Best Practice Operation Of BAM-1020

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Denver Colorado

Agenda

- BAM-1020 History
- Best Practice Operation of BAM-1020

  Met One Service
- Product Improvement Plan
- Field Testing
- Conclusion

BAM-1020 History

- PM10 Designation in 1998
- PM2.5 FEM Designation in 2008
- PM-Coarse Designation in 2009
- More than 7,000 sold worldwide
- More than 600 sold in United States

Best Practices in BAM-1020 Operation

- Overview
- Set up
- Operation
- Maintenance

Product Training – Steve Wilson

- Provided to ensure that customer needs are always met.
- Custom designed to meet your specific needs
- Can be arranged through Met One Instruments service manager (Mike Putnam – service@metone.com
- 541-244-3633

STANDARD OPERATIONAL PROCEDURE

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:

		BAM	Ref. Std.		BAM	Ref. Std.	
Leak Check Value:	as found:	lpm		as left:	lpm		
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 ☐

DAC 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
Clock Time/Date			FLOW TYPE			AP		
RS232 baud			Cv			FRl		
STATION #			Qo			FRh		
RANGE			ABS			Password		
BAM SAMPLE			µ sw			Cycle Mode		
MET SAMPLE			K Factor			RH Control		
OFFSET			BKGD			RH Setpoint		
CONC UNITS			STD TEMP			Datalog RH		
COUNT TIME			HEATER			Delta-T Control		
FLOW RATE			e1			Delta-T Setpoint		
CONC TYPE			Errors			Datalog Delta-T		

Last 6 Errors in BAM-1020 Error Log

Error	Date	Time	Error	Date	Time
1			4		
2			5		
3			6		

Audit Notes:

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 data logger if used	Monthly
Check or set BAM real-time clock	Monthly
Replace filter tape roll.	2 Months
Run the SELF-TEST function in the TAPE menu	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 73 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 in for major repairs	

Heater Setup

```
Heater Setup
          RH Control:  YES
         RH Setpoint:  35%
          Datalog RH:  YES (Chan 4)
     Delta-T Control:  NO
    Delta-T Setpoint:  99 C
     Datalog Delta-T:  YES (Chan 5)
  SAVE                            EXIT
```

RH Sensor Calibration

- During RH calibration, it is ***essential*** that the RH sensor be at ambient temperature.
- Failure to do this may lead to improper operation of the smart heater and erroneous results
- Recommend leaving it at default setting.

FILTER RH CALIBRATION

BAM: 32.5 %

REFERENCE: 33.1 %

CALIBRATE RESET Exit

Zero/BKGD TEST

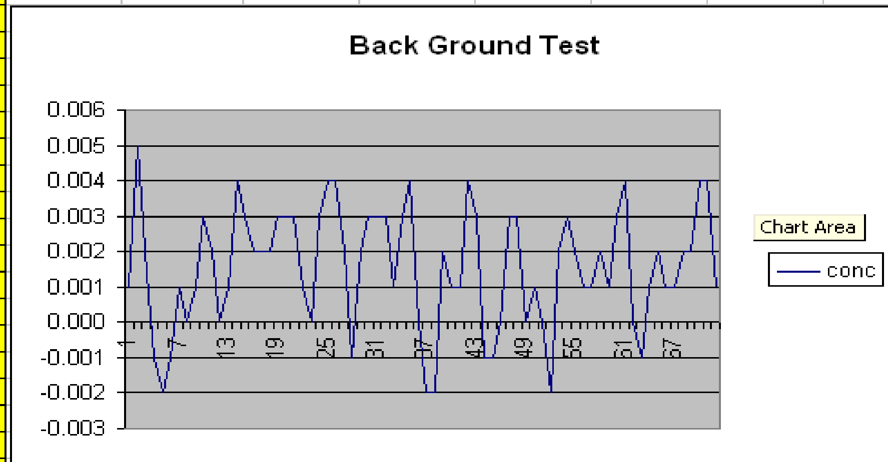
The primary purpose of the test is to fine-tune the Background Offset (BKGD) value in the BAM-1020 to compensate for minor variations in local site conditions,

Zero/BKGD Procedure – cont.

