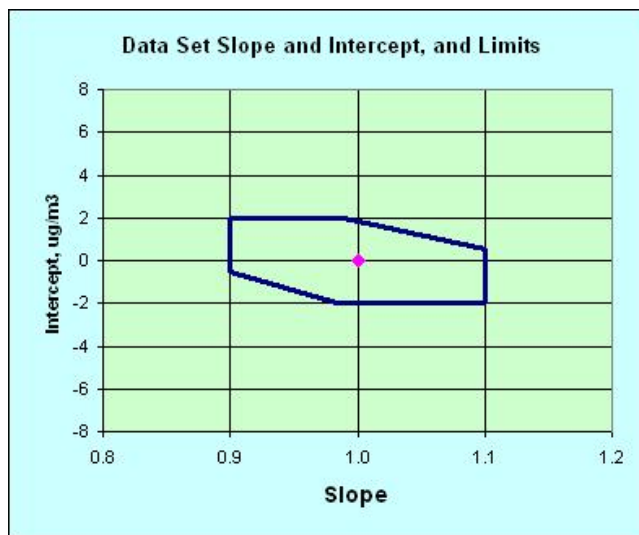


What is the Difference Between the New BAM-1020 PM2.5 FEM and Older BAM-1020 Monitors?

The Met One Instruments, Inc model BAM-1020 was the first instrument to obtain U.S. EPA Class III Federal Equivalent Method (FEM) designation for PM2.5 continuous particulate monitoring. In order to meet the requirements for the designation, the BAM-1020 was updated with a series of design improvements. These design improvements were required because of several general factors:

- The EPA criteria for PM2.5 FEM designation testing are much more strenuous than the older criteria for PM10 designation. Only a narrow range of slope and offset characteristics are allowed.
- PM2.5 particulate levels are, by nature, much more difficult to measure than PM10 or TSP due to normally low ambient concentrations. Measurement errors of just a couple of micrograms can result in large proportional errors. Also, volatile compounds are often a significant proportion of PM2.5, causing measurement difficulties for both FRM filter samplers and continuous monitors.



U.S. EPA acceptance window for FEM candidate monitors, showing allowable combinations of slopes and offsets.

The BAM-1020 was designated as a PM10 FEM in 1998, and since then thousands of units have been deployed worldwide. Some BAM-1020 users would add a PM2.5 Sharp-Cut Cyclone (SCC, Met One BX-807) or WINS Impactor (Met One BX-804) to these earlier BAMs in order to measure PM2.5 levels for particulate studies, even though this was not an EPA-designated method. Field test results from this early type of PM2.5 configuration showed that the BAMs needed some minor design upgrades before PM2.5 designation:

- The BAM-1020 slopes (multiplier) when compared to PM2.5 FRM filter samplers in linear regressions of 24 hour average measurements, were typically adequate and usually between 0.9 and 1.1, as long as the sample RH was properly controlled and there was a reasonable variety of concentration levels in the data set.
- There was typically a small positive Y-intercept offset (additive bias) of about +2 to +3 micrograms in the linear regressions of the BAM compared to an FRM.

- The hourly noise levels of the earlier BAMs made accurate measurements in concentrations below about 10 micrograms difficult.
- The old wrap-around inlet heaters often did not adequately control the sample RH levels in higher humidity environments. Controlling the sample RH to 35% results in better correlation results.

As a result of these characteristics, design improvements for the BAM-1020 were developed by Met One Instruments during 2006. Improvements were made to the BAM-1020 hardware, firmware, accessories, and calibration:

Hardware:

- The entire BAM-1020 mechanical tape control “transport” system was redesigned for filter tape positioning accuracy of better than 0.001 inch (0.025mm) on all axis. This reduced the hourly noise band of the BAM by ensuring that the exact same point of filter tape is measured clean and dirty.
- The beta source was moved 25% closer to the filter tape, increasing the count rate and improving the signal-to-noise ratio.

Firmware:

- The beta count time for the hourly clean spot (I_0) and the dirty spot (I) count periods was increased from 4 minutes to 8 minutes as a required setting for all PM2.5 FEM units, improving the statistical noise stability by 40%, known as the “2X” effect. This reduced the hourly noise band of the BAM.
- The flow calibration was changed to a three-point slope instead of a single point calibration. This improved the dynamic flow control accuracy.
- Extra flow statistics data files were added, similar to those in FRM samplers.

