr>** through the RS-232 port would set the data pointer of the main BAM data memory back to 24 hours ago.

9.9 Data Collection Using the Query Output or Bayern-Hessen Protocol

BAM-1020 touch screen units equipped with revision 4.2.0 or later firmware are capable of outputting the custom Query digital data array. European units with revision 5 series firmware are compatible with the Bayern-Hessen data protocol. The format of the Query or BH data array outputs is determined by the user-selected parameters in the SETUP > QUERY menu as described in Section 6.11. **Note:** The Query output can only be accessed through the REPORT serial port on the optional BX-965 Report Processor back panel.

Bayern-Hessen "BH" Protocol:
The Bayern-Hessen protocol is used to support certain European data networks. The complete protocol is not described in this manual, but is available a separate technical document. The primary difference between the Query and the BH data configurations is that the BH protocol does not support the time/date field used in the Query array, but the BH protocol does support a diagnostic stability field which is not accessible with the Query array.

In addition, the BH protocol can only accommodate eight alarm types (0-7) instead of the standard twelve, so some of the alarm states are grouped together. The BH protocol also supports eight real-time status bits to indicate which part of the sample cycle is in progress.

Custom Query Output:

The Query output is provided to allow easier configuration of digital datalogger and more flexibility in the BAM-1020 digital output array. The Query output array is set to include only the desired parameters in the desired order, and is accessed with a simple escape command sequence. This eliminates much of the work associated with programming a digital data logger to establish a command prompt, navigate the classic digital menu system, and parse out multiple unused data parameters.

No command prompt must be established with the BAM-1020 as with the classic digital menu access commands. Only the <Esc> escape character (hex 1B) or the <STX> character (hex 02) followed by the desired Query file and a carriage return (enter). The resulting Query output from the BAM will consist of the last data record in the BAM memory, in comma-separated format. The available Query commands are listed below:

Escape Command	Description
<Esc> QC <enter>	Custom Query output. Data is formatted exactly as specified in the SETUP > QUERY screen. All values are in comma separated format, with a fixed width of 7 characters per field excluding commas.
<Esc> QCH <enter>	Data header for the custom Query output.
<Esc> Q <enter>	Standard Query output. Data array configured exactly like the standard csv last data output (menu 6,4) regardless of the Query setup screen. All values are in comma separated format, with a fixed width of 6 characters per field excluding commas.
<Esc> QH <enter>	Data header for the standard Query output.

An example of one possible QCH (custom array header) and QC (custom Query array) command are shown below. Each escape command is followed by the response from the BAM-1020:

> **<Esc>QCH**
> **TIME,CONC(mg/m3),FLOW(lpm),AT(C),BP(mmHg),RH(%),REF(mg),ERRORS,*4348**

> **<Esc>QC**
> **07/06/10 13:22, 0.0230,   16.7,   23.6,   761,   26, 0.8160,   0,*3129**

An example of the QH and Q commands is shown below. This mirrors the familiar csv last data output of the BAM-1020, and ignores the user set format of the custom Query array:

> **<Esc>QH**
> **Time,Conc(mg/m3),Qtot(m3),WS(KPH),WS(MPS),WS(MPS),RH(%),Delta(C),AT(C),E,U,M,I,L,R,N,F,P,D,C,T,*6451**

> **<Esc>Q**
> **07/06/10 15:00, 0.023, 0.701,   0.8,   0.8,   0.8,   26, 8.6, 23.6,0,0,0,0,0,0,0,0,0,0,0,0,*4224**

If the error status is included in the custom Query array (QC), it will appear as a decimal error code as shown below. Each decimal code value corresponds to one of the twelve regular BAM-1020 error or alarm types as described in Section 7.2.

Decimal Code	Error Flag	Description
0	none	No error
1	T	Tape System Errors
2	C	Beta Count Error
4	D	Deviant Membrane Density Alarm
8	P	Pressure Drop Alarm

16	F	Flow Errors
32	N	Nozzle Error
64	R	Reference Error, Membrane Timeout
128	L	Power Failure
256	I	Internal Error, Coarse Link Down
512	M	Maintenance Flag
1024	U	Telemetry Fault
2048	E	External Reset Error

A data integrity checksum is included at the end of each Query array, after the delimiter asterisk character '*'. The checksum is the 16-bit arithmetic sum of all characters in the line up to but not including the asterisk.