- Under conditions of high T/high RH:
  - Hepa filter may be placed inside structure/shelter for convenience and to avoid aspiration of rain water
  - Temperature gradients inside the shelter to be kept to less than 2°C/hour

Time	Concentration
10/1/2009 18:00	0.001
10/1/2009 19:00	0.005
10/1/2009 20:00	0.002
10/1/2009 21:00	-0.001
10/1/2009 22:00	-0.002
10/1/2009 23:00	-0.001
10/2/2009 0:00	0.001
10/2/2009 1:00	0.000
10/2/2009 2:00	0.001
10/2/2009 3:00	0.003
10/2/2009 4:00	0.002
10/2/2009 5:00	0.000
10/2/2009 6:00	0.001
10/2/2009 7:00	0.004
10/2/2009 8:00	0.003
10/2/2009 9:00	0.002
10/2/2009 10:00	0.002
10/2/2009 11:00	0.002
10/2/2009 12:00	0.003
10/2/2009 13:00	0.003
10/2/2009 14:00	0.003
10/2/2009 15:00	0.001
10/2/2009 16:00	0.000
10/2/2009 17:00	0.003
10/2/2009 18:00	0.004
10/2/2009 19:00	0.004
10/2/2009 20:00	0.002
10/2/2009 21:00	-0.001
10/2/2009 22:00	0.002
10/2/2009 23:00	0.003
10/3/2009 0:00	0.003
10/3/2009 1:00	0.003
10/3/2009 2:00	0.001

Avg	0.0010
Std Dev	0.0017



Zero/BKGD Test

```
CALIBRATE SETUP
                              FLOW RATE:  16.7
CONC TYPE: ACTUAL    FLOW TYPE: ACTUAL
       Cv:  1.047           Qo:  0.000
      ABS:  0.822          µsw:  0.306
        K:  1.005         BKGD: -0.0030
 STD TEMP: 25C          HEATER: AUTO
  SAVE                          EXIT
```

Grounding

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.

Chassis Grounding:

This should be attached to a ground rod for best operation of the unit.

EXTERNAL DATALOGGER INTERFACE SYSTEM

-selectable between voltage output (0-1 or 0-10 volt DC)

-Isolated current output (4-20 or 0-16 mA).

-One volt voltage output is almost exclusively used for analog data logging applications.

-Digital Data logger with the BAM-1020

BX-965 Report Processor

- Special back panel
- Allows uninterrupted access to stored data
- 2 USB Ports
- Ethernet capability

Recommended Additional Options

- BX-308 Service Tool Kit - Basic
- BX-344 BAM Inlet Cleaning Kit

Summary – Operational Procedure

- BAM-1020 performance good when it is properly operated and maintained
- Met One working on an improvement for performance issues that are seen at some sites (high T/RH)

BAM Correlation with FRM (Gobeli)

- Issues relate to both FRM and FEM
- Often the result of maintenance/operation/training issues on BAM-1020.

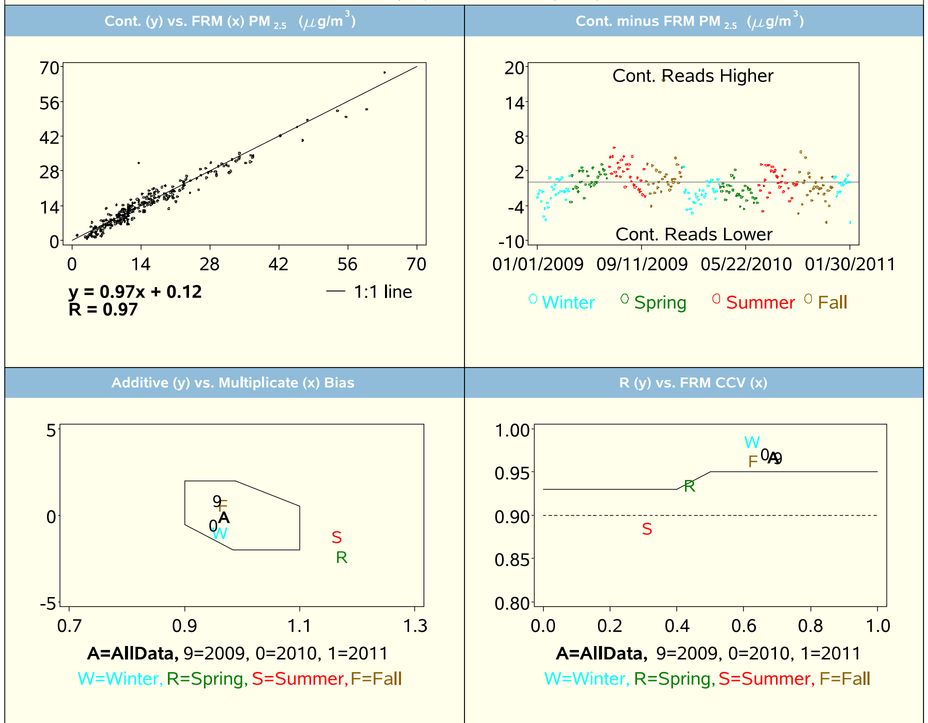
Poor Correlation with FRM (r^2<0.9)

