Met One Instruments, Inc

UK Report on the Equivalence of the Smart Heated PM_{10} BAM-1020

May 2014

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Table of Contents

List of Tables

List of Figures

TITLE OF THE METHOD

The following text has been approved by the UK Certification Committee as being an accurate description of the set-up of the instrument, and it is recommended that this text is repeated on the MCERTS certificate.

The instrument tested was the BAM-1020 measuring system consisting of the following parts:

- USEPA style PM_{10} sampling inlet operating at 16.67 l/min with louvered slats to prevent rain ingress;
- Sampling tube;
- Smart Heated Inlet (Part number BX830) set to limit the maximum relative humidity RH at the filter tape to 45 %. Smart heated inlet control by Delta T was set to 'NO';
- Ambient temperature sensor (BX-592), or optionally the combined pressure and temperature sensor (BX-596);
- BAM-1020 Beta Attenuation Mass Measuring system incorporating glass fibre filter tape programmed to perform hourly measurements with a 4 minute beta attenuation measurement at the beginning and end of every 50 minute sampling period;
- Vacuum pump and airflow controller set to ambient conditions.

The operation of instruments in permutations other than the above is not covered by this report, and is not recommended for approval without further consideration by the UK Certification Committee for the implications of any variations.

The standard filter tape used in the Met One BAM 1020 series of particulate monitors is made from glass fibre, which is commonly available. However, the filter tape used in the BAM 1020 series of instruments has critical and customised characteristics, and as such, all filter tapes should be obtained directly from Met One or from one of its authorised dealers. Met One has historically supplied a standard filter tape (product number 460130, manufactured by Sibata in Japan). This was employed in all the seven field test programmes discussed in this certificate. Thus in principle, this type of filter tape should be employed in any future use of instruments as equivalent methods. However, Met One has more recently qualified one additional tape manufacturer (Whatman, Germany, product number 460180) which has proven to be fully equivalent in terms of its physical properties, and also in terms of the filter tape producing equivalent results for ambient atmospheric particulate monitoring of $PM_{10.}$ The evidence supporting this has been reviewed in this Evaluation and considered to be satisfactory. The MCERTS certificate requires the use of one of the designated filter tapes discussed above in order to be approved within the scope of the MCERTS for UK Particulate Matter document.

EXECUTIVE SUMMARY

The Met One Instruments, Inc Smart BAM-1020 with USEPA style 16.67 l/min PM_{10} pre separator (herein referred to as the Smart Heated PM_{10} BAM-1020) has been tested in compliance with the requirements set out in the “Annex to the MCERTS Performance standards for Ambient Air Quality Monitoring Systems[1]” (herein referred to as MCERTS for UK Particulate Matter). The instrument is shown to meet the requirements and is suitable to be declared equivalent to the PM_{10} reference method in the United Kingdom (UK).

The Smart Heated PM_{10} BAM-1020 Candidate Method (CM) was tested against the European Reference Method (RM) over a series of seven field campaigns split between Germany (three tests), the UK (one test), Austria (two tests) and the Czech Republic (one test). The operation of the instruments was undertaken by TÜV Rheinland in Germany, the National Physical Laboratory (NPL) in the UK; the Austrian Environment Agency in Austria, and the Czech Hydrometeorological Institute (CHMI) in The Czech Republic. All organisations have appropriate ISO17025 accreditations which are included herein (Section 5). Calculations of the between sampler uncertainties of the Smart Heated PM_{10} BAM-1020 and the expanded uncertainties relative to the reference method were undertaken by Bureau Veritas (BV). These calculations were audited by TÜV Rheinland. BV has provided overall project management to the delivery of the programme in the UK.

A series of intensive laboratory tests was undertaken by TÜV Rheinland that go beyond the requirements set out in MCERTS for UK Particulate Matter. Additionally, the instruments were leak tested and flow tested by the ISO17025 accredited organisations throughout the seven field campaigns (Sections 8.1 and 8.2). The Maintenance Interval is discussed herein (Section 8.3). Data Capture has been calculated in accordance with MCERTS for UK Particulate Matter (Section 11).

Calculations of the suitability of the data relative to the pollution climate within the UK were undertaken by BV.

This report sets out the findings of the field campaigns, laboratory testing and pollution climate calculations. The report is structured to include the 17 numbered sections required in Section 6 of MCERTS for UK Particulate Matter[1]. This combined report is fully compatible with all the requirements of MCERTS for UK Particulate Matter[1], including its reporting structure. It will be used to provide the MCERTS Certification Body, and its certification committee, with the evidence required to assess whether all the testing carried out is compliant with all the requirements of MCERTS for UK Particulate Matter[1].

Sections of the report have been copied with permission from three TÜV Rheinland Reports:

i. The Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[2] which was published in 2006. This report considered three datasets collected in Germany, that each contained fewer than 40 data points;

ii. An addendum notice was published in 2012 that additionally considered datasets of greater than 40 points collected in the UK, the Czech Republic and Austria[3]. The addendum contains a detailed analysis of all the datasets, but does not contain any details on the laboratory tests, or the recommended maintenance and operational procedures;

1 Annex to the MCERTS Performance standards for Ambient Air Quality Monitoring Systems: Requirements of the UK Competent Authority for the Equivalence Testing and Certification of Automated Continuous and Manual Discontinuous Methods that Monitor Particulate Matter in Ambient Air. http://uk-air.defra.gov.uk/documents/MCERTS_for%20UK_Particulate_Matter_final.pdf

2 Report on the suitability test of the ambient air quality measuring system BAM-1020 with PM_{10} pre-separator of the company Met One Instruments, Inc. for the measured component suspended particulate matter PM_{10}. Report number 936/21205333/A dated 06 December 2006.

3 Addendum to the type approval test report of the measuring system BAM-1020 with PM_{10} pre-separator of the company Met One Instruments, Inc. for the component PM_{10} to the TÜV-report 936/21205333/A of Dec 06, 2006. Report number 936/21220762/A dated 12 December 2012.

iii. The $PM_{2.5}$ version of the instrument was certified in 2010 in Germany, and as such represents a more up to date study than the original PM_{10} report. Elements of this report discussing the suggested operational and maintenance procedures are therefore copied instead from the Smart Heated $PM_{2.5}$ BAM-1020 TÜV Rheinland Report[4].

Where text has been copied from the three TÜV Rheinland Reports it is clearly marked and placed within a light blue text box within this report. Within these Sections, text relating to German Legislation has been replaced with text relating to UK legislation; and some minor changes have been made for grammar. Sections have been added to discuss the implications of the findings of TÜV Rheinland for the UK.

Bureau Veritas wish to thank TÜV Rheinland and NPL for their contributions to this report.

4 Report on the suitability test of the ambient air quality measuring system BAM-1020 with $PM_{2.5}$ pre-separator of the company Met One Instruments, Inc. for the component $PM_{2.5}$. Report number 936/21209919/A dated 26 March 2010. www.qal1.de/en/hersteller/metone.htm

The following tables and notes summarise the findings in relation to MCERTS for UK Particulate Matter.

Certification Range: PM_{10} 0 to 1000 µg/m^3

Ambient temperature range: 5ºC to 40ºC

Table 1: Summary of the test results.

Test	Results	MCERTS Specification
Constancy of the sample volumetric flow	2.5% (Instruments 4924 and 4925)	To remain constant within ± 3% of the rated value
Tightness of the sampling system	0.6% (Instruments 4924 and 4925)	Leakage not to exceed 1% of the sampled volume
Maintenance Interval	One month	≥Two weeks
Data Availability	98.8%	≥90%
Number of UK Tests	1	≥1
Number of Reference Methods	2 for all sites but Tusimice where there was 1	≥1
Between sampler/instrument uncertainty for the standard method **PM_{10}**		
Full data set	0.59 µg/m^3	≤2 µg/m^3
<30 µg/m^3	0.43 µg/m^3	Not specified
≥30 µg/m^3	0.84 µg/m^3	Not specified

Table 1 Continued. *Summary of the test results.*

Test	Uncorrected	Slope Corrected	MCERTS Specification
Between sampler/instrument uncertainty for the candidate method **PM_{10}**			
Full data set	1.29 µg/m³	1.24 µg/m³	≤2.5 µg/m³
<30 µg/m³	1.14 µg/m³	1.10 µg/m³	≤2.5 µg/m³
≥30 µg/m³	1.58 µg/m³	1.53 µg/m³	≤2.5 µg/m³
Expanded uncertainty calculated at 50 µg/m³ for **Instrument Austria1**			
Full data set	16.0%	15.8%	≤25%
<30 µg/m³	42.8%	33.9%	Not specified
≥30 µg/m³	19.6%	20.1%	≤25%
Individual sites			
Graz	20.9%	20.0%	≤25%
Steyregg	9.3%	9.8%	≤25%
Expanded uncertainty calculated at 50 µg/m³ for **Instrument Austria2**			
Full data set	19.8%	17.3%	≤25%
<30 µg/m³	62.9%	52.6%	Not specified
≥30 µg/m³	22.7%	20.7%	≤25%
Individual sites			
Graz	26.1%	22.3%	≤25%
Steyregg	9.6%	11.6%	≤25%
Expanded uncertainty calculated at 50 µg/m³ for **Instrument J7860**			
Full data set (Tusimice)	18.5%	13.2%	≤25%
<30 µg/m³	40.5%	32.4%	Not specified
≥30 µg/m³	17.7%	13.0%	≤25%
Expanded uncertainty calculated at 50 µg/m³ for **Instrument J7863**			
Full data set (Tusimice)	18.2%	12.7%	≤25%
<30 µg/m³	33.7%	26.1%	Not specified
≥30 µg/m³	18.0%	12.9%	≤25%
Expanded uncertainty calculated at 50 µg/m³ for **Instrument 17011**			
Full data set (Teddington)	30.0%	22.4%	≤25%
<30 µg/m³	11.1%	5.5%	Not specified
≥30 µg/m³	Only 1 data point	Only 1 data point	≤25%
Expanded uncertainty calculated at 50 µg/m³ for **Instrument 17022**			
Full data set (Teddington)	22.3%	15.1%	≤25%
<30 µg/m³	13.5%	7.2%	Not specified
≥30 µg/m³	Only 1 data point	Only 1 data point	≤25%

Note 1: The instruments tested were operated with the standard measurement range of 0 to 1000 µg/m³ for hourly measurements. The maximum 24 hour average concentration recorded during the tests was 128.7 µg/m³.