Note: Digital dataloggers may be programmed to use the <STX> (hex 02) character instead of the <ESC>, to prevent the echoing of the command back to the logger.

10 ACCESSORIES and PARTS

10.1 Consumables, Replacement Parts, and Accessories

The following parts are available from Met One for maintenance, replacement, service, and upgrades. If unsure about a part you need, please contact the Service department and provide the serial number of your BAM-1020. Some of these parts require technical skills or special considerations before use or installation.

Consumables

Description	Part Number	Graphic
Filter Tape Roll, Glass Fiber, 60+ days per roll 30mm x 21m	**460180**	
Cotton-Tipped Applicators, nozzle cleaning, 100 pack Solon #362	**995217**	
Silicone O-Ring Grease, mini packets	**995712**	

Calibration & Service Tools

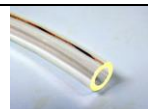| Description	Part Number	Graphic
BAM-1020 Basic Service Tool Kit: Includes nozzle shims, reel spacer, filter sensor removal tool, dark test shim, rubber leak check tool, hex wrenches.	**BX-308**	
BAM-1020 Distributor Service Tool Kit: Includes all of the above plus two spring scales.	**BX-308-1**	
BAM Inlet Cleaning Kit Includes pull-rope, tube brush, microfiber rags, cleaning brushes, o-ring grease, cotton applicators. For cleaning inlet tube and PM10, PM2.5 inlets.	**BX-344**	
Nozzle Adjustment Shim Kit. 8235/8236 Shims Only.	**BX-310**	
Rubber Leak Test Nozzle Seal Tool	**7440**	
Span Membrane Assembly, Standard Replacement Approx 0.800 mg/cm2	**8069**	
Span Membrane Assembly, Mid-Range Approx 0.500 mg/cm2	**BX-301**	
Flow Inlet Adapter Kit (Leak Test Valve) Includes short inlet tube adapter.	**BX-305**	

Description	Part Number	Graphic
Zero Filter Calibration Kit, with leak check valve. Required for PM2.5 FEM monitoring. Same as BX-305 but with 0.2 micron filter.	**BX-302**	
Volumetric Flow Calibration Kit (BGI deltaCal™) Flow, Temp, and Pressure Reference Standards Met One recommended flow meter	**BX-307**	

Vacuum Pumps & Pump Parts

Description	Part Number	Graphic
Pump, Medo, 115 VAC, 50/60 Hz, Low Noise	**BX-126**	
Pump, Medo, 230 VAC, 50/60 Hz, Low Noise	**BX-127**	
Pump, Gast, Rotary Vane, 100/115 VAC, 50/60 Hz	**BX-121**	
Pump, Gast, Rotary Vane, 220/240 VAC, 50/60 Hz	**BX-122**	
Muffler, Medo/Gast Pump, Replacement	**580293**	
Gast Pump Rebuild Kit. Vanes, filters.	**680828**	
Medo Pump Rebuild Kit, Piston, filters	**680839**	
Pump Service Kit, Filter Replacement, Medo	**8588**	
Pump Controller (Relay Module Only) Medo/Gast	**BX-839**	

Flow System Components

Description	Part Number	Graphic
Flow Sensor, Mass, 0-20 LPM, Internal Assembly	**80324**	
Automatic Flow Controller	**BX-961**	
Filter Assembly, Pisco In-line	**580291**	
Filter Element Only, Pisco In-line	**580292**	
Filter Temperature and RH Sensor Kit	**BX-962**	
Filter RH Sensor Replacement Only	**9278**	
Filter Temperature Sensor Replacement Only	**9279**	
Nozzle, Stainless Steel, Replacement Part	**8009**	
Nozzle Spring, Replacement	**2998**	
O-Ring, Nozzle	**720066**	
Nozzle Rebuild Kit, with parts and tools	**80355**	
O-Ring, Inlet Tube Receiver, 2 required.	**720069**	
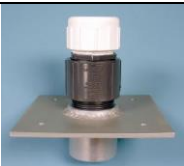
Description	Part Number	Graphic
O-Ring Kit, Inlet Tube Receiver and Nozzle.	**9122**	
Pump Tubing, Clear, 10mm O.D., 6.5mm I.D. Polyurethane, 25 foot roll standard	**960025**	