- Insufficient dispersion in data set.
  – Need concentrations ranging from 0 - ~20 $\mu g/m^3$, adequately dispersed
- 24-hourly values must correspond to FRM cycle
- FRM issues

$PM_{2.5}$ Continous Monitor Comparability Assessment

Site 06-107-2002: Visalia, CA

FRM: R & P Model 2025 PM2.5 Sequential w/WINS-GRAVIMETRIC (118), PM2.5 - Local Conditions (88101)
Cont: Met-One BAM-1020 W/PM2.5 SCC-Beta Attenuation (731), PM2.5 Raw Data (88501)



Mean $PM_{2.5}$ ($\mu g/m^3$)

Dataset	N	FRM	Cont	Ratio (Cont/FRM)
AllData	**249**	**15.4**	**15.0**	**0.97**
Winter	71	19.9	18.3	0.92
Spring	60	9.2	8.6	0.94
Summer	58	11.6	12.4	1.07
Fall	60	19.8	19.9	1.00
2009	119	16.2	16.5	1.02
2010	120	13.6	12.6	0.92
2011	10	26.1	25.3	0.97

Appendix A Statistics

Dataset	N (all observations)	Bias	N (only >= 3 ug/m^3)	Bias
AllData	**249**	**-4.0**	**232**	**-0.9**
Winter	71	-11	65	-7.6
Spring	60	-12	50	-2.5
Summer	58	6.1	58	6.1
Fall	60	2.5	59	0.8
2009	119	3.0	116	4.3
2010	120	-11	106	-6.4
2011	10	-3.9	10	-3.9