Note 2: The CM does not fulfil the relevant Data Quality Objective of EU Directive 2008/50/EC when used without correction, therefore test results were also subjected to correction for each of intercept, slope and both slope and intercept. Expanded uncertainties for the Candidate Method were calculated for both uncorrected datasets as well as data that have been adjusted for slope and/or intercept. **Slope correction of dividing by 1.035 is required in order to make the Smart Heated PM_{10} BAM-1020 equivalent.** It is not necessary to correct for intercept, but it is essential that thorough and frequent on-going QA/QC procedures are employed (as prescribed in EN12341:2014[5] and

5 CEN Standard EN12341:2014 Ambient air - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2,5}$ mass concentration of suspended particulate matter.

CEN/TS16450[6]) including to precisely quantify analyser baseline performance and ensure that the instrument specific baseline correction factor programmed in to the instrument is correctly monitored and maintained.

Table 2: Summary of the slope, intercept and expanded uncertainties with and without slope and/or intercept correction.

Smart Heated PM_{10} BAM-1020	Calculated slope of all paired data	Calculated intercept of all paired data (µg/m^3)	Expanded uncertainty of all paired data	Range of individual expanded uncertainties
Uncorrected data	1.035	0.947	17.4%	9.3% to 30.0%
Data corrected for intercept by subtracting 0.947	1.035	0.000	15.4%	9.0% to 26.3%
Data corrected for slope by dividing by 1.035	1.000	0.924	13.8%	9.8% to 22.4%
Data corrected for slope and intercept by subtracting 0.947 and then dividing by 1.035	1.000	0.009	13.4%	11.4% to 21.6%

Note 3: In order to be consistent with the 2012 TÜV Rheinland Report[2], in this report the instruments tested have been referred to by the serial numbers and acronyms provided by the site operators. The true serial numbers as designated by the manufacturer and the corresponding manufacture year are summarised in *Table 3.*

Table 3: Details of the instruments deployed in this study

Descriptor assigned in this report	Serial number assigned by manufacturer	Build Year
4924 (Lab Tests)	E4924	2005
4925 (Lab Tests)	E4925	2005
Austria 1 (Field Tests)	G8210	2007
Austria 2 (Field Tests)	G8211	2007
J7860 (Field Tests)	J7860	2009
J7863 (Field Tests)	J7863	2009
17011 (Field Tests)	G2757	2007
17022 (Field Tests)	G4044	2007

Note 4: A study of pollution climate relevant to sites in the UK, the Czech Republic and Austria has demonstrated that in all cases the particulate geometric mean criteria are met and at least one site

6 CEN Technical Specification CEN/TS16450:2013 Ambient air - Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2,5}$)

meets the lower threshold and higher threshold criterion for wind speed, ambient temperature, ambient dew point and semi volatile nitrate content. The pollution climate criteria are satisfied for all the equivalence tests.

Note 5: For the purposes of quality control of these monitors in the field, as with all PM instruments that are not the reference method, the Smart Heated PM_{10} BAM-1020 should be calibrated on a test site at intervals against the gravimetric reference method EN12341:2014 (that has recently replaced EN 12341:2014[7] and EN 14907[8]) and as given in the recommendations of the GDE 2010[9] and CEN/TS16450[6].

Note 6: Three German datasets of Cologne Parking Lot; Titz-Rödingen; and Cologne Frankfurter Strasse each had fewer than the required 40 data points, but were included in the 2012 TÜV Rheinland Report at the request of the German Certification Committee. The conclusion of the TÜV Rheinland Report when considering all seven datasets was that slope correction of dividing by 1.034 is required in order to make the instrument equivalent. For UK purposes it is necessary to consider only those datasets with greater than 40 data points. It has been shown that when considering only the four datasets with greater than 40 data points that it is required to slope correct by a slightly different constant; namely: **slope correction of dividing by 1.035 is required in order to make the Smart Heated PM_{10} BAM-1020 equivalent.**

Note 7: A comprehensive set of laboratory tests were undertaken by TÜV Rheinland and are discussed in the TÜV Rheinland report. It is not necessary to review the results of these tests under the MCERTS for UK Particulate Matter certification scheme.

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7 CEN Standard EN 12341:1998. Air Quality – Determination of the PM_{10} fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods.

8 CEN Standard EN 14907:2005. Reference Gravimetric Measurement Method for the Determination of the $PM_{2.5}$ mass fraction of suspended particulate matter in Ambient Air.

9 Guidance for the Demonstration of Equivalence of Ambient Air Monitoring Methods, EC Equivalence Group, January 2010, http://ec.europa.eu/environment/air/quality/legislation/pdf/equivalence.pdf

GENERAL INFORMATION

1. Summary of Principles of the Candidate Method

1.1 Measuring Principle

The following text is copied with minor alterations from Section 3.1 of the 2006 Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[2].

The ambient air measuring system BAM-1020 is based on the measuring principle of beta-attenuation.

The principle of the radiometric determination of mass is based on the physical law of attenuation of beta-rays when passing a thin layer of material. There is the following relationship:

$$c\left(\frac{\mu g}{m^3}\right) = \frac{10^6 A(cm^2)}{Q\left(\frac{l}{min}\right)\Delta t(min)\mu\left(\frac{cm^2}{g}\right)} \ln\left(\frac{I_0}{i}\right)$$

where:

C	particle-mass concentration	A	sampling area for particles (filter spot)
Q	sampling flow rate	Δt	sampling time
µ	mass absorption coefficient	I_0	beta count rate at the beginning (clean)
I	beta count at the end (collect)		

The radiometric determination of mass is calibrated in the factory. During routine operation of the instrument this is checked hourly both on the clean filter prior to collection of the sample and using the built-in reference foil. The values obtained can be compared with any stability requirements (such as drift effects) relative to the values obtained during factory calibration.

1.2 Functionality of the Measuring System

The following text is copied with minor alterations from Section 3.2 of the 2006 Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[2].

The particle sample passes the PM_{10}-sampling inlet with a flow rate of 1 m³/h and arrives *via* the sampling tube at the measuring instrument BAM-1020.

Within the scope of the test work, the measuring system was operated with the sample heater BX-830 (Smart Inlet Heater).

The heater can be controlled *via* two methods:

1. The maximum relative humidity RH at the filter tape (factory setting: 45 %)
2. The temperature difference Delta-T between ambient temperature and temperature at the filter tape (factory setting: 5 °C)

As soon as the relative humidity RH is 1 % below the nominal value or the critical value for Delta-T is exceeded, the heater is switched off. When operating with both methods simultaneously, the criterion for Delta-T is given priority by the system, which means that if the relative humidity RH is above the nominal value, yet the value for Delta-T is above or equal the critical value, the heater is switched off.

During the test work, the candidates were installed in an air-conditioned trailer. In this configuration, the control of the heater by the Delta-T criterion is not feasible. For this reason, the heater was only controlled by RH during both the laboratory and field tests.

The particles are collected on the glass fiber filter tape for subsequent radiometric measurement.

One measurement cycle (including automatic check of the radiometric measurement) consists of the following steps (setting: measuring time for radiometry 4 min):

1. The initial count of the clean filter tape I_0 is performed at the beginning of the cycle for a period of four minutes.
2. The filter tape is advanced four windows and the sampling (vacuum pumping) begins on the spot in which I_0 was just measured. Air is drawn through this spot on the filter tape for approximately 50 minutes.
3. At the same time the second count I_1 occurs (at a point on the tape 4 windows back) for a period of four minutes. The purpose of the measurement is to perform the verification for instrument drift caused by varying external parameters such as temperature and relative humidity. A third count I_2 occurs with the reference membrane extended over the same place on the tape. Four minutes before the end of sampling time, another count I_{1x} occurs on the same point of the tape. With the help of I_1 and I_{1x}, the stability at the zero point can be monitored.
4. After sampling, the filter tape is moved back four windows to measure the beta ray absorption through the section that has collected dust (I_3). Finally the concentration calculation is performed to complete the cycle.
5. The next cycle begins with step 1

During the suitability test work, a cycle time of 60 min with a time need of 4 min for the radiometric measurement was set.

Therefore the cycle time consists of 2 x 4 min for the radiometric measurement (I_0 & I_3) as well as approximately 1-2 min for filter tape movements. Thus the effective sampling time is around 50 min.

Figure 1 gives an overview on the sampling- and measurement part of the BAM-1020, *and Figure 2 shows an overview of the timing* schedule within the instrument.

Figure 1: Overview of the sampling and measurement part of the BAM-1020.