Electrical & Electronic Parts

Description	Part Number	Graphic
LCD Display, 8x40 Character, Backlit	**2823**	
Circuit Board, Keypad Interface	**2960-2**	
Circuit Board, CPU	**3230-8**	**Contact Technical Service for Circuit Board Replacement Information.**
Circuit Board, Board Stack Interface	**3250-1**	
Circuit Board, Rear Panel Interconnect, Standard	**3260-1**	
Circuit Board, Rear Panel, Report Processor Version	**80350**	
Circuit Board, AC Motor Driver	**3110-2**	
Circuit Board, High Voltage	**3150-1**	
Front Door Assembly, BAM-1020 Standard Version	**9628**	
Fuse, 3.15A, 250V, 5x20mm, 2 Required	**590811**	
Motor, with gear box, 4 RPM. 4 per unit.	**8105-1**	
Motor, with gear box, 10 RPM, Capstan Drive Only.	**8106-1**	
Power Supply Assembly, 115 VAC, 60 Hz	**BX-115**	
Power Supply Assembly, 115 VAC, 50 Hz	**BX-116**	
Power Supply Assembly, 230 VAC, 60 Hz	**BX-230**	
Power Supply Assembly, 230 VAC, 50 Hz	**BX-231**	
Power Supply Assembly, 100 VAC, 60 Hz	**BX-100**	
Power Supply Assembly, 100 VAC, 50 Hz	**BX-101**	
40W Switching Supply Only, With Wire Harness	**80315**	

Inlet Components

Description	Part Number	Graphic
PM10 Size-Selective Inlet Head, EPA Specified	**BX-802**	
TSP Sampling Inlet, with insect screen	**BX-803**	
PM2.5 WINS Impactor	**BX-804**	
PM2.5 Sharp Cut Cyclone	**BX-807**	
PM2.5 Very Sharp Cut Cyclone, BGI Inc. VSCC™ Required for PM2.5 FEM monitoring	**BX-808**	
PM2.5 Cyclone - URG	**BX-809**	

Description	Part Number	Graphic
Inlet Roof Mounting Kit, with waterproof roof flange, inlet tube and braces. 8 foot inlet tube standard.	**BX-801**	
Inlet Tube Coupler Assembly, with o-rings Connects two inlet tubes together Inlet tube sold separately	**BX-821**	
Inlet Tube Extension Kit, 4 foot, with coupler and tube	**BX-822**	
Inlet Tube Extension Kit, 8 foot, with coupler and tube	**BX-823**	
Inlet Tube, Aluminum, 8 foot length standard	**8112**	
Inlet Tube, Custom Length Dash number is length in feet, 8' max per tube	**8112-X**	
Smart Heater Option, 115 VAC	**BX-827**	
Smart Heater Option, 230 VAC	**BX-830**	
Smart Heater Upgrade Kit, 115VAC	**9307**	
Smart Heater Upgrade Kit, 230VAC	**9308**	
O-Rings, BX-807 SCC Cyclone, set of 6	**720097**	
O-Rings, BX-808 VSCC Cyclone, set of 8	**720105**	
O-Rings, PM10 Head, set of 3	**8965**	

Meteorological Sensors

Description	Part Number	Graphic
590 Wind Direction Sensor, Auto ID	**BX-590**	
591 Wind Speed Sensor, Auto ID	**BX-591**	
592 Ambient Temperature Sensor, Auto ID	**BX-592**	
592 Room/Shelter Temperature Sensor, Auto ID	**BX-592-1**	
593 Ambient Relative Humidity Sensor, Auto ID	**BX-593**	
594 Ambient Barometric Pressure Sensor, Auto ID	**BX-594**	

595 Solar Radiation Sensor, Auto ID	**BX-595**	
596 AT/BP Combo Sensor, -40 +55C. 596-1 AT/BP Combo Sensor, -50 +50C. 597 AT/BP/RH Combo Sensor, -50 +70C.	**BX-596** **BX-596-1** **BX-597**	
Real-Time Module (RTM) Instantaneous particulate mass trending option	**BX-895**	