Data Source: EPA AQS Data Mart

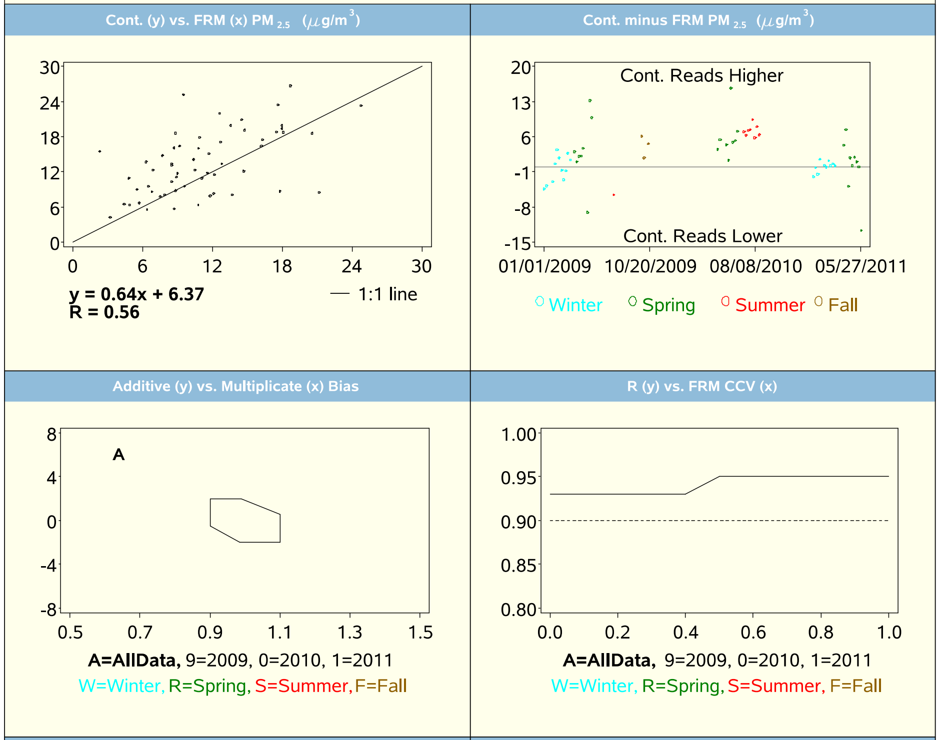
Generated on: March 2, 2012

Low multiplicative bias
Low additive bias
Very good correlation

PM2.5 Continous Monitor Comparability Assessment

Site 17-163-0010: East Saint Louis, IL

FRM: Andersen RAAS2.5-300 PM2.5 SEQ w/WINS-GRAVIMETRIC (120), PM2.5 - Local Conditions (88101)
Cont: Met-One BAM-1020 W/PM2.5 SCC-Beta Attenuation (731), Acceptable PM2.5 AQI & Speciation Mass (88502)



Mean PM 2.5 (µg/m3)

Dataset	N	FRM	Cont	Ratio (Cont/FRM)
AllData	**58**	**11.2**	**13.5**	**1.20**
Winter	21	12.7	12.5	0.98
Spring	25	9.7	12.6	1.30
Summer	9	13.3	19.0	1.43
Fall	3	7.3	11.4	1.57
2009	23	9.9	11.1	1.12
2010	16	11.6	18.1	1.57
2011	19	12.6	12.6	1.00

Appendix A Statistics

Dataset	N (all observations)	Bias (all observations)	N (only >= 3 ug/m^3)	Bias (only >= 3 ug/m^3)
AllData	**58**	**35.9**	**57**	**26.5**
Winter	21	-1.2	21	-1.2
Spring	25	59.1	24	37.6
Summer	9	47.5	9	47.5
Fall	3	67.5	3	67.5
2009	23	39.7	22	15.4
2010	16	63.5	16	63.5
2011	19	8.1	19	8.1

Data Source: EPA AQS Data Mart

Generated on: March 2, 2012

Poor multiplicative bias

Poor additive bias

Poor correlation

Additive (offset) Bias

- Usually easily correctable
- Verify BKGD, zero
- Logger/scaling issues
- Confirm logger values the same as digital stored values
- Verify FRM field blanks/trip blanks

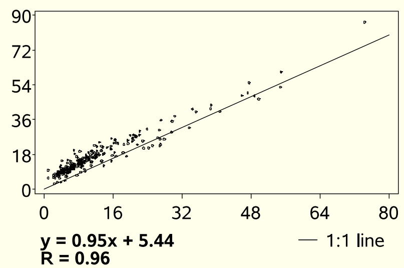
Example of additive (bias)

PM2.5 Continous Monitor Comparability Assessment

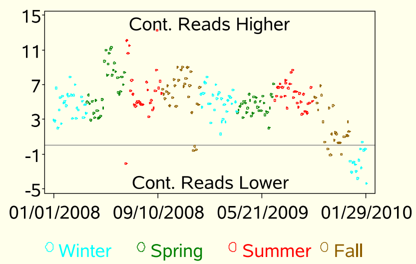
Site 06-067-0006: Arden-Arcade, CA

FRM: R & P Model 2025 PM2.5 Sequential w/WINS-GRAVIMETRIC (118), PM2.5 - Local Conditions (88101)
Cont: Met-One BAM-1020 W/PM2.5 SCC-Beta Attenuation (731), PM2.5 Raw Data (88501)

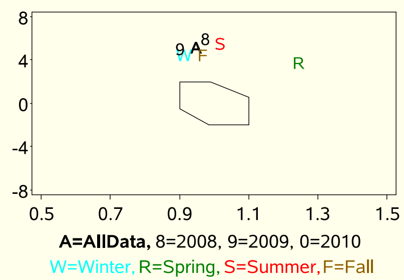
Cont. (y) vs. FRM (x) $PM_{2.5}$ ($\mu g/m^3$)