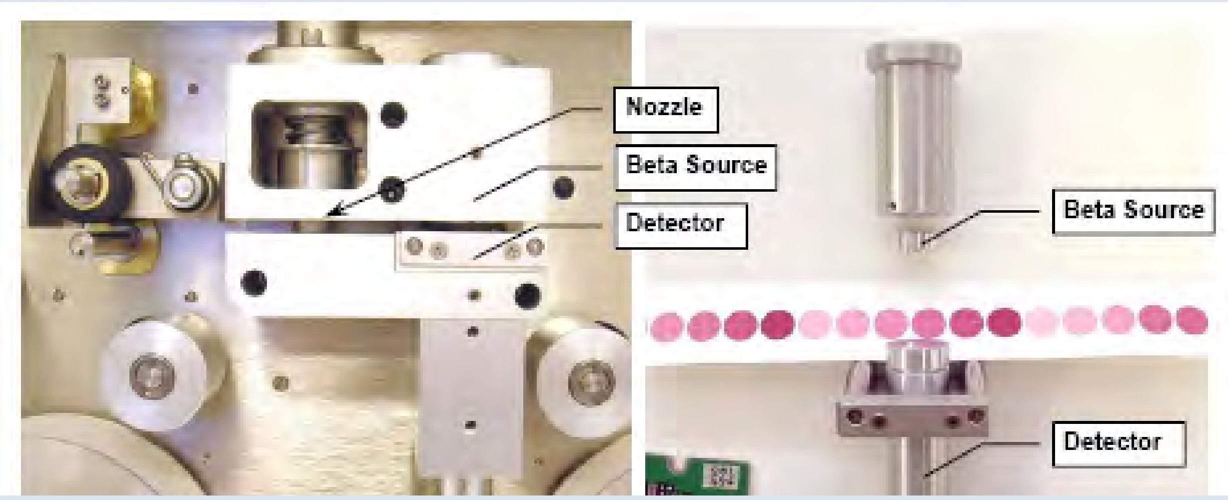
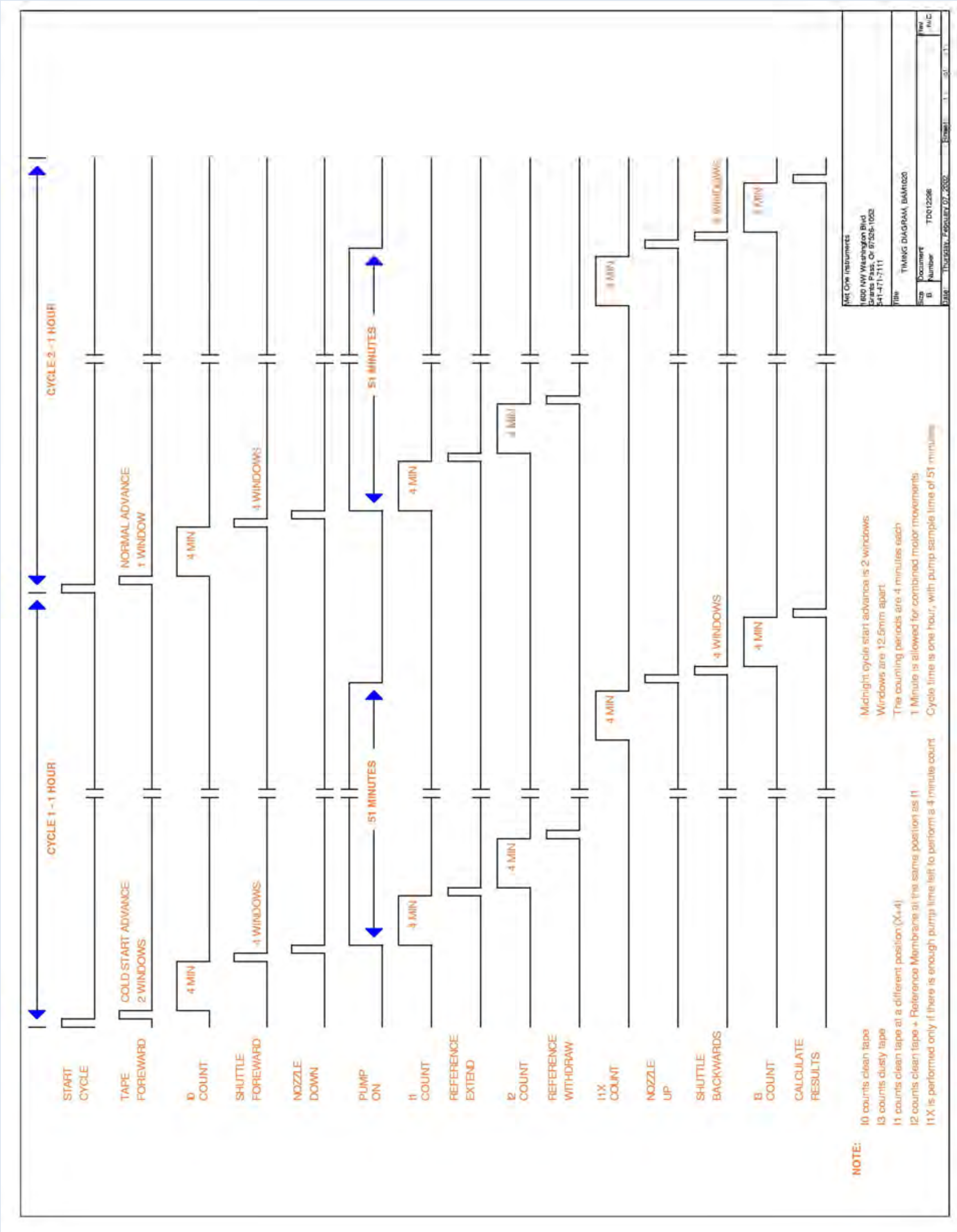


Figure 2: Timing diagram of the measurement cycle BAM-1020



1.3 Candidate Instrument Scope and Layout

The following text is copied from Section 3.3 of the of the 2006 Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report [2] as well as Section 3.3 of the Smart Heated $PM_{2.5}$ BAM-1020 TÜV Rheinland Report[4]. This Section has been edited in order to remove repetition between the two source reports and to reduce the number of photographs. In accordance with the requirements of MCERTS for UK Particulate Matter[1], discussion on the operating procedures of the instrument is given in Appendix A. The manual for the BAM-1020 is given in Appendix F.

The ambient air measuring system BAM-1020 is based on the measuring principle of beta-attenuation. A diagram of the instrument is given in Figure 3.

The tested measuring system consists of the PM_{10}-sampling inlet (BX-802) (Figure 4), the sampling tube, the sample heater (BX-830) (Figure 5), the combined pressure and temperature sensor (BX-596) (including radiation protection shield, as an alternative the ambient temperature sensor (BX-592)), the vacuum pump (BX-127), the measuring instrument BAM-1020 including glass fiber filter tape (Figure 6 and Figure 7), the respective connecting tubes and lines as well as adapters, the roof flange as well as the manual in English language.

The measuring instrument BAM-1020 offers the possibility to connect up to 6 different sensors at the available analogue inputs. For example, besides the combined pressure and temperature sensor (BX-596) or the the ambient temperature sensor (BX-592), the connection of sensors for the air pressure BX-594, the wind direction (BX-590), for the wind velocity (BX.591), for the air humidity (BX-593) as well as for solar radiation (BX-595) is possible.

Concerning the sampling inlets, a US-PM_{10} sampling inlet (type: BX-802, manufactured according to Guideline EPA 40 CFR Part 50) is available. This has with louvered slats to prevent rain ingress. The sampling inlet serves as a pre-separator for the suspended particulate matter in the fraction PM_{10}. The instruments are operated with a constant, regulated volume flow of 16.67 l/min = 1.0 m³/h.

The sampling tube connects the sampling inlet and the measuring instrument. Differing lengths can be used dependent upon the local site requirements.

The sample heater BX-830 is installed at the lower end of the sampling tube (approximately 50 mm above the instrument inlet of BAM-1020). The operation of the heating systems is performed as described in point 3.2.

The vacuum pump BX-127 is connected to the measuring instrument at the end of the sampling path with a hose. The pump is controlled *via* the measuring system on actual volume in relation to the ambient conditions (Mode ACTUAL).

The measuring system BAM-1020 contains, besides the radiometric measurement part, the glass fiber filter tape including transport system, large parts of the pneumatic system (flow measurement by mass flow sensor), the control unit of the sample heater and all necessary electronic parts and microprocessors for the control and operation of the measuring system as well as for communication with the system.

Figure 3: Overview of the Smart Heated BAM-1020 measuring system

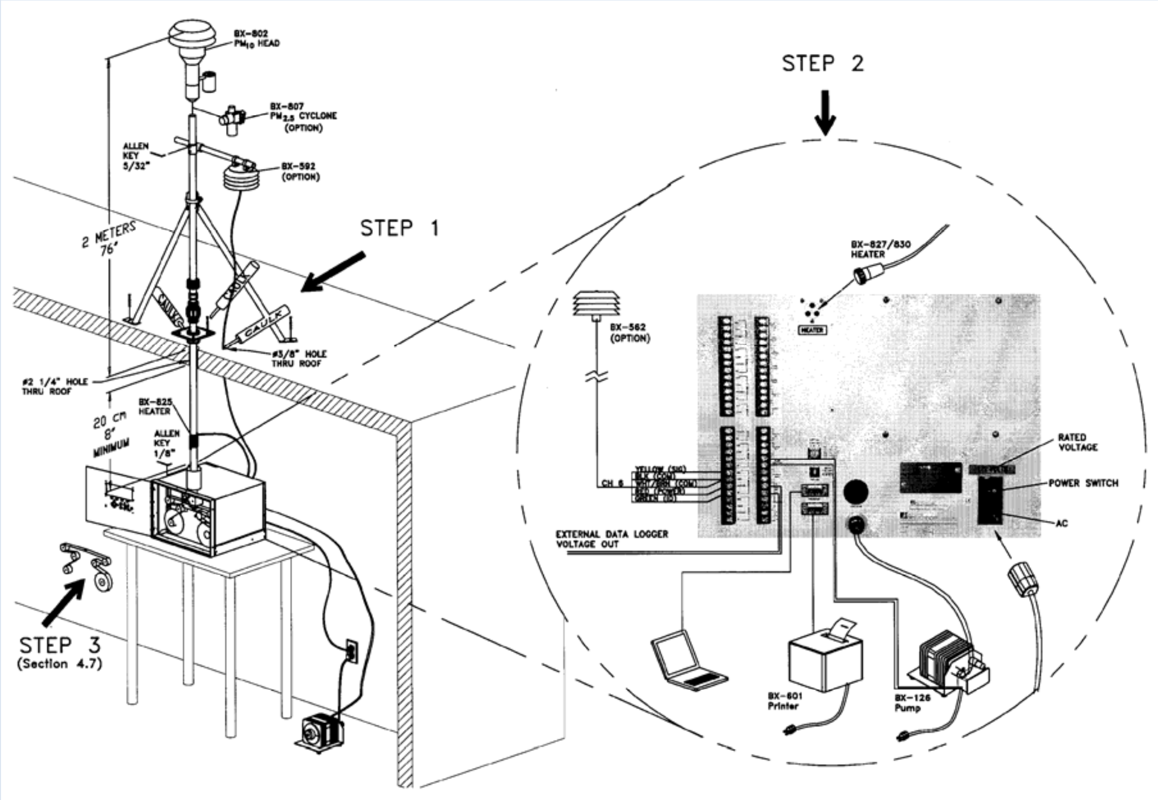


Figure 4: US- PM-sampling inlet BX-802 for the BAM-1020

Figure 5: Sample heater BX-830

Figure 6: Smart Heated BAM-1020 measuring systems installed in the trailer

Figure 7: Front view of the BAM-1020 with the front cover opened

Table 4: Device-related data Smart Heated BAM-1020 (Manufacturer's data)

Dimensions / weight	Smart Heated BAM-1020
Measuring system	310 x 430 x 400 mm / 24.5 kg (without pump)
Sampling line	1.65 m (different lengths available)
Sampling inlet	BX-802 (US)
Energy supply	100/115/230 V, 50/60 Hz
Power consumption	75 W, main unit
Ambient conditions	
Temperature	-30 - +60 °C (manufacturer´s data) +5 - +40 °C in suitability test
Humidity	non condensing

Sampling flow rate	16.67 l/min = 1 m³/h
Radionuclide Activity	^{14}C, <2,2 MBq (< 60 µCi)
Detector	Scintillation probe
Check procedure	Hourly internal zero and reference point checks (reference foil), deviations from the nominal value are recorded.
Parameter of filter change	
Measurement cycle (cycle time)	1 min – 200 min Default: 60 min
Measuring time radiometry	selectable 4,6 or 8 min for PM_{10}: 4 min
Sampling time	depending on measuring time radiometry 50, 46 or 42 min for PM_{10}: 50 min
Parameter sample heater BX-830	
maximum temperature difference filter tape – ambient temperature	Default: 5°C
Nominal value for relative humidity at filter tape	Default: 45 %
Buffer capacity (internal)	approx. 180 days for 1h-measuring values
Analogue output	0 – 1 (10) V or 0 – 16 mA / 4 – 20 mA – can be set to 0-0.100, 0.200, 0.250, 0.500, 1.000, 2.000, 5.000 or 10.000 mg/m³
Digital output	2 x RS 232 – interface for data transmission and remote control
Status signals / error messages	available, for an overview refer to chapter 8 in the manual
Buffer capacity (internal)	approx. 180 days for 1h-measuring values

In order to be consistent with the 2012 TÜV Rheinland Report[2], in this report the instruments tested have been referred to by the serial numbers and acronyms provided by the site operators. By consultation with Met One Instruments, it has been possible to assign the true serial numbers as designated by the manufacturer and the corresponding manufacture year, and these are summarised in Table 5.