Communications Options & Accessories

Description	Part Number	Graphic
Touch Screen Display Option. Complete Front Door Assembly for BAM-1020.	**BX-970**	
Report Processor kit. Complete back panel assembly or plug-in board. **Call Met One for upgrade details**. Required for PM-Coarse Configuration.	**BX-965**	
Modem Kit for BAM-1020	**BX-996**	
Cellular/IP Modem Kit for BAM-1020	**BX-911**	
BAM-1020 Serial Cable, DB-9 Female Ends, Null.	**400658**	
Belkin F5U109 USB-to-RS-232 Adapter	**550067**	
Serial Printer Kit	**BX-601**	
Converter for Parallel Printers	**BX-602**	

Weatherproof Mini Shelters/Enclosures

| Description	Part Number	Graphic
Mini Enclosure, Heated and Vented. Mfg by Shelter One	**BX-902B**	
Mini Enclosure, Heated and Air Conditioned. Mfg by Ekto. 2000 BTU A/C.	**BX-903**	
Mini Enclosure, Heated and Air Conditioned. Mfg by Ekto. 4000 BTU A/C.	**BX-904**	
Enclosure, Dual Unit, Heated and Air Conditioned. Mfg by Ekto. 4000 BTU A/C.	**BX-906**	

10.2 BX-500 Series Meteorological Sensor Configurations

The BAM-1020 has six channels of inputs available on the back of the unit for data logging external sensors. The BX-500 Series sensors are a set of meteorological sensors designed for direct compatibility with these channels. The sensors each have an auto-identification (ID) signal wire with a voltage unique to that type of sensor. When one of these sensors is attached to the BAM, the unit senses this ID voltage and automatically configures the channel with all the correct scaling parameters. **The ID MODE for the desired channel must be set to ON in the SETTINGS > MET INPUTS menu in order for the unit to identify the sensor**. See Section 6.8 for details about setting up the channels in the BAM-1020. The setup values of the series BX-500 sensors are shown in the chart below.

Temperature Input for Flow Control: The ambient temperature signal used for BAM-1020 flow control must always be connected to channel six. BAM-1020 units are equipped with at least a BX-592 ambient temperature sensor. If the BAM is configured as a PM$_{2.5}$ FEM monitor, then the BX-596 sensor is required. This is a combination ambient temperature and barometric pressure sensor which attaches to channels six (AT) and seven (BP) for actual flow control and flow statistics. *The channel 7 pressure signal is not logged in the standard BAM data arrays.* In order to log the barometric pressure from the BX-596, you must jumper the channel 7 signal terminal over to another unused channel input with a short wire. Then you must manually scale the second channel with the multiplier, offset, and full scale voltage of the BX-596 as shown below. BX-596-1 is an special extended range version for very low temperature or high altitude locations. BX-597 has an additional ambient RH signal and extended ranges on the other parameters.

500 Series Sensor Setup Parameters									
Model	**Type**	**Units**	**Range**	**Mult**	**Offset**	**FS Volts**	**S/V**	**Inv Slope**	**ID Voltage**
BX-590	**WD**	Deg	0 to 360	360	0	1.0	**V**	N	1.10v
BX-591	**WS**	mph	0 to 100	100	0	1.0	S	N	0.20v
		m/s	0 to 44.704	44.70	0	1.0	S		
BX-592	**AT**	^{0}F	-22 to +122	144	-22	1.0	S	N	1.80v
		^{0}C	-30 to +50	80	-30	1.0	S		
BX-593	**RH**	%	0 to 100	100	0	1.0	S	N	2.10v
BX-594	**BP**	inHg	20 to 32	6	26	1.0	S	N	2.60v
		mmHg	508.0 to 812.8	152.40	660.40	1.0	S	N	
		mbar	677.1 to 1083.6	203.19	880.46	1.0	S		
BX-595	**SR**	Ly/ min	0 to 2	2	0	1.0	S	N	3.70v
		W/M2	0 to 2000	2000	0	1.0	S		
BX-596	**AT/BP**	^{0}C	-40 to +55	95	-40	2.5	S	N	3.50v
		mmHg	525 to 825	300	525	2.5	S		
BX-596-1	**AT/BP**	^{0}C	-50 to +50	100	-50	2.5	S	N	4.10v
		mmHg	400 to 825	425	400	2.5	S		
BX-597	**AT**	^{0}C	-50 to +70	120	-50	2.5	S	N	4.20v
	BP	mmHg	375 to 825	450	375	2.5	S		
	RH*	%	0 to 100	100	0	2.5	S		