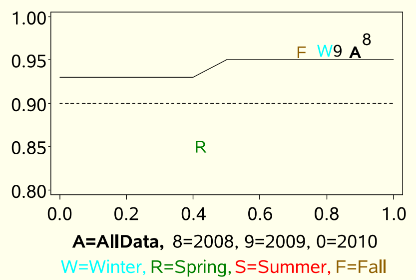
Cont. minus FRM $PM_{2.5}$ ($\mu g/m^3$)



Additive (y) vs. Multiplicate (x) Bias



R (y) vs. FRM CCV (x)



Mean $PM_{2.5}$ ($\mu g/m^3$)

Dataset	N	FRM	Cont	Ratio (Cont/FRM)
AllData	**244**	**12.2**	**17.0**	**1.39**
Winter	69	15.0	18.5	1.23
Spring	62	6.8	12.4	1.84
Summer	59	11.6	17.6	1.52
Fall	54	15.5	19.7	1.27
2008	118	13.4	19.3	1.44
2009	116	10.7	14.9	1.40
2010	10	16.1	14.2	0.88

Appendix A Statistics

Dataset	N (all observations)	Bias	N (only >= 3 ug/m^3)	Bias
AllData	**244**	**69.8**	**236**	**62.6**
Winter	69	54.4	65	45.8
Spring	62	95.6	60	92.1
Summer	59	86.6	57	70.6
Fall	54	41.7	54	41.7
2008	118	74.8	115	70.2
2009	116	71.5	112	60.7
2010	10	-8.1	9	-11

Data Source: EPA AQS Data Mart

Generated on: March 2, 2012

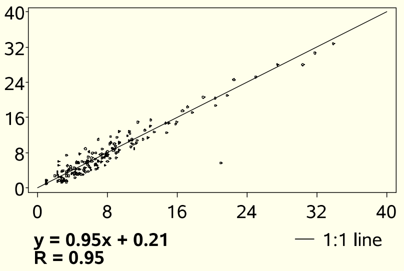
Results after correction of BKGD

PM2.5 Continous Monitor Comparability Assessment

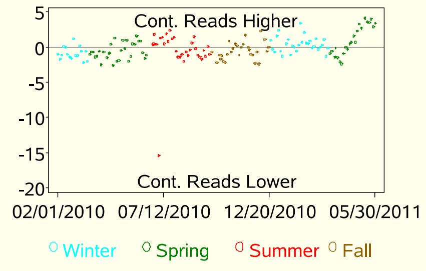
Site 06-067-0006: Arden-Arcade, CA

FRM: R & P Model 2025 PM2.5 Sequential w/WINS-GRAVIMETRIC (118), PM2.5 - Local Conditions (88101)
Cont: Met-One BAM-1020 W/PM2.5 SCC-Beta Attenuation (731), Acceptable PM2.5 AQI & Speciation Mass (88502)

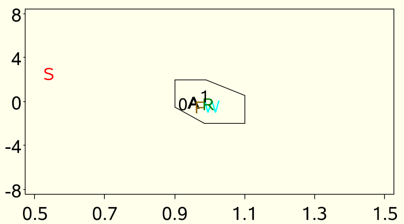
Cont. (y) vs. FRM (x) $PM_{2.5}$ ($\mu g/m^3$)



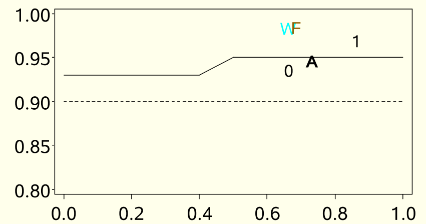
Cont. minus FRM $PM_{2.5}$ ($\mu g/m^3$)



Additive (y) vs. Multiplicate (x) Bias



R (y) vs. FRM CCV (x)



Mean $PM_{2.5}$ ($\mu g/m^3$)