Table 5: Details of the instruments deployed in this study

Descriptor assigned in this report	Serial number assigned by manufacturer	Build Year	Sensor Type	Software Version
4924	E4924	2005	BX-592	3236-02 V3.2.1b
4925	E4925	2005	BX-592	3236-02 V3.2.1b
Austria 1	G8210	2007	BX-592	3236-02 V3.2.1b
Austria 2	G8211	2007	BX-592	3236-02 V3.2.1b
J7860	J7860	2009	BX-596	3236-07 V5.0.5
J7863	J7863	2009	BX-596	3236-07 V5.0.5
17011	G2757	2007	BX-596	3236-07 V5.0.10
17022	G4044	2007	BX-596	3236-07 V5.0.10

The instruments were tested with a variety of software versions depending upon the build year and the year in which they were tested. The Smart Heated PM_{10} BAM-1020 has previously been certified by Sira under the MCERTS certification scheme, but not under MCERTS for UK Particulate Matter. Sira have certified all Smart Heated PM_{10} BAM-1020 instruments fitted with Software Version 3236-02 3.2.1b onwards and serial number D0001 (*i.e.* 1st January 2004) onwards. Software Version 3236-02 3.2.1b was chosen as being used in the three original German tests (discussed herein) upon which that certification was based. The serial number of D0001 corresponds to the earliest instrument produced with the same build specification as the instruments used in those tests (E4924 and E4925). TÜV Rheinland have audited all subsequent versions of the software that have been released, and the list of their approval can be found in the TÜV Rheinland Certificate of 22nd March 2013[10]. A subsequent TÜV Confirmation dated 6th August 2013[11], on changes regarding certificate 0000037055 states that the currently approved software version as 3236-07 5.1.1 for instruments without a touch screen display, and 3236-77 V5.2.0 for instruments with a touch screen display.

It is recommended that the certification is retained as instruments from serial number D0001 onwards with Software Version 3236-02 3.2.1b onwards. It is further recommended that every effort should be made by operators of the instruments to install the latest approved version of the instrument firmware suitable for the particular model being operated.

For the UK and Czech datasets the instruments were equipped with the combined pressure and temperature sensor (BX-596), whereas for the German and Austrian datasets the instruments were fitted with ambient temperature sensor (BX-592). The difference is that with the BX-596 you get additional control with the changes of the barometric pressure during the hour, while the BX-592 configuration uses the barometric pressure at the beginning of each cycle to control the flow. The Smart Heated $PM_{2.5}$ BAM-1020 TÜV Rheinland Report[4] and allows for the $PM_{2.5}$ instrument to be configured with either sensor, and it is recommended that that approach is also adopted in the UK for the Smart Heated PM_{10} BAM-1020.

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10 UmweltBundesAmt & TÜV Rheinland, Certificate of Product Conformity, number of Certificate 0000037055, BAM-1020 with PM_{10} pre-separator, Met One Instruments Oregon, USA, 22 March 2013.http://www.qal1.de/15267/0000037055_00_metone_BAM1020_10_en.pdf

11 Addendum to the type approval test report of the measuring system BAM-1020 with PM_{10} pre-separator of the company Met One Instruments, Inc. for the component PM_{10} to the TÜV-report 936/21205333/A of Dec 06, 2006.TÜV-Report: 936/21220762/A, Cologne December 12, 2012

2. Scope of Equivalence Testing

As discussed in Section 1, the Smart Heated PM_{10} BAM-1020 is based on the measuring principle of beta attenuation. The Reference Method conversely takes 24 hour samples on to filters which are weighed on a balance before and after sampling. As such, there are significant differences between the Candidate and Reference methods, necessitating that the full test procedures are undertaken as discussed in MCERTS for UK Particulate Matter.

There should be a total of at least four field tests of at least 40 data pairs. The field test was carried out at the following test sites (Table copied from the 2012 addendum to the Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[3]):

Table 6: Field test sites

No.	Country	Test site	Time period	Candidates	Characterisation
1	Germany	Cologne Parking Lot	02/2006 – 04/2006	SN4924 / SN 4925	Urban background
2	Germany	Titz-Rödingen	07/2006 – 09/2006	SN4924 / SN 4925	Rural
3	Germany	Cologne Frankfurter Strasse	09/2006 – 11/2006	SN4924 / SN 4925	Traffic-influenced
4	Austria	Steyregg	06/2008 – 08/2008	AUSTRIA 1 / AUSTRIA 2	Suburban
5	Austria	Graz	12/2007 – 03/2008	AUSTRIA 1 / AUSTRIA 2	Urban background + traffic
6	Czech Republic	Tusimice	01/2010 – 06/2010	J7860 / J7863	Industrial
7	UK	Teddington	04/2012 – 05/2012	17011 / 17022	Urban background

As all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter (31st July 2012), allowances are made for the scope of the field tests:

1. It is not necessary that all the field test sites have a similar pollution climate similar to that of the UK, though these calculations are presented herein;
2. There is a requirement for there to be only at least one UK field test, and this requirement is met by the Smart Heated PM_{10} BAM-1020;
3. There is no requirement that two collocated reference methods are used for each field test, though two reference methods were used in six of the seven tests (*i.e.* all but Tusimice);
4. There is no requirement for there to be at least 90 % data availability, though these calculations are presented herein.

While the German certification process required the inclusion of the three datasets with fewer than 40 data pairs each, for UK purposes, it is required that all of the datasets have at least 40 data pairs. As such, this report discusses the results of considering both all seven datasets, and just the four datasets where there are greater than 40 data pairs.

3. Conditions for which Equivalence is Claimed

The requirements of CEN/TS16450:2013[6] are that measurement ranges are defined as:

- 0 µg/m^3 to 1000 µg/m^3 as a 24-hour average value; and
- 0 µg/m^3 to 10000 µg/m^3 as a 1-hour average value if applicable.

The following measuring ranges can be set at the measuring system:

0 – 0.100, 0 – 0.200, 0 – 0.250, 0 – 0.500, 0 – 1.000, 0 – 2.000, 0 – 5.000 as well as 0 – 10.000 mg/m^3.

During the suitability test, the measuring range has been set to 0 – 1.000 mg/m^3 = 0 – 1,000 µg/m^3.

A measurement range of 0 to 1000 µg/m^3 is recommended in the 2006 TÜV Rheinland Report[2] and it is recommended that this is also adopted for UK purposes.

While the concentrations observed in the four field campaigns were significantly lower than these measurement ranges - as the equivalence calculations have been made relative to the 24 hour Reference Method - we suggest that the Smart Heated PM_{10} BAM-1020 is certified for the measurement range:

- 0 µg/m^3 to 1000 µg/m^3.

The pollution climate calculations are presented in Section 15. These calculations show that the requirements for the sites to be of a similar pollution climate to the UK, and for there to be a suitable range of wind speed, temperature, dew point and volatile components are all met. The field test sites utilised cover urban background, suburban, industrial, rural and traffic locations. While the rural site had fewer than 40 data pairs, the relationship to the reference method was good, and we propose therefore, that this instrument is suitable for use at urban background, suburban, industrial, rural and traffic locations within the UK.

4. Sources of Uncertainty for the Reference Method

A summary of the key criteria for each site is given in Table 7, and a more detailed summary of the weighing procedures employed at each site are summarised in Appendix B.

Table 7: Summary of key reference method criteria

Test site	Filter Type	Instrument	Filters Changed At	Filters Stored At
Cologne Parking Lot	50 mm Whatman Quartz	Leckel LVS3	Manually changed at 8 am	Kept in the sampling cabin at 20 °C
Titz-Rödingen		Leckel SEQ47/50	Automated change at 8 am	Kept in instrument which was installed inside the cabin at 20 °C
Cologne Frankfurter Strasse				
Steyregg	Munktell glass fibre with organic binder. 46 mm stamped from 150 mm.	Leckel SEQ47/50	Automated change at 8 am	Manually refrigerated each day
Graz				
Tusimice	47mm Whatman glass fibre	Derenda LVS3	Manually changed at 7 am	20 °C in Analyslides
Teddington	47 mm Pall Emfab	Leckel LVS3	Manually changed at 10 am	Refrigerated in Analyslides

The reference method used in three of the field tests were the small filter device “Low Volume Sampler LVS3” manufactured by Sven Leckel GMBH (Berlin, Germany) or Comde Derenda GMBH (Berlin, Germany). These instruments are single-shot samplers that require the filters to be changed manually. They do not have sheath air cooling.

The reference method used in the other four field tests were the small filter device “Sequential Sampler for 47 or 50 mm filters SEQ47/50” manufactured by Sven Leckel GMBH (Berlin, Germany). These instruments change filters automatically. They have sheath air cooling to cool filters to ambient conditions while sampling. The versions of the SEQ47/50 used in these tests did not have the ability to cool filters after sampling, though newer versions of the SEQ47/50 have this facility.