Accessories:

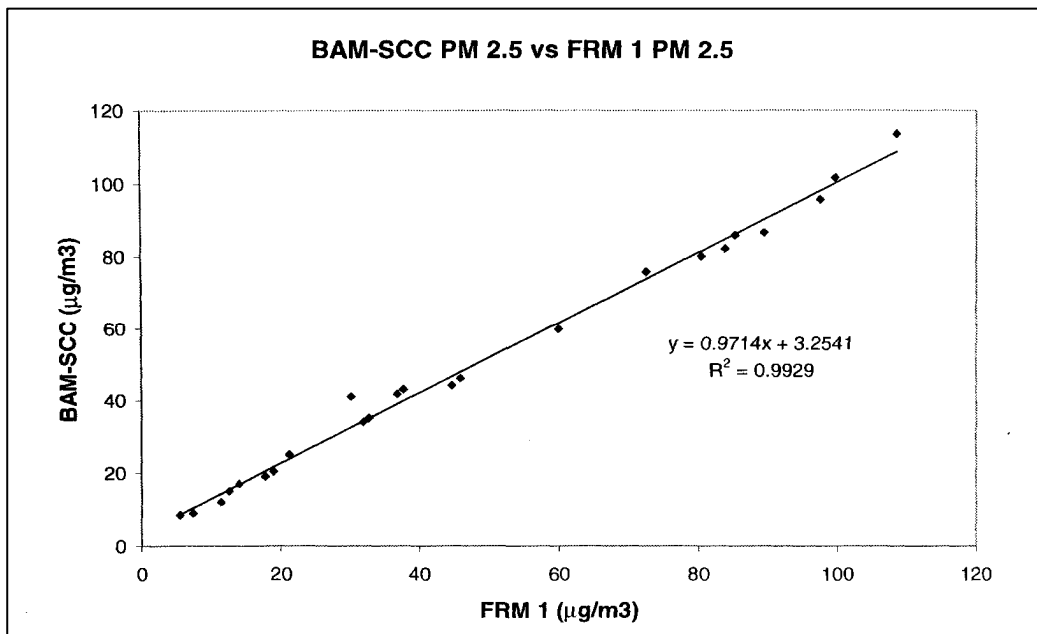
- The BX-596 ambient temperature and barometric pressure combination sensor was developed as a required accessory for the PM2.5 FEM BAM-1020. This provides a larger -40 to +55 C temperature range, and allows the BAM to measure the ambient pressure throughout the sample hour, improving flow control.
- The BX-302 zero filter kit was adapted as a required accessory for all PM2.5 FEM units. This allows users to adjust the background correction offset (BKGD) on each BAM to suit the local characteristics of the sample site. This improves the Y-intercept offset to near zero when compared to a collocated FRM sampler.
- The BX-827 or BX-830 Smart Heater with a 35% RH setpoint was adapted as a required accessory for PM2.5 FEM units. This controls the sample RH levels to prevent measurement errors due to moisture mass, while limiting affects on volatile compounds.
- The BX-961 automatic flow controller was changed from optional to a standard part on all BAMs, and is required for all PM2.5 FEM BAMs, which all must use actual volumetric flow control.
- The BGI Inc. model VSCC-A PM2.5 Very-Sharp-Cut Cyclone (Met One stock number BX-808) was adapted as the required PM2.5 particle separator for the BAM-1020 PM2.5 FEM. This is because the VSCC is a U.S. EPA FRM designated particle separator, while the older SCC cyclones are not. The VSCC has improved PM2.5 cut-point characteristics compared to the SCC cyclones.

Calibration:

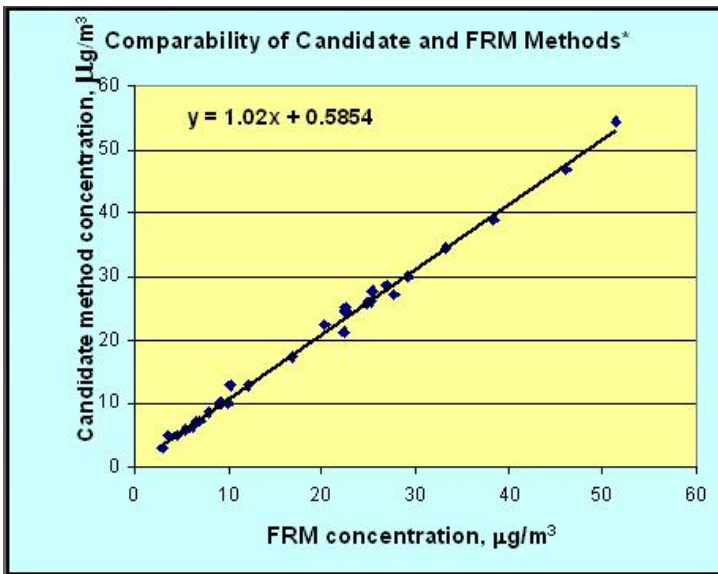
- The BAM-1020 calibration process was modified slightly to improve the accuracy of the unit in ambient concentrations below 50 micrograms.
- Test criteria were added to ensure the hourly noise levels of each BAM meet the specifications.

