BAM-1020
Beta Attenuation Mass Monitor

$PM_{2.5}$ FEM Configuration
The New Evolution of BAM Technology

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Overview – The Big Picture

- The success of any BAM-1020 monitoring program is directly proportional to how well the site operators and program administrators understand how and why the unit works.
- Basic knowledge of how and why (not just how) the various setups, checks, and calibrations are performed always leads to better end results.
- Met One is making a strong effort to provide this information through improved documentation, field training, and expanded technical service.

Overview – Topics of Discussion

- Brief History of the BAM-1020 PM2.5 Configuration
- What is the FEM PM2.5 Configuration?
- Basic Theory of Operation
- Three Basic Systems: Flow, Measurement, and Data
- Critical Checks and Maintenance
- Measurement Challenges

Brief History of the PM2.5 FEM Configuration

- 1930s - Beta attenuation measurement technology first developed for industrial processes and paper manufacturing.
- 1970s - Beta attenuation technology adapted to measure airborne particulate levels.
- 1990s – The Met One BAM-1020 was developed with reduced size and advanced microprocessor control. EPA PM10 FEM approval obtained in 1998.
- 2002 – The Met One E-BAM was developed as a sister product for rapid deployment and emergency response with variable data intervals.
- 2006 – The FEM PM2.5 BAM-1020 Configuration was developed and FEM testing began.
- 2007 – PM2.5 FEM Candidate Configuration released for sale.
- March, 2008 - EPA PM2.5 FEM designation obtained for the BAM-1020.

What is the PM2.5 FEM Configuration?

- The classic BAM-1020 had appropriate accuracy and sensitivity for measuring PM10 levels, and was also often used for PM2.5 monitoring with the addition of a standard SCC cyclone or WINS impactor, even without equivalency.
- Field results from these early PM2.5 systems showed that the BAM needed slight detection limit and Y-intercept (offset) improvements for accurate measurements below about 15 micrograms. The slopes were typically quite adequate.
- PM2.5 levels by nature are much more difficult to measure due to low concentrations and greater volatile content. Small measurement errors may cause large proportional errors.

What is the PM2.5 FEM configuration?

- The transport assembly was redesigned for filter tape positioning accuracy of about 1/1000 of an inch.
- The beta source gap geometry was reduced 25%, resulting in higher signal-to-noise levels and reduced air density effects.
- The beta count time was increased from 4 to 8 minutes, improving the statistical noise stability by about 40%. Known as the “2X” effect.
- The firmware was extensively revised to provide flow statistics, new settings, and improved field calibrations.
- The field zero background test was implemented to fine-tune the slope offset characteristics in the field.
- The BX-596 Temp/Baro combination sensor was designed.

What is the PM2.5 FEM configuration?

- The combined effect of these improvements resulted in the typical detection limit (2σ) of the unit improving from about 6ug to about 3ug for hourly measurements, and below 1ug for 24 hour averages.
- Met One began PM2.5 FEM testing immediately upon release of the final U.S. EPA specifications for candidate monitors.
- The units had to meet stringent requirements for both FRM correlation and inter-unit comparison during both winter and summer seasons at multiple sites around the country.

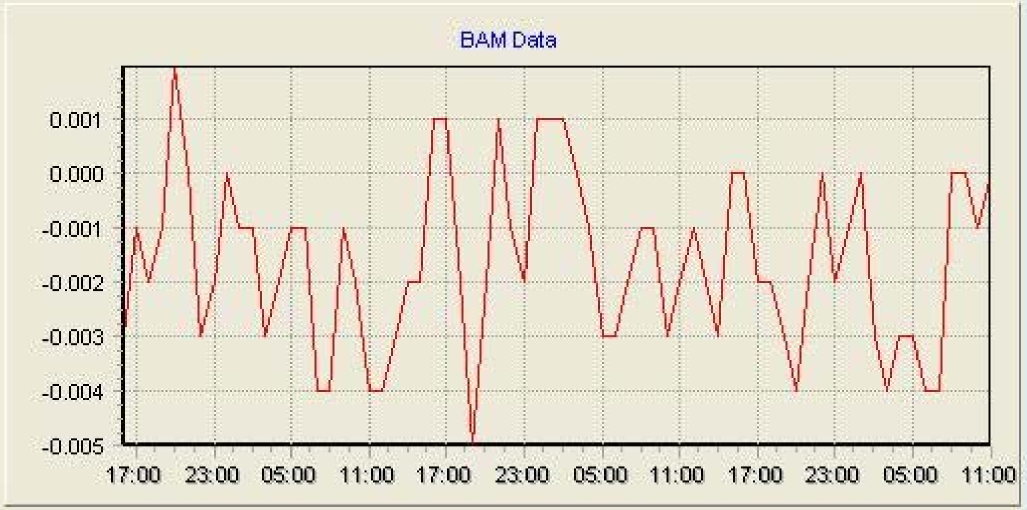
Factory Calibration Example

Bam View

File View Action Mode Help

Time vs Conc

- E5632
- G4043
- B1136
- G4159
  - Zero
    - Running
- G8408
- G8410
- G9275
- G9276