In Germany the instruments were operated with quartz filters in accordance with the requirements of the then PM_{10} standard: EN12341:1998[7]. In Austria and the Czech Republic, glass fibre filters were used, and in the UK, the samplers were operated with Emfab (Teflon-coated glass fibre) filters. While glass fibre and Emfab filters are not listed in the 1998 standard, they are allowed in the later $PM_{2.5}$ standard (EN14907:2005[8]) as well as the recently published revised PM_{10} and $PM_{2.5}$ standard (EN12341:2014[5]).

Weighing procedures varied between sites. For the three German test sites, measurements were made in line with the then current PM_{10} standard EN12341:1998[7]. The weighing procedures for the UK, the Czech Republic and Austria were conducted to the $PM_{2.5}$ standard EN14907:2005[8], which improves on the 1998 standard, most notably with the requirement to weigh filters twice rather than once. The new PM_{10} and $PM_{2.5}$ standard EN12341:2014[5] requires a weighing procedure that is almost identical to that of EN14907:2005[8], and differs primarily in that the RH range has been reduced from 45 - 55 % to 45 - 50 %.

In terms of the physical differences between the instruments utilised in these tests and the new PM_{10} and $PM_{2.5}$ standard, the new PM_{10} and $PM_{2.5}$ standard states the following:

“The present European Standard represents an evolution of earlier European Standards (EN 12341:1998 and EN 14907) through the development of the 2,3 m^3/h sampler to include sheath air cooling, the ability to cool filters after sampling, and the ability to monitor temperatures at critical points in sheath air cooling the sampling system. It is recommended that when equipment is procured, that it complies fully with the present European Standard. However, older versions of these 2,3 m^3/h samplers that do not employ sheath air cooling, the ability to cool filters after sampling, or the ability to

monitor temperatures at critical points in the sampling system have a special status in terms of their use as reference samplers. Historical results obtained using these samplers will remain valid. These samplers can still be used for monitoring purposes and for equivalence trials, provided that a well justified additional allowance is made to their uncertainties."

As the field tests of the Smart Heated PM_{10} BAM-1020 pre date the publication of the finalised standard and it's enacting through a revised Air Quality Directive, it is not necessary to consider the difference between the instrument used and the future standard. However, for completeness, the potential effects are as follows:

While filters were not always cooled after sampling, they were in all cases kept at or below 20 °C. this is in line within the recommendations of EN12341:2014[5] which is to keep sampled filters at or below a temperature of 23 °C. Recent research presented at the working group responsible for developing the European Reference Method (CENTC264/WG15) suggests that cooling of filters after sampling has limited benefit. A difference between the single shot and automated systems used is that there is sheath air cooling in the automated instruments. As the filters were changed between 7 and 10 am each morning, this is before the ambient temperature reached a level capable of volatilising ammonium nitrate from the sampled filters, and it is expected that losses due to the absence of sheath air cooling would be minimal.

5. Competencies of the Laboratories Involved

Four organisations (TÜV Rheinland, The Austrian Environment Agency, CHMI and NPL) were involved in the field and laboratory testing.

TÜV Rheinland Energie und Umwelt GmbH are accredited for the following work areas according to ISO 17025[12]:

- Determination of emissions and ambient airs of air pollution and odour substances;
- Inspection of correct installation, function and calibration of continuously running emission measuring devices including systems for data evaluation and remote monitoring of emissions;
- Suitability testing of measuring systems for continuous monitoring of emissions and ambient airs, and of electronic systems for data evaluation and remote monitoring of emissions

The accreditation is valid up to 31-01-2013. DAkkS-register number: D-PL-11120-02-00.

The National Physical Laboratory are accredited for the following work areas according to ISO 17025:

- determination of particulate mass collected on filters; and
- determination of particulate analyser flow rates.

These services were last accredited on the 22nd October 2012, and the 28th November 2012 respectively by the United Kingdom Accreditation service (UKAS).

The Austrian Environment Agency (Umweltbundesamt) was formally nominated to the EC as Austrian Air Quality Reference Laboratory by the Ministry of Environment, Youth and Family in February 2000. As air quality monitoring in Austria is a federally organized, Umweltbundesamt had to accredit as a calibration lab, providing traceability for the networks. Accreditation according to ISO 17025 was first received on the 29th July 2009 by the Austrian Ministry of Economy, Family and Youth. The current accreditation is dated 26th of January 2012, and Umweltbundesamt are in the process of adding volume flow to the scope of the accreditation.

Inspections of all regional offices and employees of Air Quality Monitoring (IM) at CHMI are carried out periodically for quality control and quality assurance. The Central Laboratory of Air Quality (CLI) is part of the IM CHMI, which is a testing laboratory no. L 1460 accredited by the Czech Accreditation Institute (CAI) for tests and sampling listed in the Appendix of the Certificate of Accreditation. The accreditation according to ISO 17025 was issued in 2005. CHMI also fulfilled conditions for accreditation by the norm ISO 9001 in 2007.

Extracts of the ISO 17025 accreditations for all four organisations are given in Appendix C.

12 ISO Standard 17025:2005 General requirements for the competence of testing and calibration laboratories

LABORATORY TEST PROGRAMME

6. Parameters Tested in the Laboratory Programme

As the Candidate Method is not a variation of the Reference Method, only two tests are required to be undertaken in the laboratory in accordance with MCERTS for UK Particulate Matter. These include:

- Constancy of the sample Volumetric Flow; and
- Tightness of the Sampling System.

It is also necessary to consider the:

- Maintenance Interval.

These tests were undertaken and are discussed in detail in Sections 7 and 8. These tests were undertaken under field conditions rather than laboratory conditions.

A number of other tests were undertaken by TÜV Rheinland in accordance with the requirements of the German Government. These tests include:

- Easy maintenance;
- Functional check;
- Set-up and warm-up times;
- Instrument design;
- Unintended adjustment;
- Data output;
- Measuring range;
- Negative output signals;
- Analytical function;
- Linearity;
- Detection limit;
- Response time;
- Dependence of the zero point on ambient temperature;
- Dependence of the measured value on ambient temperature;
- Drift of zero point;
- Drift of measured value;
- Reproducibility RD;
- Daily averages.

These tests are not detailed in this report, and further details can be found in the 2006 TÜV Rheinland Report[2]. Details of these tests are not repeated in the 2012 addendum[3].

7. Laboratory Test Procedures Used

The laboratory test was performed with two identical devices of the type BAM-1020 with the serial numbers SN 4924 and SN 4925 that were operated in the German field tests.

In order to improve the clarity of the report, the Laboratory test procedures used (Section 7) and the Laboratory test results (Section 8) are considered together for each of the three tests in turn.

8. Laboratory Test Results

8.1. Constancy of Sample Volumetric Flow

MCERTS for UK Particulate Matter[1] lists the following requirement for constancy of the sample volumetric flow:

> *"Constancy of the sample volume flow, is tested as specified in the MCERTS Standard, using selective filters loaded with particulates to 80%, 50% and 0% of the maximum permissible filter loading specified, and the constancy of the sample volumetric flow is recorded as a 3 minute average every 30 minutes for at least 24 hours – to remain constant within ± 3% of the rated value"*

The following text is copied with minor alterations from Section 6.1 - 5.3.7 of the 2006 TÜV Rheinland Report[2]. It is noted that the tests were conducted considering the three datasets where there are each fewer than 40 data pairs. It is noted that the flow tests are still valid irrespective of the number of data pairs.

Equipment

An Inlet adapter (Part number BX-305), and a flow meter were provided.

Carrying out the test

The sample volumetric flow has been calibrated before the first field test site and afterwards checked on correctness and re-adjusted if necessary before each field test site with the help of a dry gas meter. In order to determine the constancy of the sample volumetric flow, a flow meter has been connected to the measuring systems and 5-second-values for the flow rate have been recorded and evaluated over a time period of 6 hours (=6 measurement cycles).

Evaluation

From the determined average for the flow rate, average, standard deviation, and maximum and minimum values were defined.

Assessment

The results of the check of the sample volumetric flow, carried out before each field test site, are shown in Table 8.

Table 8: Summary of the Flow Check Results

Check of flow rate before test site	SN 4924		SN 4925	
	[l/min]	Dev. from nominal value [%]	[l/min]	Dev. from nominal value [%]
Cologne Parking Lot	16.67	-	16.67	-
Titz-Rödingen	16.51	-1.0	17.09	2.5
Cologne Frankfurter Strasse	16.45	-1.3	15.5	-7.0*

* flow rate re-adjusted

The graphic presentation of the flow rate over 6 measurement cycles shows, that all measured values, which have been determined during sampling, deviate less than ±5 % from the nominal value of 16.67 l/min. Likewise the deviation of the daily averages is smaller than the required ±3 % of nominal value.

All determined averages over the measurement cycle deviate less than ± 3 %, all instantaneous values deviate less than ± 5 % from the nominal value

Detailed representation of the test results

In Table 9 and Table 10 the determined parameter for the flow are shown. Figure 8 and Figure 9 show the graphical representation of the flow measurements at candidates SN 4924 and SN 4925.

Table 9: Parameter for the total flow measurement SN 4924

Characteristic	Unit	1	2	3	4	5	6
Average	l/min	16.67	16.74	16.69	16.78	16.69	16.70
Dev. from AVG	% of nominal value	0.00	0.43	0.12	0.66	0.12	0.17
Standard deviation	l/min	0.02	0.04	0.03	0.05	0.04	0.04
Maximum	l/min	16.74	16.90	16.86	17.02	16.94	16.94
Minimum	l/min	16.66	16.66	16.46	16.66	16.66	16.34

Table 10: Parameter for the total flow measurement SN 4925

Characteristic	Unit	1	2	3	4	5	6
Average	l/min	16.67	16.61	16.55	16.52	16.56	16.56
Dev. from AVG.	% of nominal value	0.00	-0.36	-0.69	-0.89	-0.67	-0.67
Standard deviation	l/min	0.14	0.05	0.01	0.04	0.02	0.03
Maximum	l/min	16.83	16.83	16.59	16.59	16.83	16.83
Minimum	l/min	15.99	16.55	16.51	15.95	16.55	16.51