The result of these design improvements is that the BAM-1020 PM2.5 FEM units are more accurate for both hourly and 24 hour average PM2.5 measurements, and are able to pass the EPA PM2.5 FEM criteria as described in 40CFR part 53, when properly operated and maintained.

- The 24-hour average linear regression slopes of the BAM-1020 FEM compared to an FRM sampler are typically very close to one (1) when the filter RH control system is set properly and when there are is a reasonable variety of concentration levels in the data set.
- The Y-intercept of the linear regression between the BAM-1020 FEM and an FRM is typically within 1 microgram of zero, when the field background test with the zero filter has been done correctly, and data is collected digitally to prevent conversion errors.
- The standard deviation (sigma, σ) of the hourly noise band of the BAM improved from about 3.0 micrograms typical for old units, to about 1.8 micrograms typical on new FEM units. This results in an hourly detection limit (2σ) of typically less than 3.6 micrograms, and a 24-hour detection limit ($2\sigma/\sqrt{24}$) of typically less than 0.7 micrograms.



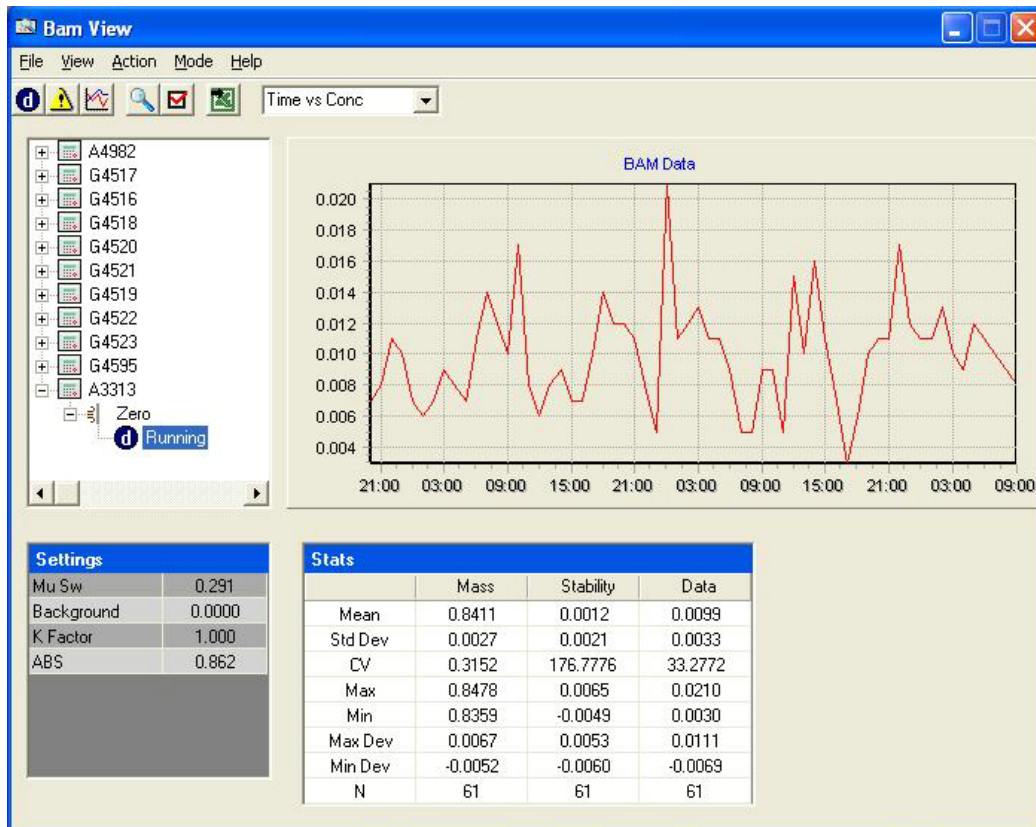
Linear regression of an older (unimproved) BAM-1020 compared to FRM, showing acceptable slope but typical positive Y-intercept offset.