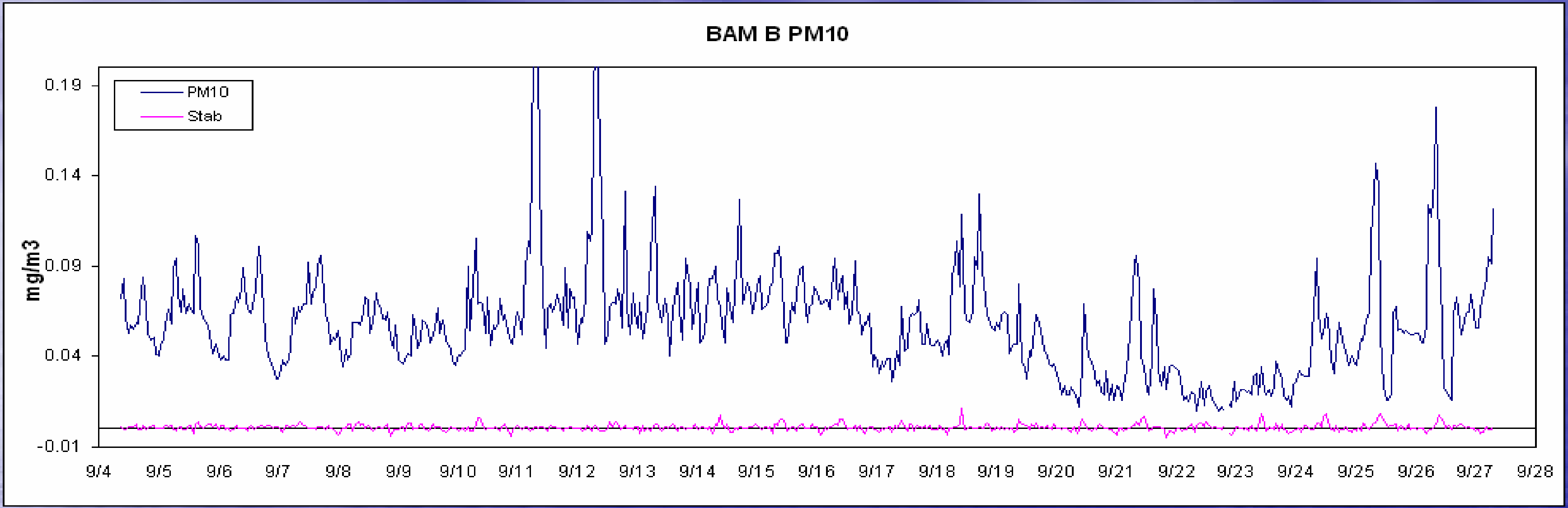
Settings

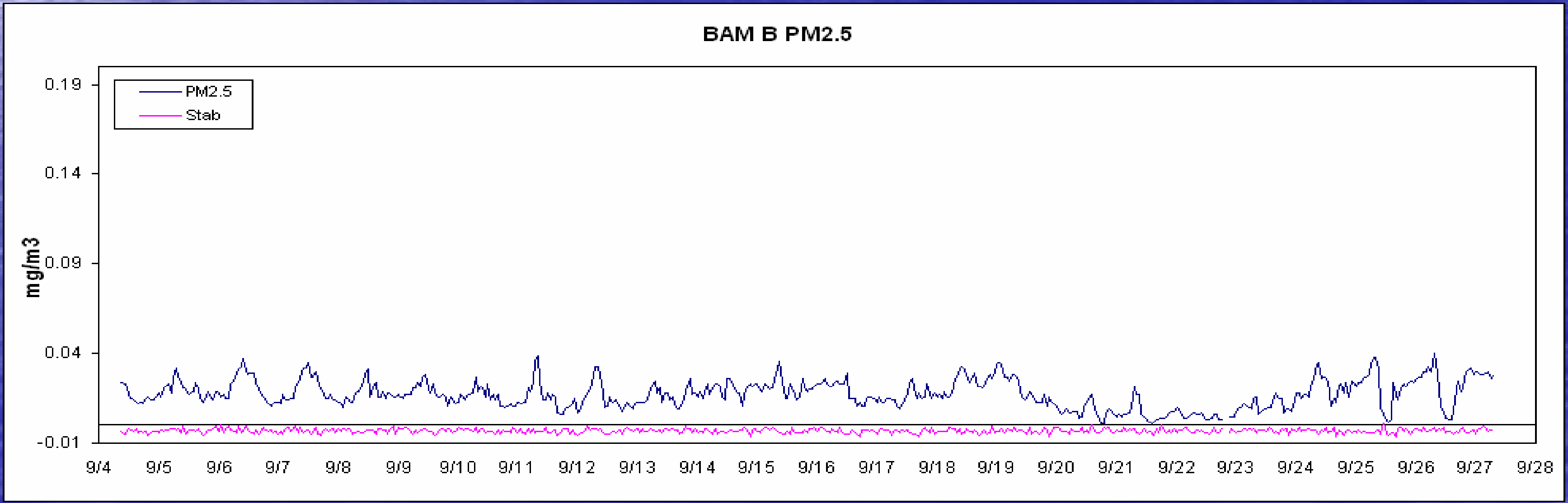
Mu Sw	0.303
Background	0.0000
K Factor	0.974
ABS	0.829