Figure 8: *Figure Flow rate at candidate SN 4924*

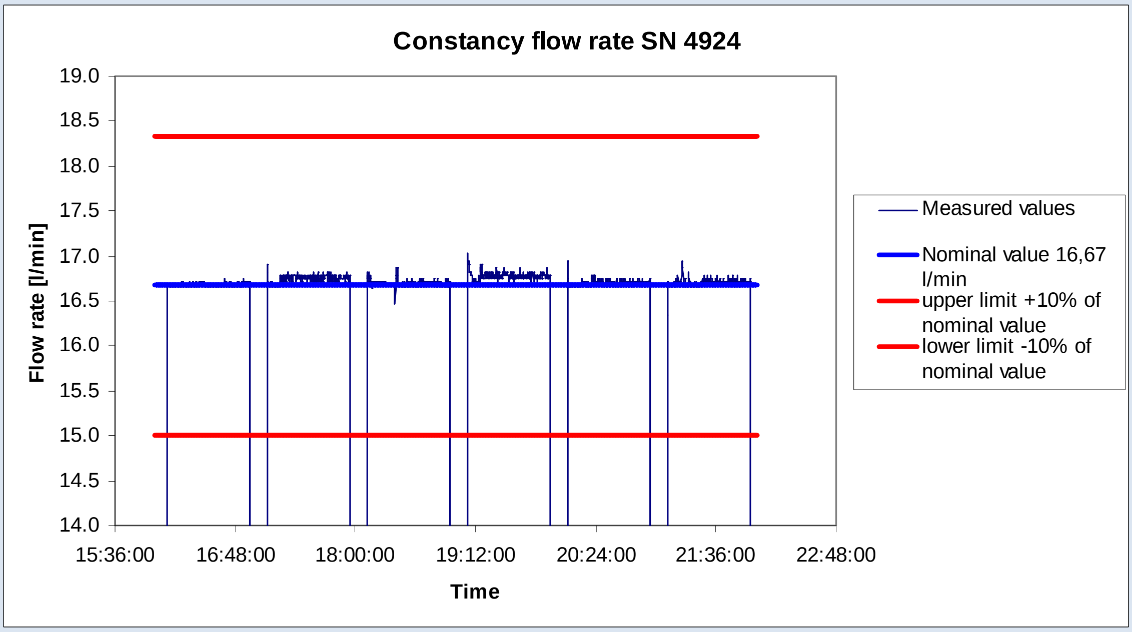
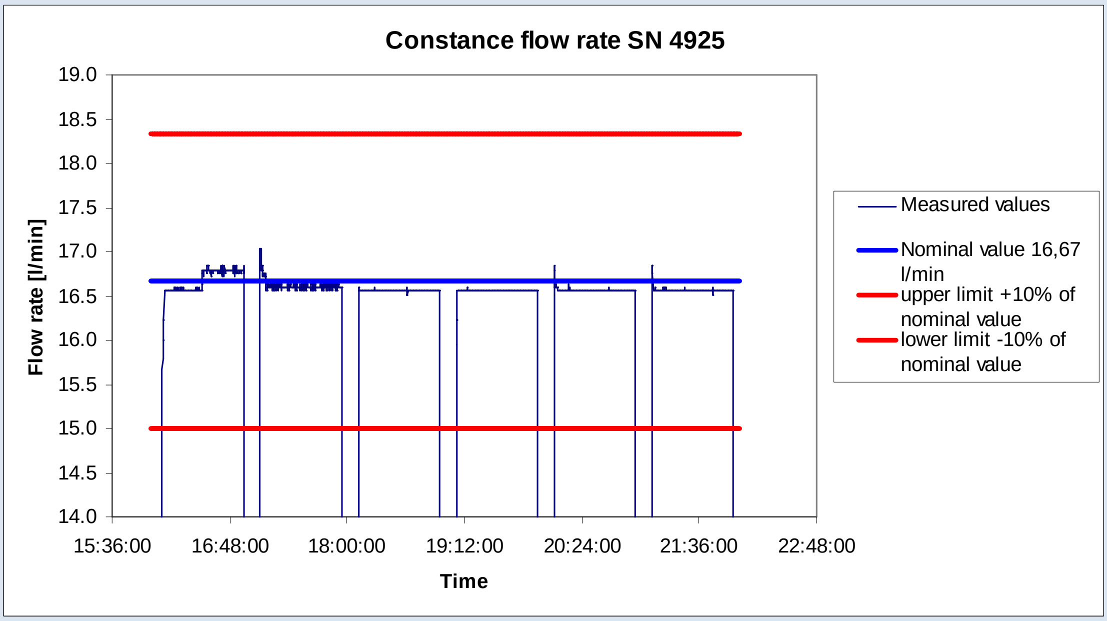


Figure 9: *Flow rate at candidate SN 4925*



Conclusion for UK Purposes

As the highest deviation from the nominal value is 2.5%, it is this value that should be transferred to the MCERTS certificate. This is less than the required ± 3%. The flow rate tests were done under flow conditions at a variety of filter loadings as opposed to 0%, 50 % and 80% of the mass load as prescribed in MCERTS for UK Particulate Matter[1]. The variable filter load is not a requirement in Technical Specification CEN/TS16450[6].

8.2. Tightness of the Measuring System

MCERTS for UK Particulate Matter[1] lists the following requirement for the tightness of the measuring system:

> *"The leak tightness of the sampling system is carried out using flow and pressure monitoring equipment to determine the leak rate of the entire instrument where feasible, or by evaluating the leaks of different parts separately. The tests can be made by measuring the volume flow at the inlet and outlet of the system, or by determining the pressure – to achieve the performance criterion shall not exceed 1 % of the sample volume."*

The following text is copied with minor alterations from Section 6.1 - 5.3.6 of the 2006 TÜV Rheinland Report[2].

Equipment

An Inlet adapter (Part number BX-305) was provided.

Carrying out the test

In order to determine the leak rate, the inlet adapter BX-305 has been installed at the inlet of the sampling tube and the ball valve of the adapter has been closed slowly. The leak rate has been determined from the difference between the flow rate with the pump switched off (zero point of flow rate measurement) measured in the device, and the measured flow rate with the sealed instrument inlet. The procedure has been repeated three times.

Evaluation

The leak rate has been determined from the difference between the flow rate with the pump switched off (zero point of flow rate measurement) measured in the device, and the measured flow rate with the sealed instrument inlet.

The maximum value of the three determined leak rates has been specified

Assessment

The tightness check may only be performed using the tightness check assistant to avoid damages of the instrument.

The maximum determined leakages have been 0.6 % for device 1 (SN 4924) and 0.6 % for device 2 (SN 4925).

Detailed representation of the test results

Table 11 contains the determined values from the tightness check

Table 11: Results of the tightness check during field test expressed as l/min

	Flow rate (pump off)	Flow rate (pump on, inlet sealed)				
		1	2	3	Mean	Maximum leak rate
	l/min	l/min	l/min	l/min	l/min	% of nom. value
SN 4924	0.0	0.1	0.0	0.1	0.067	0.6
SN 4925	0.0	0.1	0.1	0.1	0.1	0.6

It is noted that the tests were conducted considering the instruments used to collect the three datasets where there are each fewer than 40 data pairs. It is noted that the leak tests are still valid irrespective of the number of data pairs.

Conclusion for UK Purposes

As the greatest leak detected is 0.6%, it is this value that should be transferred to the MCERTS certificate. This is less than the required 1%.

8.3. Maintenance Interval

MCERTS for UK Particulate Matter[1] lists the following requirement for the Maintenance Interval of the measuring system:

> *"Frequency of the QA/QC checks etc. shall be the same as those intended for the operational field conditions, to the extent that it is demonstrated that no additional uncertainty terms would arise during subsequent field operation (e.g. greater drift occurs between calibrations due to longer periods between checks). Otherwise an extra uncertainty term shall be added to provide the overall uncertainty during operational field conditions, and this then shall conform to the Directive's data quality objectives [Directive 2008/50/EC Annex I, and GDE2010 Annex D]."*

Within Directive 2008/50/EC[14] there is no guidance as to the maintenance interval. Within GDE2010[9], it is recommended that maintenance is required as per the manufacturer's instructions. There is however no guidance as to an absolute maintenance interval.

Within CEN/TS16450[6] there is very clear guidance, namely: "*The maintenance interval is the longest time without intervention as recommended by the manufacturer.*" During this period the instrument shall not need any maintenance or adjustment. The minimum maintenance interval is defined as "*at least 14 days*".

For the MCERTS certification process for instruments assessed prior to the launch of MCERTS for UK Particulate Matter[1], the minimum maintenance interval was defined as two weeks.

Further, the TÜV Rheinland Report[2] defines the minimum maintenance interval as:

> *"Preferably 28 days, at least 14 days."*

It is therefore recommended that the minimum maintenance interval is defined as ≥ 2 weeks.

The following text is copied with minor alterations from Sections 6.1 – 4.1.2 and 6.1 – 5.2.20 of the 2006 TÜV Rheinland Report[2]. Additions have been made based on the extra experience gained with the 2010 Smart Heated $PM_{2.5}$ BAM-1020 TÜV Rheinland Report[4].

Equipment

No additional equipment is required.

Carrying out the test

This test was done in order to determine which maintenance procedures are required at which period to maintain correct functionality of the measuring system. Moreover, the results of the drift test for zero and span point according to the long-term drift were included into the determination of the maintenance interval.

Evaluation

Necessary regular maintenance works were carried out according to the instructions of the operating manual. No unacceptable drifts were detected for the measuring systems during the entire field test period. During operation, the maintenance works can be limited to contamination, plausibility and status / error message checks. Therefore, the maintenance interval is determined by scheduled maintenance procedures listed below.

The following maintenance works should be carried out. All procedures can usually be carried out with commonly available tools. It is generally recommended to perform a self-test according to Chapter 3.5 of the manual after each action, which interrupts the measurement operation:
:

1. Check of device status - the device status can be monitored and controlled by controlling the system itself or controlling it on-line.
2. In general the sampling inlet shall be cleaned according to the manufacturer´s instructions with taking into account the local suspended particulate matter concentrations (during suitability test every 4 weeks).
3. Monthly cleaning of the device. This includes also the cleaning of the nozzle area above the filter tape. In any case, the measuring system has to be cleaned after each measuring operation.
4. Check of the filter tape stock – a 21 m-filter tape is hereby sufficient for approximately 60 days in case of a measurement cycle of 60 min. It is recommended, to check as a matter of routine the filter tape stock at every visit of the measurement site.
5. According to the manufacturer, a flow rate check and a leak check shall be carried out every 4 weeks. Furthermore a plausibility check of the ambient temperature and air pressure measurement is recommended within this context. These workings can be done together with the workings according to point 4.
6. Replacement of filter tape after approx. 2 months (measurement cycle: 60 min). After the replacement, it is strongly advised to perform a self-test according to chapter 3.5 of the manual.
7. According to the manufacturer, the calibration of the flow rate should be performed every 2 months.
8. The muffler at the pump should be replaced semi-annually.
9. The sensors for the ambient temperature, air pressure, filter temperature and filter rH have to be checked every 6 months according to the manual.
10. The flow controller, the pump and the sample heater have to be checked every 6 months according to the manual.
11. Once a year, a 72 h background test with the help of the zero filter kit BX-302 according to the manual point 7.7 should be performed
12. Once a year the carbon vanes of the vacuum pump (only rotary vane pump) have to be checked and replaced if necessary during an annual base maintenance.
13. During the annual basic maintenance, the sampling tube should be inspected and cleaned.