* The RH signal from the BX-597 sensor may optionally be connected to an unused met channel. These setup parameters must be manually entered by the user in the SETUP > SENSOR screen for the selected channel.
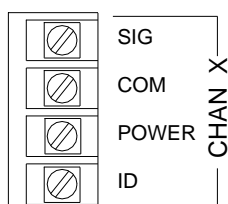
BAM-1020 Back Panel Met Sensor Input Terminal

BX-500 Series Met Sensor Wiring Connections for BAM-1020

BX-590 Wind Direction Sensor	
Terminal Block	**Cable Wire Color**
SIG	Yellow
COM	Black/Shield
POWER	Red
ID	Green

BX-591 Wind Speed Sensor	
Terminal Block	**Cable Wire Color**
SIG	Yellow
COM	Black/Shield
POWER	Red
ID	Green

BX-592 Ambient Temp Sensor	
Terminal Block	**Cable Wire Color**
SIG	Yellow
COM	Black/Shield
POWER	Red
ID	Green

BX-593 Relative Humidity Sensor	
Terminal Block	**Cable Wire Color**
SIG	Yellow
COM	Green/Shield
POWER	White
ID	Red

BX-594 Barometric Pressure Sensor	
Terminal Block	**Cable Wire Color**
SIG	White
COM	Black/Shield
POWER	Red
ID	Yellow

BX-595 Solar Radiation Sensor	
Terminal Block	**Cable Wire Color**
SIG	Yellow
COM	Black/Shield
POWER	Red
ID	Green

BX-596 Temperature/Baro Combo Sensor	
Terminal Block	**Cable Wire Color**
Channel 6 SIG	Yellow (AT)
Channel 6 COM	Black/Shield
Channel 6 POWER	Red
Channel 6 ID	Green
Channel 7 SIG	White (BP)

BX-597 Temp/Baro/RH Combo Sensor	
Terminal Block	**Cable Wire Color**
Channel 6 SIG	Yellow (AT)
Channel 6 COM	Black/Shield
Channel 6 POWER	Red
Channel 6 ID	Green
Channel 7 SIG	White (BP)
Channel 1-3 SIG*	Blue (RH)

* The BX-597 RH signal can be connected to any unused met channel, typically 1, 2, 3, or 5. It must be manually scaled.
The BX-596 BP signal must be connected to unlogged channel 7, but may be jumped to another unused channel for logging.

Sensor Physical Mounting:

The BX-500 series sensors typically mount near the top of the BAM-1020 inlet tube with a supplied short cross-arm and/or related hardware. The sensors can also be mounted to a separate nearby tripod, such as Met One model 905. Wind sensors must be mounted to avoid any possible wind obstructions caused by the BAM inlet components.

11 THEORY OF OPERATION and MATHEMATICAL ANALYSIS

When the high-energy electrons emanating from the radioactive decay of ^{14}C (carbon-14) interact with nearby matter they lose their energy and, in some cases, are absorbed by the matter. These high-energy electrons emitted through radioactive decay are known as beta rays and the process is known as beta-ray attenuation. When matter is placed between the radioactive ^{14}C source and a device designed to detect beta rays, the beta rays are absorbed and/or their energy diminished. This results in a reduction in the number of beta particles detected. The magnitude of the reduction in detected beta particles is a function of the mass of the absorbing matter between the ^{14}C beta source and the detector.

The number of beta particles passing through absorbing matter, such as dust deposited on a filter tape, decrease nearly exponentially with the mass through which they much pass. Equation 1 shows this relationship.

Equation 1

$$I = I_0 e^{-\mu x}$$

In Equation 1, I is the measured beta ray intensity (counts per unit time), of the attenuated beta ray (dust laden filter tape), I_0 is the measured beta ray intensity of the un-attenuated beta ray (clean filter tape), μ is the absorption cross section of the material absorbing the beta rays (cm^2/g), and x is the mass density of the absorbing matter (g/cm^2).

Equation 1 very closely resembles the Lambert-Beers Law, which is used in spectrometric analysis. Just as the Lambert-Beers Law is an idealization of what is actually observed, Equation 1 is also an idealized simplification of the true processes occurring meant to simplify the corresponding mathematics. However, experimental measurement shows that in properly designed monitors, such as the BAM-1020, the use of this equation introduces no substantial error.

Equation 1 may be rearranged to solve for x, the mass density of the absorbing matter. This is shown in Equation 2.