Stats

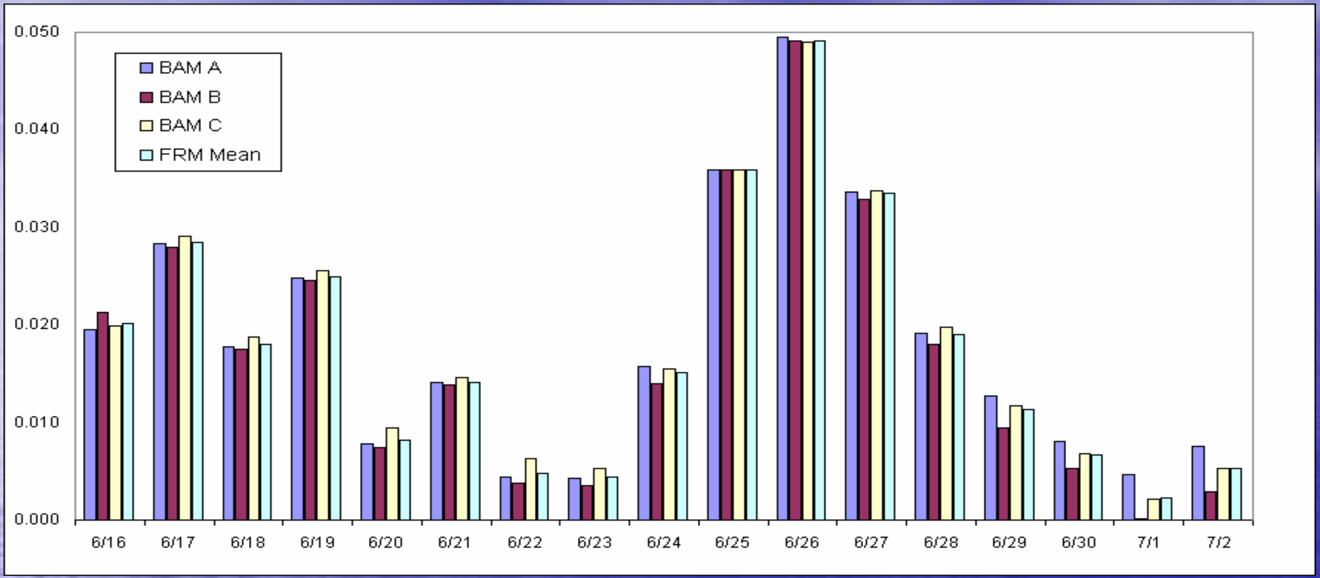
	Mass	Stability	Data
Mean	0.8269	-0.0008	-0.0016
Std Dev	0.0018	0.0015	0.0016
CV	0.2141	-179.4225	-96.9518
Max	0.8308	0.0030	0.0020
Min	0.8232	-0.0038	-0.0050
Max Dev	0.0039	0.0038	0.0036
Min Dev	-0.0037	-0.0030	-0.0034
N	68	68	68