Assessment

Maintenance works can be carried out with commonly available tools taking reasonable time and effort. The workings according to point 6 in the above list have to be done during shutdown of the system. These workings are only necessary in a two month interval as well as semi-annually or annually. During the remaining time, the maintenance can be basically restricted to the check of contaminants, plausibility checks and possible status/error messages.

Detailed representation of the test results

The maintenance works were carried out during the test in accordance with the instructions given in the manual. No problems were noticed while following the described procedures. All maintenance works could be done with customary tools without taking much time and effort.

Conclusion for UK Purposes

The maintenance interval is defined by necessary maintenance procedures and is 4 weeks, and this is this value that should be transferred to the MCERTS certificate. This is greater than the required ≥ 2 weeks. Further information as to the maintenance procedures required is given in Appendix D.

FIELD EQUIVALENCE TEST PROGRAMME

9. Field Test Locations, Periods and Conditions

The following text is copied from Section 1 of the 2012 addendum to the TÜV Rheinland Report[3].

The field test was carried out at the following test sites:

Table 12: Field test sites

No.	Country	Test site	Time period	Candidates	Characterisation	Test institute
1	Germany	Cologne Parking Lot	02/2006 – 04/2006	SN4924 / SN 4925	Urban background	TÜV Rheinland
2	Germany	Titz-Rödingen	07/2006 – 09/2006	SN4924 / SN 4925	Rural	TÜV Rheinland
3	Germany	Cologne Frankfurter Strasse	09/2006 – 11/2006	SN4924 / SN 4925	Traffic-influenced	TÜV Rheinland
4	Austria	Steyregg	06/2008 – 08/2008	AUSTRIA 1 / AUSTRIA 2	Sub-urban	UBA Austria
5	Austria	Graz	12/2007 – 03/2008	AUSTRIA 1 / AUSTRIA 2	Urban background + traffic	UBA Austria
6	The Czech Republic	Tusimice	01/2010 – 06/2010	J7860 / J7863	Industrial	CHMI
7	UK	Teddington	04/2012 – 05/2012	17011 / 17022	Urban background	NPL / Bureau Veritas

Figure 10 to Figure 16 show the time series of the average the PM_{10}-concentrations as measured by the reference method at each of the seven field test sites.

Figure 10: Time Series of the PM_{10}-concentrations at the test site: Cologne Parking Lot[2]

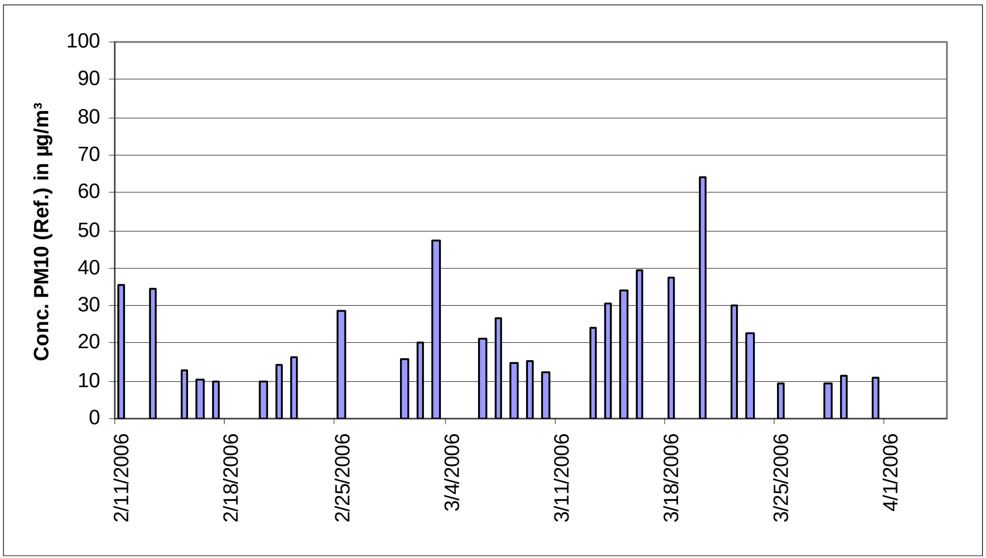


Figure 11: Time Series of the PM_{10}-concentrations at the test site: Titz-Rödingen[2]

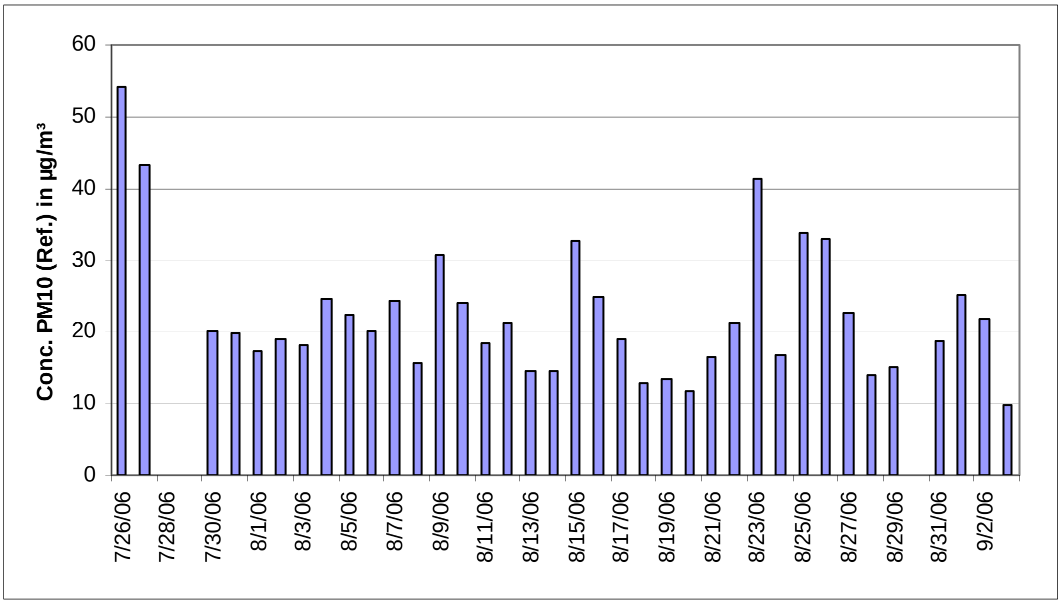


Figure 12: Time Series of the PM_{10}-concentrations at the test site: Cologne Frankfurter Strasse.[2]