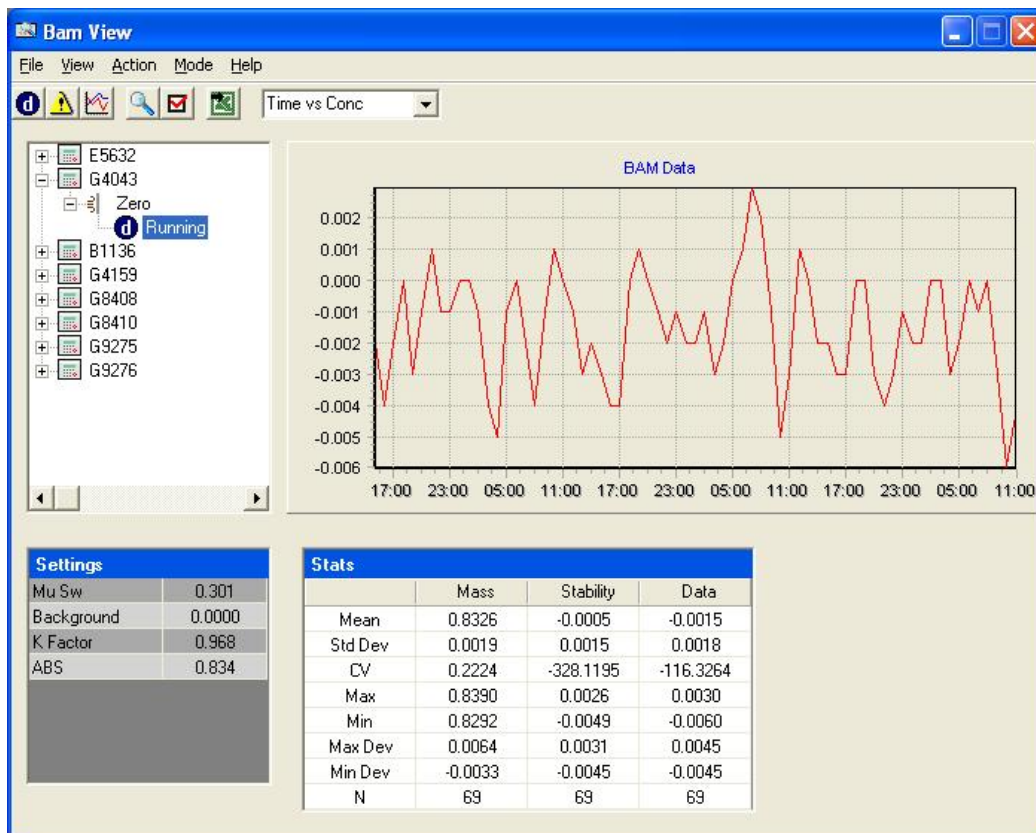
Regression statistics		Slope ¹	Intercept ²	Correlation (r)
Statistics for this test site:		1.020	0.585	0.99765
Limits for PM2.5 Class III	Upper:	1.100	1.586	
	Lower:	0.900	-2.000	0.95000
Test Results (Pass/Fail):		PASS	PASS	PASS



Linear regression and acceptance window of an improved PM2.5 FEM BAM-1020 compared to FRM, showing good results.



Zero filter test from an older (unimproved) BAM-1020 showing typical higher hourly noise levels (3.3 ug sigma).



Zero filter test from a new (improved) BAM-1020 with close geometry source, 8-minute counts, and improved tape transport showing typical lower hourly noise levels (1.8 ug sigma).

These improvements were released for new units in March, 2007. All BAM-1020 units built after this are PM2.5 FEM compatible when equipped with the appropriate firmware (Rev 3.2 or later) and the appropriate accessories. EPA PM2.5 FEM designation was officially obtained for the BAM-1020 in March 2008.

- PM2.5 FEM units must be equipped with the BX-808, BX-596, BX-302, BX-827 or 830, BX-802, and Rev 3.2.4 or later firmware.
- New PM10 BAMs have all of the latest hardware and calibration, and are exactly the same as PM2.5 FEM units, except that they have different firmware (only 4-minute beta counts allowed), and the extra accessories such as the BX-808 cyclone, BX-302 zero filter, and BX-596 AT/BP sensor are not required.
- All PM2.5 FEM BAM-1020 units can still be used for PM10 by simply removing the VSCC cyclone and changing a few settings in the user-interface.
- Older BAM-1020 units built after 2003, but before March, 2007 (serial numbers starting with D, E, and F) can usually be upgraded to the PM2.5 FEM type. This upgrade can only be done at the Met One factory, because a full recalibration is necessary. All upgraded units will be tested to meet new-unit specifications. Contact the Technical Service Department.
- Old units built in 2003 or earlier (serial numbers starting with C, B, A, Z, Y, X) are generally too old to upgrade due to many obsolete parts. These may be traded in for a new unit at a significant discount. Contact the Sales Department.