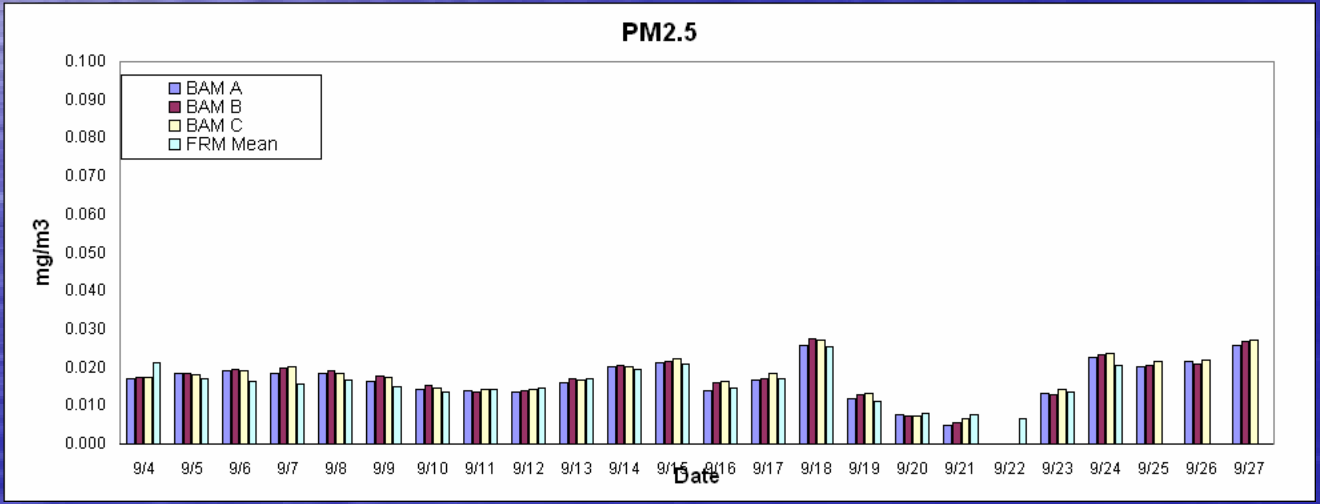
Data Example 1 – PM10 and PM2.5 Levels



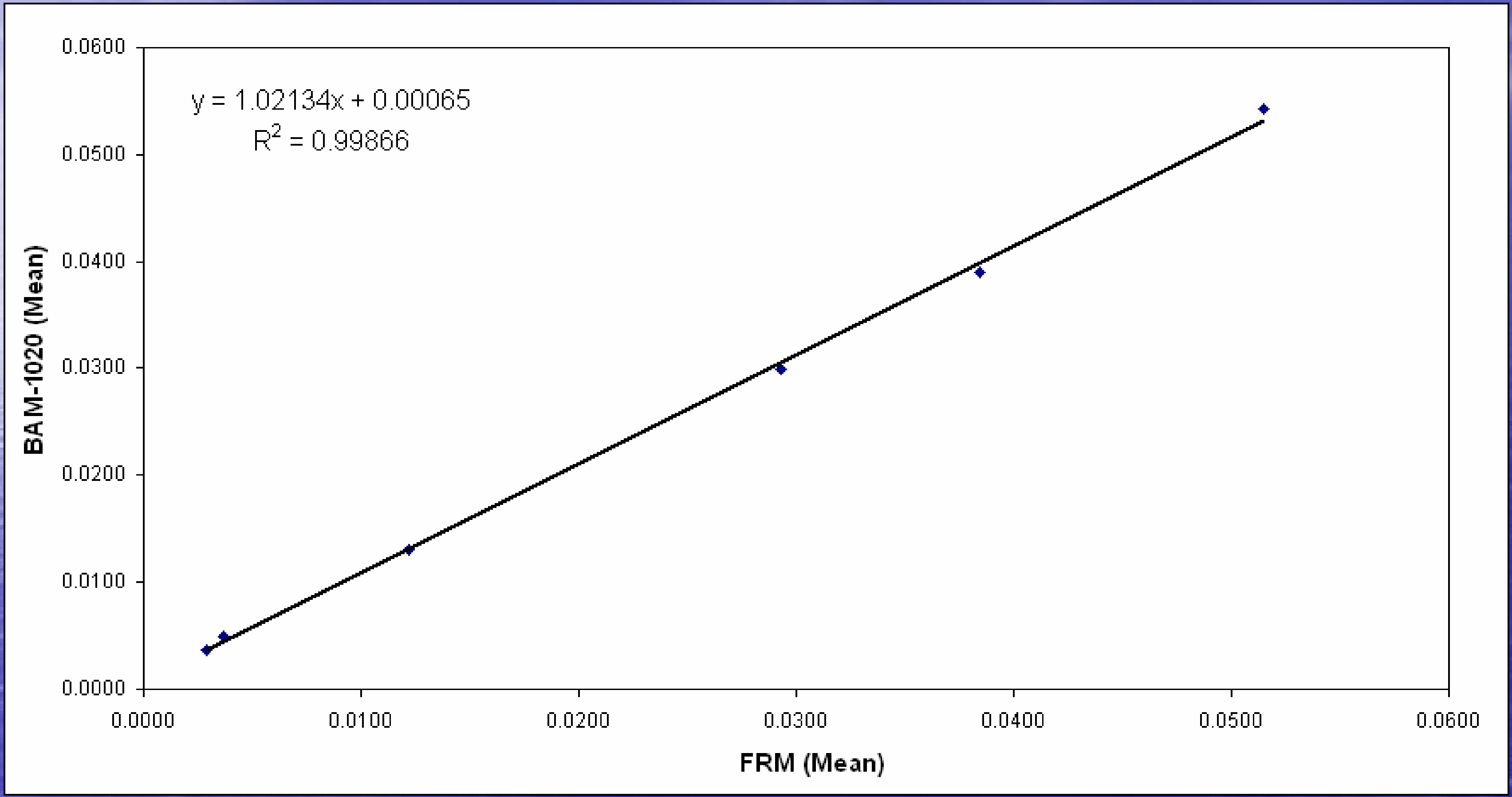


Data Example 2 – PM10 and PM2.5 Levels

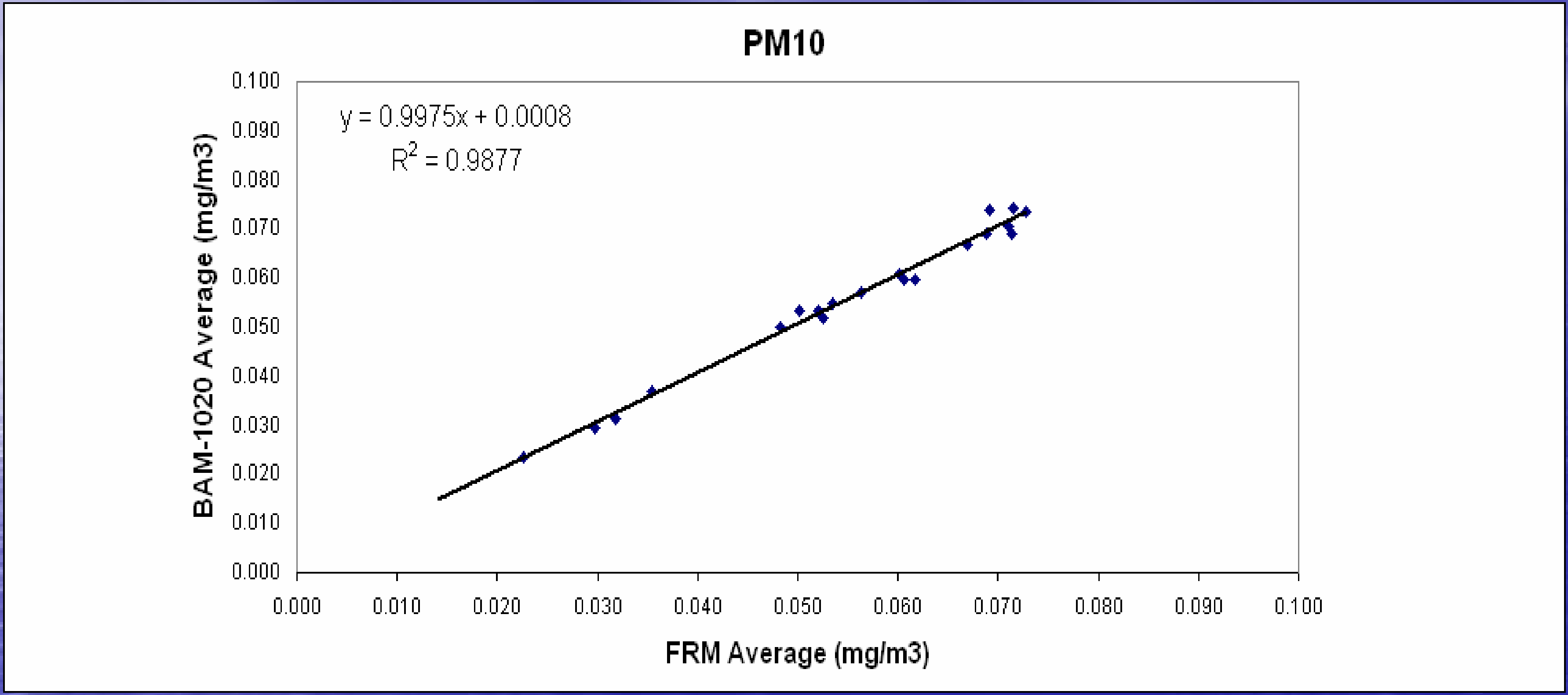




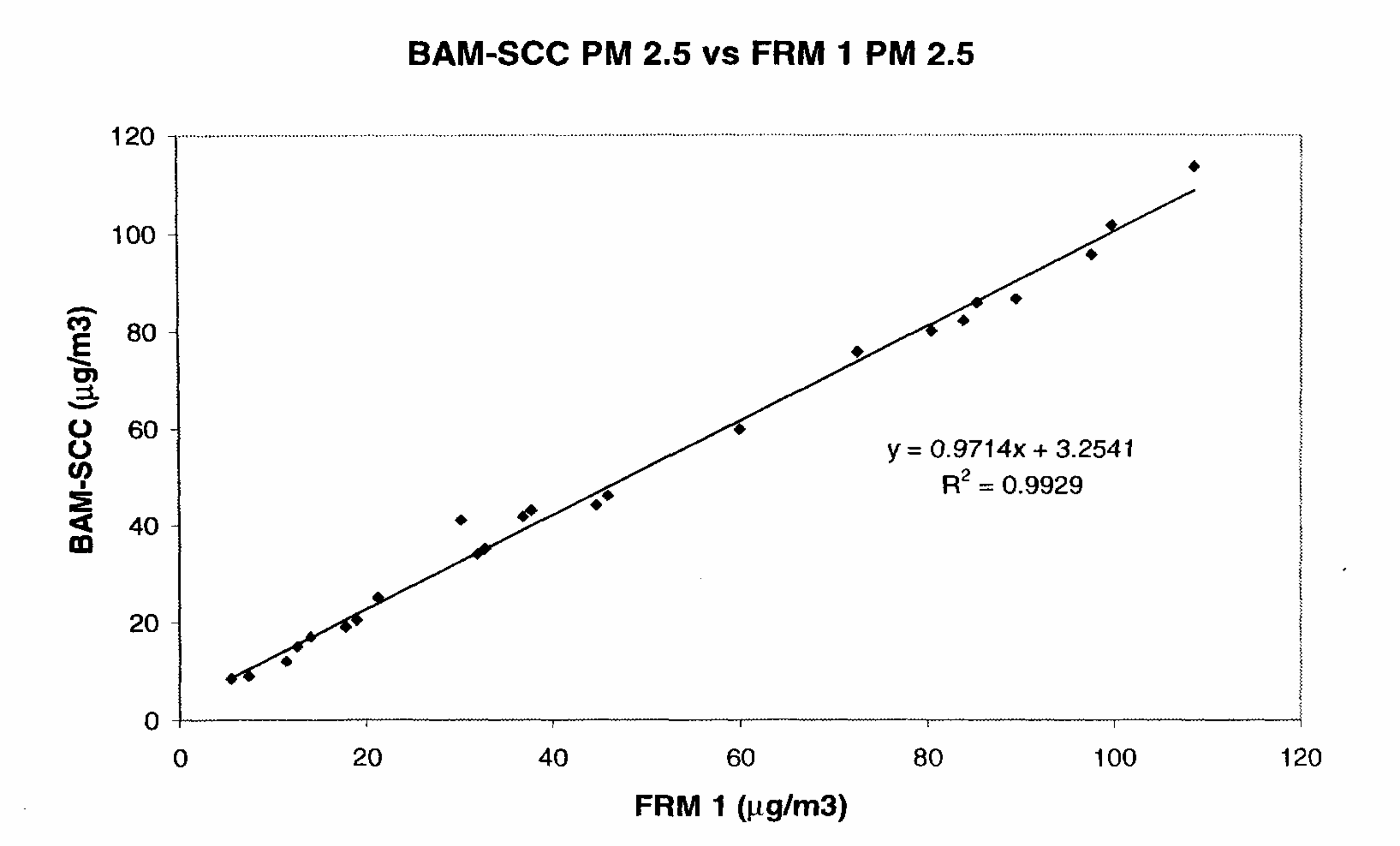
Data Example 3 – PM2.5 Slope / Offset



Data Example 4 – PM10 Slope / Offset



Typical older unimproved unit comparison to FRM for PM2.5, showing Y-intercept offset



What is the PM2.5 FEM configuration?

- Met One filed the official FEM PM2.5 application with the EPA in late summer 2007.
- EPA review of the application took several months.
- The BAM-1020 was the first instrument to successfully complete PM2.5 FEM candidate testing, and is the first (and currently only) instrument to obtain EPA FEM status for PM2.5.
- All BAM-1020 units built after March 2007 are FEM compatible when equipped with the appropriate settings and accessories.