Dataset	N	FRM	Cont	Ratio (Cont/FRM)
AllData	**158**	**8.1**	**7.9**	**0.98**
Winter	45	10.8	10.7	0.99
Spring	53	4.8	4.9	1.02
Summer	32	7.2	6.8	0.94
Fall	28	11.0	10.4	0.95
2009	0	.	.	.
2010	110	8.0	7.5	0.93
2011	48	8.3	9.0	1.08

Appendix A Statistics

Dataset	N (all observations)	Bias	N (only >= 3 ug/m^3)	Bias
AllData	**158**	**-0.7**	**131**	**-0.7**
Winter	45	0.7	40	-0.8
Spring	53	3.8	34	6.0
Summer	32	-5.2	29	-3.0
Fall	28	-6.3	28	-6.3
2009	0	.	.	.
2010	110	-7.7	95	-5.6
2011	48	15.4	36	12.2

Data Source: EPA AQS Data Mart

Generated on: March 2, 2012

Multiplicative Bias (slope >> 1 or << 1)

- Heater malfunction
- FRM handling issues
- Other

Performance Improvement Plan

- Met One service department is contacting all US customers operating BAMs and uploading data to AQS
- Goal is to fix obvious issues
- Improve comparability throughout the network

Performance Improvement Plan- Short Term

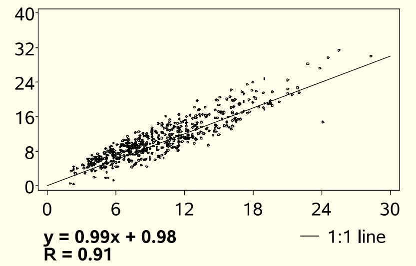
- Deviations can often be minimized by increased insulation of inlet tube (which we will provide free of charge to existing and future users)
- Deviations can also often be minimized by increasing the ambient temperature of the shelter into which the BAM is installed

PM2.5 Continous Monitor Comparability Assessment

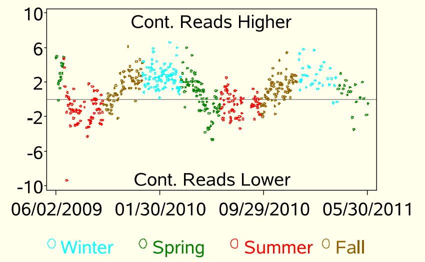
Site 37-183-0014: Raleigh, NC

FRM: R & P Model 2025 PM2.5 Sequential w/WINS-GRAVIMETRIC (118), PM2.5 - Local Conditions (88101)
Cont: Met One BAM-1020 Mass Monitor w/VSCC-Beta Attenuation (170), PM2.5 - Local Conditions (88101)

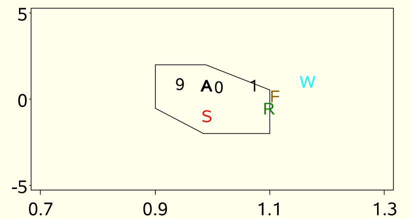
Cont. (y) vs. FRM (x) $PM_{2.5}$ ($\mu g/m^3$)



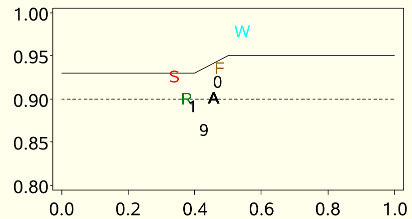
Cont. minus FRM $PM_{2.5}$ ($\mu g/m^3$)



Additive (y) vs. Multiplicate (x) Bias



R (y) vs. FRM CCV (x)



Mean $PM_{2.5}$ ($\mu g/m^3$)

Dataset	N	FRM	Cont	Ratio (Cont/FRM)
AllData	**530**	**9.9**	**10.8**	**1.09**
Winter	121	8.7	11.4	1.30
Spring	116	10.9	11.6	1.07
Summer	142	12.2	11.4	0.93
Fall	151	8.0	9.2	1.16
2009	169	10.0	10.5	1.05
2010	317	10.1	11.1	1.10
2011	44	8.2	9.8	1.19