Equation 2

$$-\frac{1}{\mu} \ln\left[\frac{I}{I_0}\right] = \frac{1}{\mu} \ln\left[\frac{I_0}{I}\right] = x$$

In practice, the absorption cross section is experimentally determined during the calibration process. Once I and I_0 are experimentally measured, it is a simple matter to calculate x, the predicted mass density.

In practice, ambient air is sampled at a constant flow rate (Q) for a specified time Δt. This sampled air is passed through a filter of surface area A. Once x, the mass density of collected particles, has been determined, it is possible to calculate the ambient concentration of particulate matter ($\mu g/m^3$) with Equation 3.

Equation 3

$$c\left(\frac{\mu g}{m^3}\right) = \frac{10^9 A(cm^2)}{Q\left(\frac{liter}{min}\right)\Delta t(min)\mu\left(\frac{cm^2}{g}\right)}$$

In Equation 3, c is the ambient particulate concentration ($\mu g/m^3$), A is the cross sectional area on the tape over which dust is being deposited (cm^2), Q is the rate at which particulate matter is being collected on the filter tape (liters/minute), and Δt is the sampling time (minutes). Combining these equations yields to the final expression for the ambient particulate concentration in terms of measured quantities. This is shown in Equation 4.

Equation 4

$$c\left(\frac{\mu g}{m^3}\right) = \frac{10^9 A(cm^2)}{Q\left(\frac{liter}{min}\right)\Delta t(min)\mu\left(\frac{cm^2}{g}\right)}\ln\left(\frac{I_0}{I}\right)$$

The key to the success of the beta attenuation monitor is due in part to the fact that μ, the absorption cross-section, is almost insensitive to the nature of the matter being measured. This makes the BAM-1020 very insensitive to the chemical composition of the material being collected.

It is instructive to perform a conventional propagation of errors analysis on Equation 4. Doing so, one can develop an equation for the relative measurement error (σ_c/c) as a function of the uncertainty in each of the parameters comprising Equation 4. This leads to Equation 5.

Equation 5

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

Inspection of Equation 5 reveals several things. The relative uncertainty of the measurement (σ_c/c) is decreased (improved) by increasing the cross sectional area of the filter tape (A), the flow rate (Q), the sampling time (t), the absorption cross-section (μ), I and I_0.

In practice, the uncertainty associated with the filter area (σ_A/A), may be minimized by ensuring that the tape is in exactly the same position during the I_0 measurement as in the I measurement phase. Careful design of the shuttle and tape control mechanisms inside of the BAM-1020 results in minimal error here.

The uncertainty in the flow rate (σ_Q/Q) may be minimized by properly controlling the flow of the instrument. For BAM-1020 units with a manual flow valve, this value is on the order of $\pm$ 3%. For BAM-1020 units equipped with the mass flow controller device, (σ_Q/Q) decreases to $\pm$ 1%.

The relative error due to the uncertainly in the absorption cross section (σ_μ/μ), is due to its slight variation as a function of the chemical composition of the matter being monitored. Generally, this relative error is on the order of $\pm$ 2-3%, with judicious selection of the calibrated value of μ.

The uncertainty associated with the measurement of I and I_0 has to do with the physical nature of the process leading to the emission of beta particles from the decay of ^{14}C. This process follows Poisson statistics. Poisson statistics show the uncertainty in the measurement of I (σ_I/I) and I_0 (σ_{I0}/I_0) are minimized by increasing the sampling time. Mathematical analysis shows that doubling the sampling time and hence the measured intensity of I or I_0 will reduce the uncertainty of the measurement by a factor of 1.41 (square root of 2).

11.1 Converting Data Between EPA Standard and Actual Conditions

As described in this manual, the BAM-1020 can obtain concentration data using either actual or standard values for ambient temperature and pressure. In some cases, it is necessary to convert past concentration data collected in standard conditions to actual conditions, or the other way around. Note: temperature is in degrees Kelvin (C+273) and pressure is in mmHg.

Equation 6

$$C_{std} = C_{amb} * (P_{std} / P_{amb}) * (T_{amb} / T_{std})$$

Equation 6 can be used to calculate the standard concentration (C_{std}) from the ambient concentration (C_{amb}) data using ambient barometric pressure and temperature data (P_{amb} and T_{amb}) from the same time period in which the ambient concentration was recorded. P_{std} and T_{std} are the values of standard barometric pressure and standard ambient temperature. These values are usually the EPA mandated 760 mmHg and 298 degrees Kelvin (25 C). **Note:** Some other countries use different values for standard temperature and pressure.