- The new BAM-1020 configuration maintains it's longstanding FEM status for PM10 monitoring.

What is the PM2.5 FEM configuration?

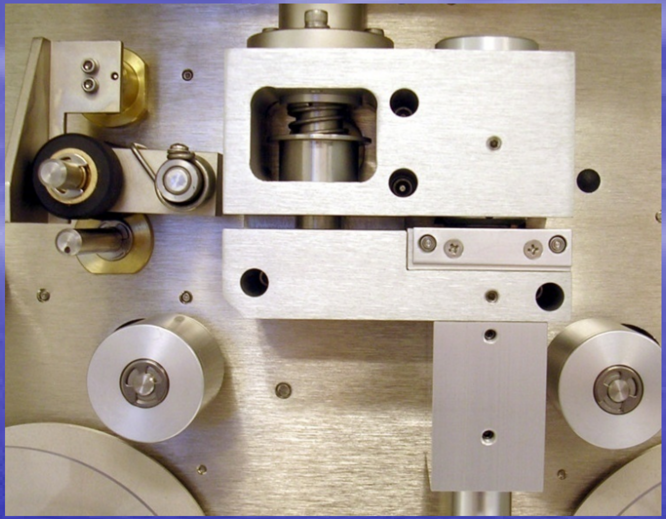
- The unit must use the EPA-mandated VSCC-A™ cyclone from BGI Inc., and the standard EPA PM10 inlet.
- The unit must be equipped with revision 3.2.4 or later firmware, and must be operated per the revision F or later manual.
- The unit must use the BX-596 AT/BP sensor.
- The unit must be operated with 8 minute counts and 42 minute samples on standard glass fiber filter tape.
- The unit must use the inlet Smart Heater, with an RH control set-point of 35%.
- The unit must be set for Actual volumetric flow control.
- The BKGD value must be audited in the field with the BX-302 zero filter kit upon deployment.