Appendix A Statistics

Dataset	N (all observations)	Bias	N (only >= 3 ug/m^3)	Bias
AllData	**530**	**11.7**	**517**	**12.3**
Winter	121	33.9	118	33.8
Spring	116	6.6	113	8.6
Summer	142	-7.9	142	-7.9
Fall	151	16.5	144	17.5
2009	169	7.1	166	7.0
2010	317	12.8	309	13.5
2011	44	21.6	42	24.5

Data Source: EPA AQS Data Mart

Generated on: March 2, 2012

Winter readings higher than Summer readings

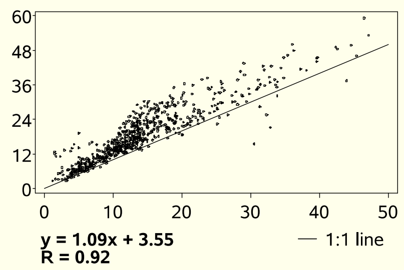
Summer readings higher than winter readings

PM2.5 Continous Monitor Comparability Assessment

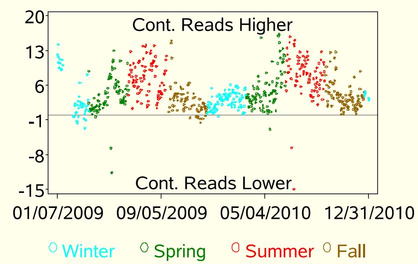
Site 06-065-8001: Rubidoux, CA

FRM: Andersen RAAS2.5-300 PM2.5 SEQ w/WINS-GRAVIMETRIC (120), PM2.5 - Local Conditions (88101)
Cont: Met One BAM-1020 Mass Monitor w/VSCC-Beta Attenuation (170), PM2.5 - Local Conditions (88101)

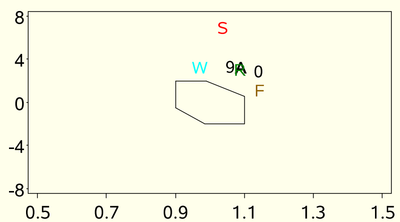
Cont. (y) vs. FRM (x) PM 2.5 ($\mu g/m^3$)



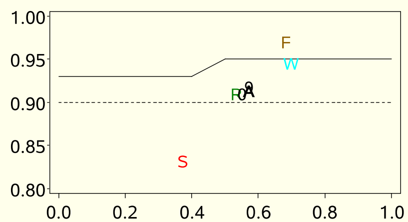
Cont. minus FRM PM 2.5 ($\mu g/m^3$)



Additive (y) vs. Multiplicate (x) Bias



R (y) vs. FRM CCV (x)



Mean PM 2.5 ($\mu g/m^3$)

Dataset	N	FRM	Cont	Ratio (Cont/FRM)
AllData	**647**	**14.2**	**19.0**	**1.34**
Winter	141	12.9	16.0	1.25
Spring	173	14.6	19.1	1.31
Summer	168	15.2	23.0	1.51
Fall	165	13.8	17.3	1.25
2008	0	.	.	.
2009	299	15.4	20.0	1.29
2010	348	13.1	18.1	1.39

Appendix A Statistics

Dataset	N (all observations)	Bias	N (only >= 3 ug/m^3)	Bias
AllData	**647**	**43.0**	**631**	**38.2**
Winter	141	51.9	134	34.2
Spring	173	37.1	172	35.1
Summer	168	54.7	168	54.7
Fall	165	29.7	157	27.5
2008	0	.	.	.
2009	299	42.7	291	34.5
2010	348	43.2	340	41.4

Data Source: EPA AQS Data Mart

Generated on: March 2, 2012

Field Tests – Long Term Improvement Plan

- BAM-1020 currently being field-tested at:
  - Dearborn, MI
  - Salt Lake City, UT
  - Mira Loma (Los Angeles Area) CA
  - Toronto area
  - Additional sites pending

Field Tests

- Goal of field tests is to develop performance enhancements for BAM-1020 which will:
  - Improve accuracy throughout the network
  - Improve reliability
- Improvement must be an “easy” enhancement to installed BAM-1020 PM2.5 FEM base.

Summary

- BAM-1020 performance good when it is properly operated and maintained
- Met One is currently working with customers whose BAM/FRM comparison needs improvement.
- We anticipate progress update by late summer