Equation 7

$$C_{amb} = C_{std} * (P_{amb} / P_{std}) * (T_{std} / T_{amb})$$

Equation 7 can be used to calculate the ambient concentration (C_{amb}) from the standard concentration (C_{std}) data using the ambient temperature and pressure. It is necessary to have access to valid data for the ambient temperature and pressure for the desired sample hour in order to be able to make the calculations.

Example: You have a data value of 27μg from a BAM which was configured to report data in EPA Standard conditions (298K and 760 mmHg), but you need to know what the concentration would have been in actual conditions. The actual average temperature for the hour in question was 303K and the average pressure was 720mmHg.

$$C_{amb} = C_{std} * (P_{amb} / P_{std}) * (T_{std} / T_{amb})$$
$$C_{amb} = 27 * (720/760) * (298/303)$$
$$C_{amb} = 27 * 0.9474 * 0.9835$$
$$\mathbf{C_{amb} = 25.1\ \mu g}$$

BAM-1020 Audit Sheet

Model: | BAM-1020 | **Serial Number:** |

Audit Date: | | **Audited By:** |

Flow Audits			
Flow Reference Standard Used:	Model:	Serial No:	Calibration Date:
Temperature Standard Used:	Model:	Serial No:	Calibration Date:
Barometric Pressure Standard Used:	Model:	Serial No:	Calibration Date:

Leak Check Value: as found: [ ] lpm   as left: [ ] lpm

		BAM	Ref. Std.		BAM	Ref. Std.	
Ambient Temperature:	as found:	C	C	as left:	C	C	N/A [ ]
Barometric Pressure:	as found:	mmHg	mmHg	as left:	mmHg	mmHg	
Flow Rate (Actual Volumetric):	as found:	lpm	lpm	as left:	lpm	lpm	N/A [ ]
Flow Rate (EPA Standard):	as found:	slpm	slpm	as left:	slpm	slpm	N/A [ ]

Mechanical Audits		

Pump muffler unclogged:	as found [ ]	as left [ ]	PM10 particle trap clean:	as found [ ]	as left [ ]	N/A [ ]
Sample nozzle clean:	as found [ ]	as left [ ]	PM10 drip jar empty:	as found [ ]	as left [ ]	N/A [ ]
Tape support vane clean:	as found [ ]	as left [ ]	PM10 bug screen clear:	as found [ ]	as left [ ]	N/A [ ]
Capstan shaft clean:	as found [ ]	as left [ ]	PM2.5 particle trap clean:	as found [ ]	as left [ ]	N/A [ ]
Rubber pinch rollers clean:	as found [ ]	as left [ ]	Inlet tube water-tight seal OK:	as found [ ]	as left [ ]	
Chassis ground wire installed:	as found [ ]	as left [ ]	Inlet tube perpendicular to BAM:	as found [ ]	as left [ ]	

Analog Voltage Output Audit		N/A [ ]
Test Screen	**BAM Voltage Output**	**Logger Voltage Input**
0.000 Volts	Volts	Volts
0.500 Volts	Volts	Volts
1.000 Volts	Volts	Volts

Membrane Audit	
LAST m (mg):	
ABS (mg):	
Difference (mg):	
% Difference:	

Flow Control Range	
Flow Setpoint	**BAM Flow**
15.0 LPM	
16.7 LPM	
18.4 LPM	

Setup and Calibration Values								
Parameter	**Expected**	**Found**	**Parameter**	**Expected**	**Found**	**Parameter**	**Expected**	**Found**
Configuration			CV			Station Number		
Cycle Mode			Q0			Baud Rate		
BAM Sample			ABS			Met Average		
BAM Count Time			μsw			AP Pressure Drop		
Conc Type			K					
Conc Units			BKGD					
Range			Heater Control					
Range Offset			RH Setpoint					
Flow Rate			Data Log RH					
Flow Type			Data Log Filter T					
Standard Temp			Heater Idle Mode					

Last 6 Errors in BAM-1020 Error Log					
Error	**Date**	**Time**	**Error**	**Date**	**Time**
1			4		
2			5		
3			6		

Audit Notes:

Manual Notes:

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