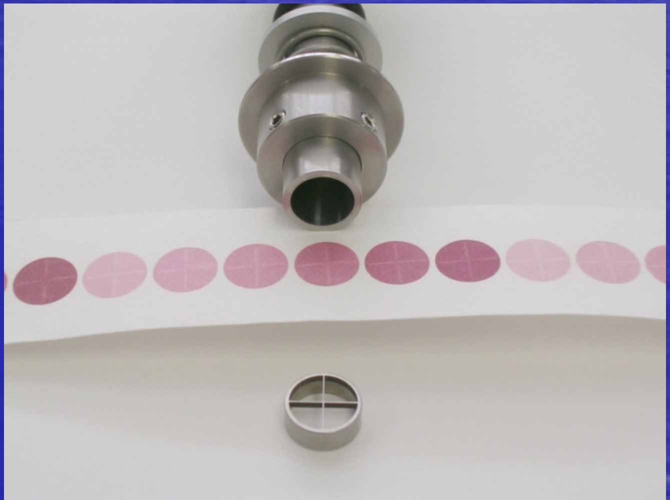
What is the PM2.5 FEM configuration?

- Many older units can be upgraded to the latest hardware and the FEM PM2.5 version. The upgrade involves a complete rebuild and calibration of the unit at the factory.
- Units built before March, 2007 will need mechanical upgrades to the hardware before they can be configured for PM2.5. All BAM-1020 units built after this have the latest hardware parts.
- Most units built after 2003 (serial prefix C) are upgradeable. Met One does not recommend upgrades for older units.
- Contact the Sales Dept for the current price of upgrades.
- Met One now offers substantial discounts for trade-ins of old units. This also results in much faster turn around time than an upgrade of an old unit.

Theory of Operation

- At the beginning of the hour, a small Carbon 14 element emits a constant source of beta rays through a clean spot of filter tape to determine a zero reading.
- The unit advances this spot to the sample nozzle where air containing particulate is sampled and deposited on the filter tape.
- At the end of the hour, the dirty spot is placed back at the source where is it re-measured with beta rays.
- The difference between the two measurements is proportional to the mass concentration.





Mass Calculation

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

$$x = -\frac{1}{\mu} \ln\left(\frac{I}{I_0}\right)$$

$$C = \frac{Ax}{V}$$

Mass Calculation

- DEFINITIONS:
  - I_0– beta measurement across clean filter
  - I – beta ray measurement across dirty filter
  - μ – calibration coefficient
  - x – mass density on filter tape (mg/cm^2)
  - A – dust spot deposition area on filter tape (cm^2)
  - V – sampled volume (m^3)
  - C – particulate matter concentration (mg/m^3)

General Beta Gauge Advantages

- Seasonal and geographical correction factors are not needed.
- It is not necessary to ever calibrate the beta measurement system in the field.
- BAMs are calibrated to provide excellent agreement with FRM gravimetric standards when properly maintained and operated.
- Beta technology is virtually unaffected by the chemical composition of the sampled particulate.

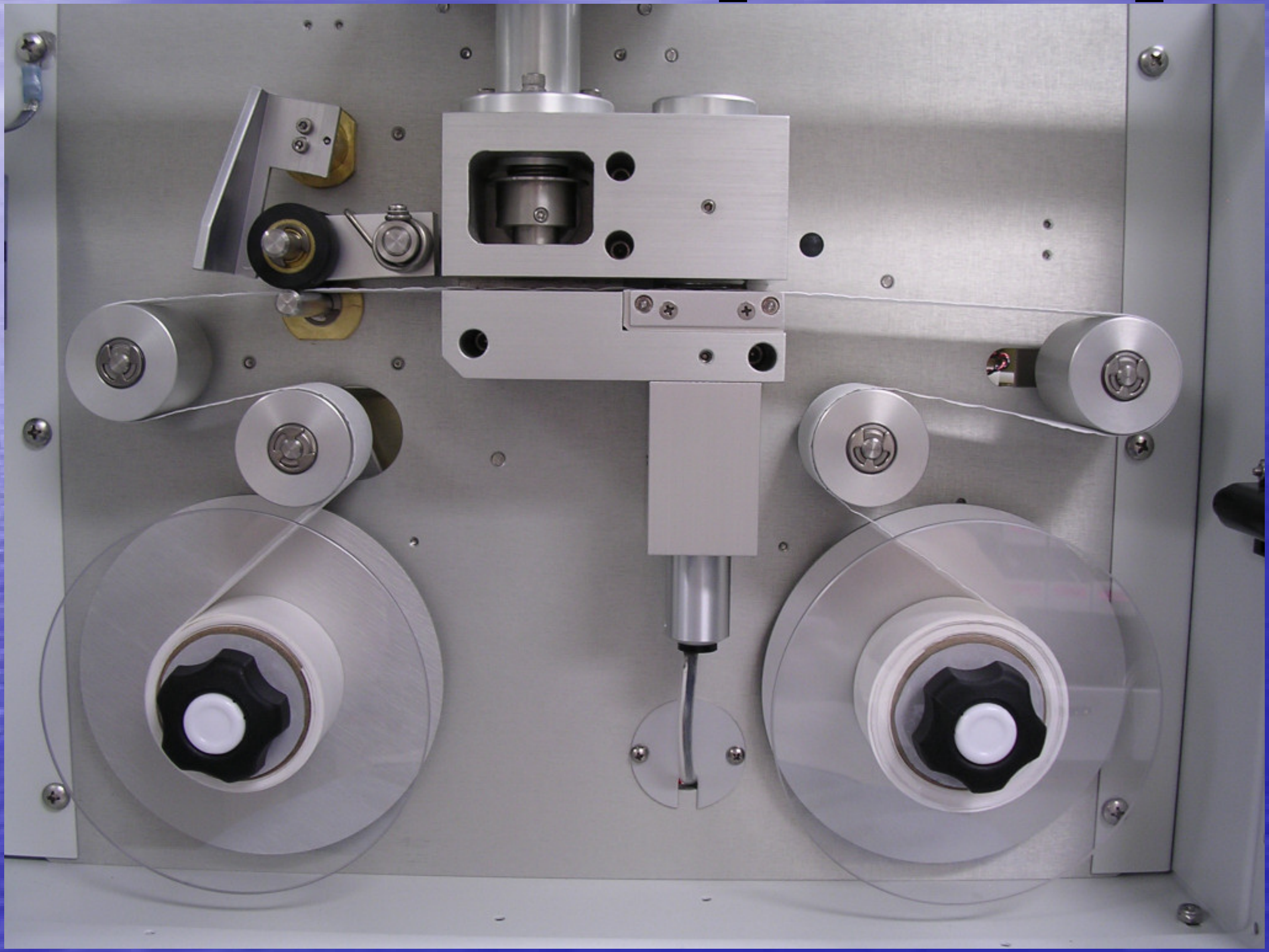
Beta Gauge Safety

- The BAM-1020 contains a small amount of ^{14}C (Carbon 14), a naturally occurring radioactive isotope of carbon, in the form of barium carbonate.
- Activity level of the 60 µCi ^{14}C source is similar to several commercial smoke detectors, and is licensed with the NRC under the same provisions.
- Sources with activity under 100 µCi require no special government licensing to own.
- Met One Instruments has an “Exempt Distribution License” from the US-NRC to distribute the beta sources.

Beta Gauge Safety

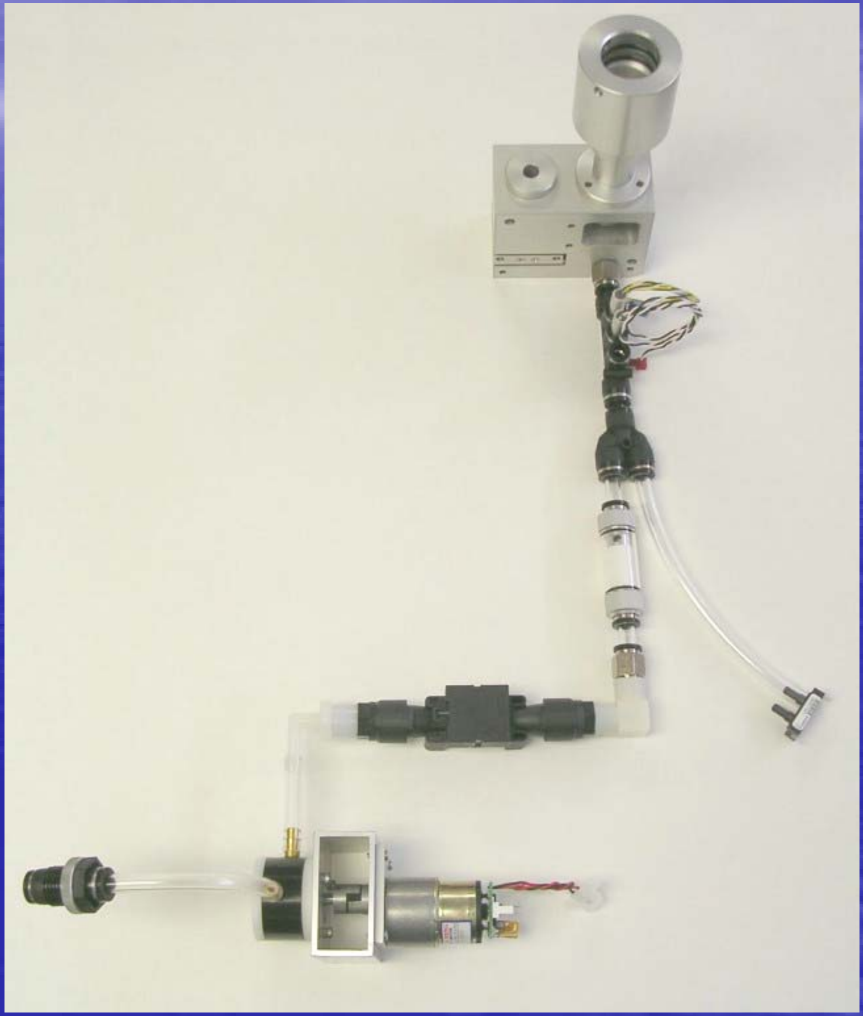
- Users are not required to take any specific precautions when handling the BAM-1020 unit.
- USA customers do not require any licenses to own a Met One beta gauge.
- The end user will never need to remove, replace, or handle the beta source.
- The unit may be returned to the factory for disposal at the end if its service life, although this is not required.

BAM-1020 Tape Transport



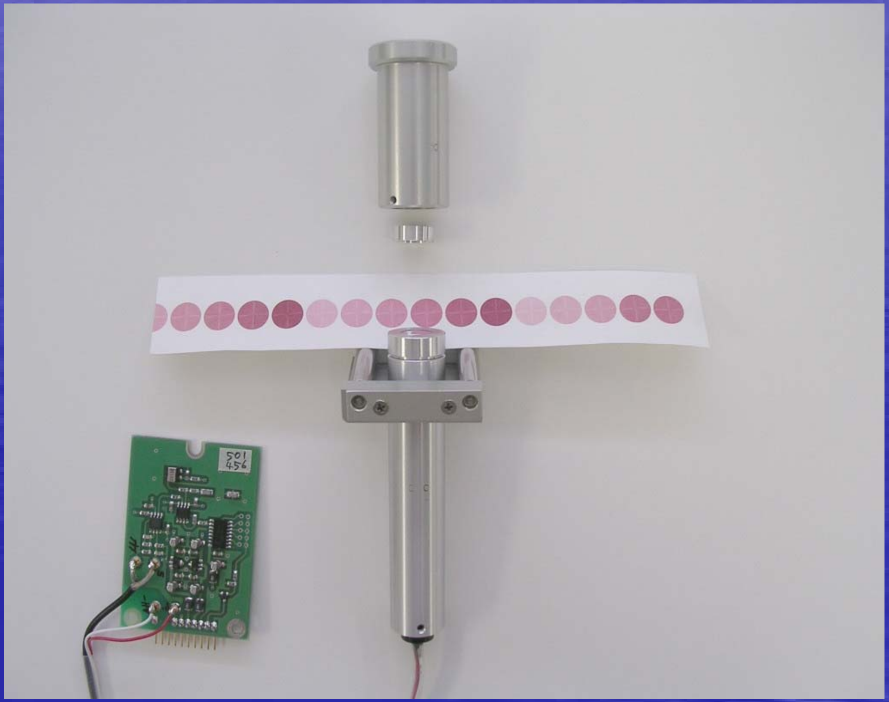
Simplicity – Flow System

- The BAM-1020 airflow system consists of a few simple components:
  - Inlet/Nozzle
  - Filter Temp/RH/BP sensors
  - Debris filter
  - Honeywell mass flow sensor
  - Flow controller
  - Pump (external)



Simplicity – Measurement System

- The BAM-1020 measurement system consists of a few components:
  - Carbon 14 Beta source
  - Filter tape control system
  - Photomultiplier detector
  - Preamp circuitry
  - Automatic hourly span check



Simplicity – Data System

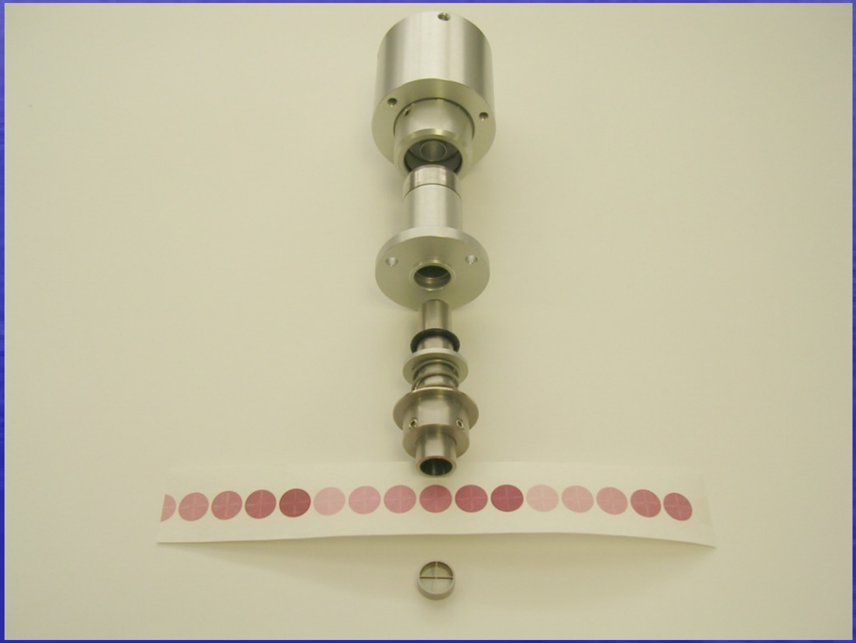
- The BAM-1020 data system consists of the CPU, data reports, user interface, error handling system, and telemetry.
- All units are equipped with a six channel external data logger for external sensors.
- The BAM-1020 may also function as a sensor in a larger data collection system using an external datalogger.

Critical Checks

- **Leak Check, Flow Check, Nozzle Cleaning!**
- The flow system should be calibrated or verified on a regular basis. Flow errors affect the concentration.
- A leak check is performed with every flow check. Leaks cause measurement errors, and the unit cannot automatically detect a leak.
- The nozzle and support vane must be cleaned to prevent leaks and tape damage.
- The nozzle and vane may need to be cleaned more frequently in humid environments.

Critical Checks

- The nozzle seal against the filter tape is important for proper airflow regulation.
- The nozzle and support vane need to be cleaned at least as often as the filter tape is changed.



BAM-1020 Span Check

- The BAM-1020 makes an automatic span check each hour by measuring a Mylar calibration foil with a constant and known mass density.
- No calibration changes are made based on the span check however.
- If the span check falls outside of an acceptance band, an error is generated.
- The span check may be manually audited.

Measurement Challenges

- Environmental conditions can play a role in the accuracy of beta attenuation measurements. The main factors are:
  - Enclosure internal air temperature stability.
  - Relative humidity and sample moisture.
  - Electromagnetic and radio interference sources.

Measurement Challenges

- Enclosure Temperature Stability:
  - The BAM-1020 should be in a stable temperature environment, to the extent possible.
  - The exact temperature is not critical as long as it is fairly stable during the hour.
  - Changes in air density between the source and detector may be measured as mass noise.

Measurement Challenges

- Humidity:
  - The filter tape is semi-hydrophobic, but particulate on the tape is not.
  - Moisture accumulation on the sample spot may be measured as mass noise.
  - BAM-1020 uses smart heater technology to lower the RH of incoming air to about 35%.
  - Mild heat and hourly spot changes limit the effects on VOCs.
  - Humid conditions can increase nozzle fouling.

Electromagnetic Interference

- Sources of high RF energy may cause noise in the BAM-1020 if in close proximity. Examples: Radio towers or cell antennas in very close proximity.
- Sources of high EMI fields may cause noise in the system. Examples: Large AC motors, Medical imaging equipment.
- Static electricity (ESD) may cause measurement errors.
- Lightning strike on the inlet will damage the unit.
- Solutions: Proper site selection and grounding.

Conclusion

- Met One Instruments, Inc. is constantly testing and experimenting to improve the beta gauge product lines and documentation.
- We welcome suggestions for future improvements.

Supplemental Materials

- BAM-1020 Manual: Completely reorganized and rewritten for more value to the operator and administrator. Available in electronic format for SOPs. Current Revision G.
- BAM-1020 data sheet and specifications: Dependable and defensible.
- www.metone.com BAM users area:
  Login: metone   Password: oregon

Contacts

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