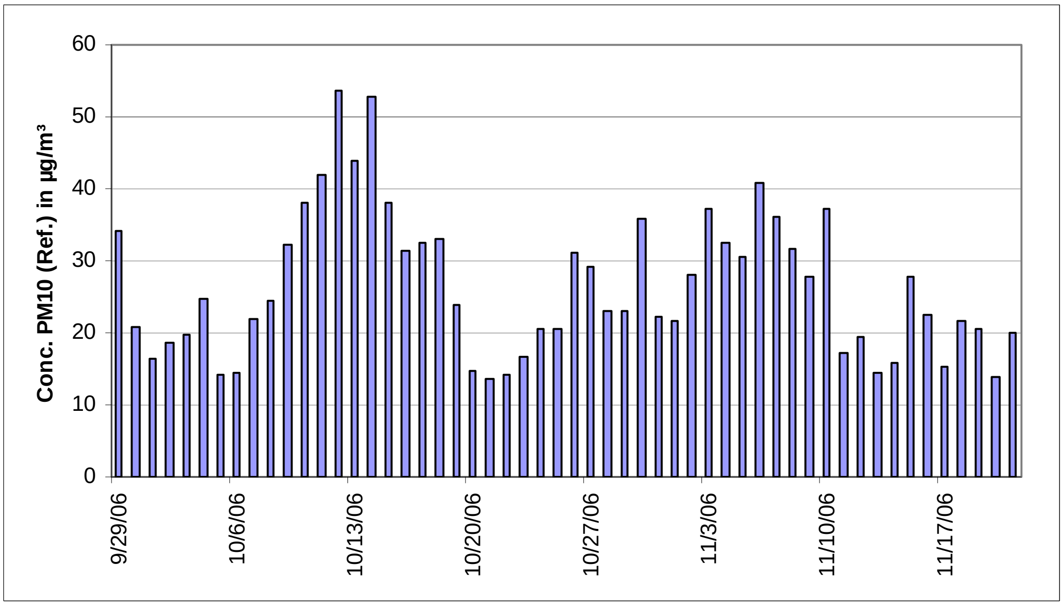


Figure 13: Time Series of the PM_{10}-concentrations at the test site: Steyregg

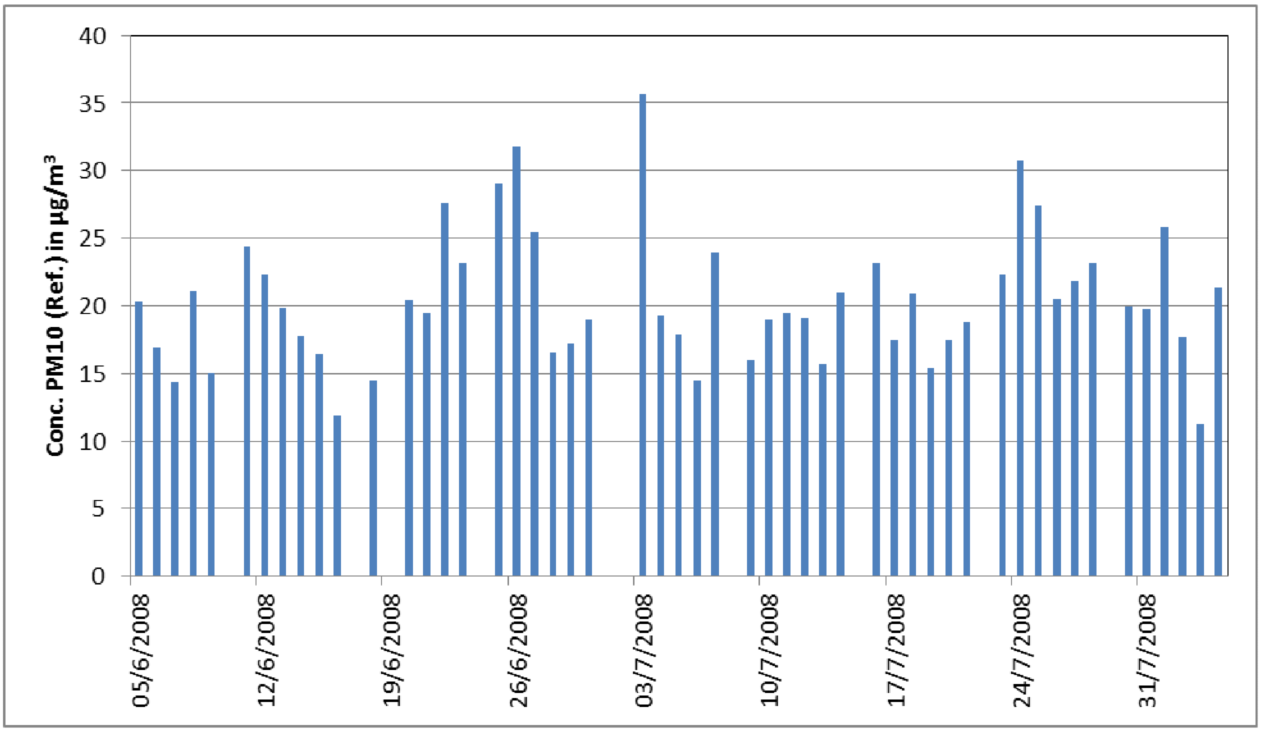


Figure 14: Time Series of the PM_{10}-concentrations at the test site: Graz

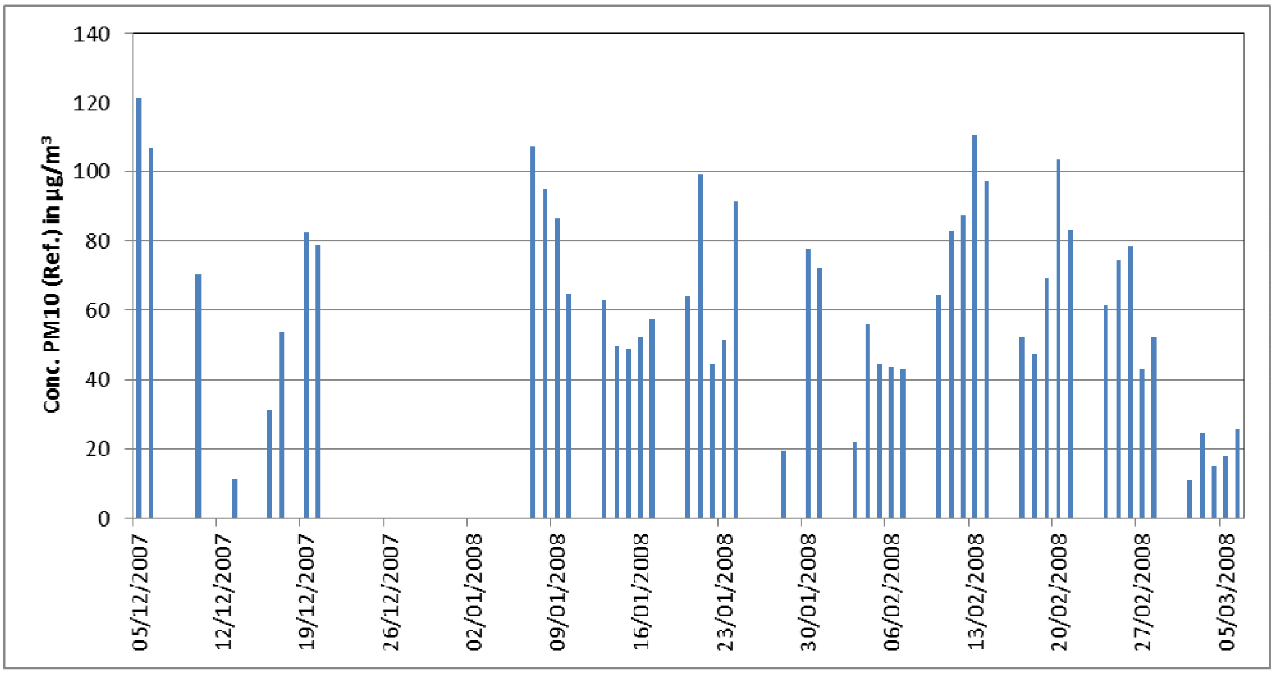


Figure 15: Time Series of the PM_{10}-concentrations at the test site: Tusimice

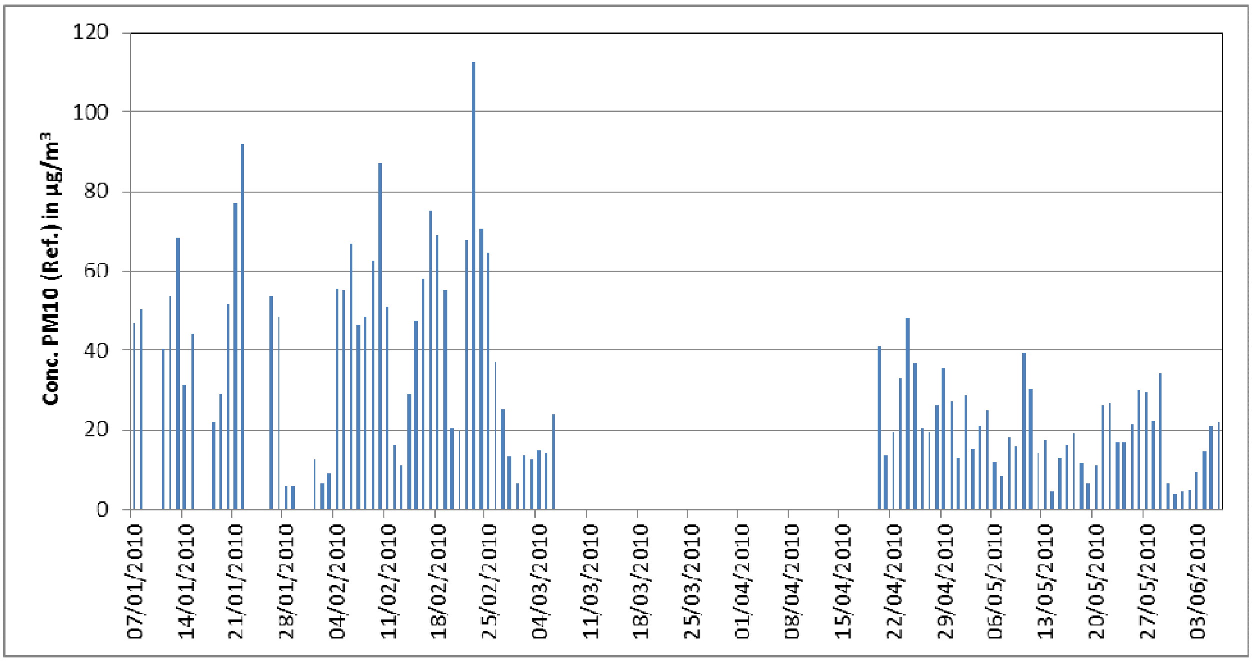


Figure 16: Time Series of the PM_{10}-concentrations at the test site: Teddington

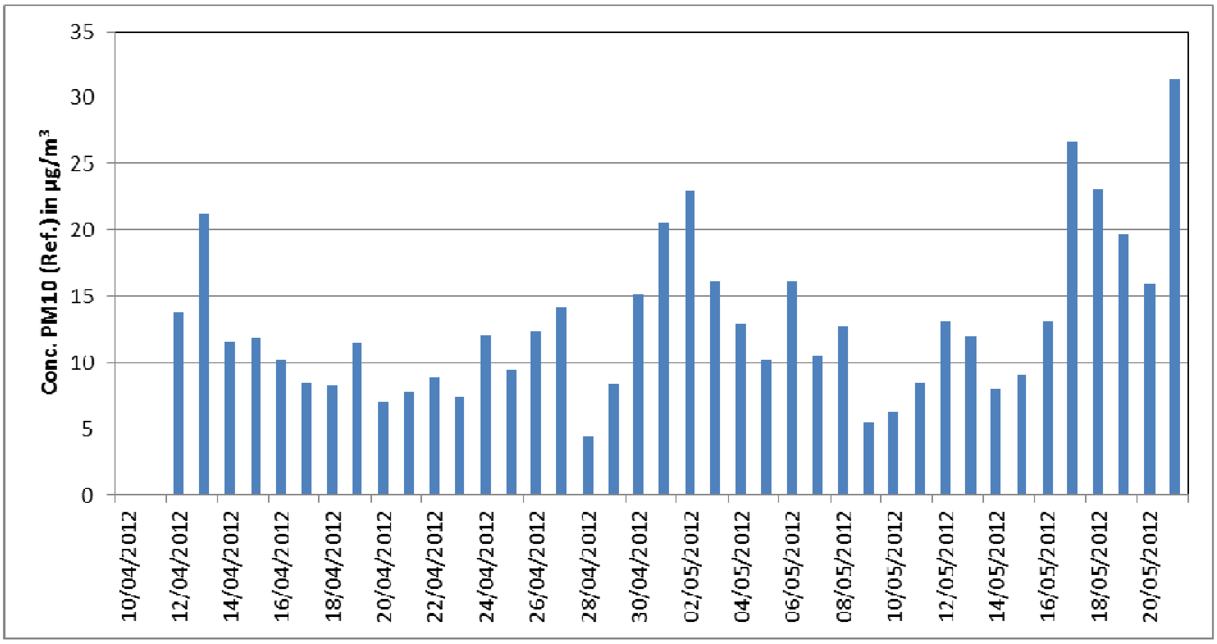


Figure 17 to Figure 23 show photographs of the monitoring sites.

Figure 17: Field test site: Cologne Parking Lot[2]

Figure 18: Field test site: Titz-Rödingen[2]

Figure 19: Field test site: Cologne Frankfurter Strasse.[2]

Figure 20: Field test site: Steyregg.[13]

[13] *Equivalence Test of Optical PM Monitors by order of the company GRIMM at 4 measurement locations in Austria. Umweltbundesamt of Austria report of January 2010.Andreas Wolf, Marina Fröhlich, Lorenz Moosmann.*

Figure 21: Field test site: Graz[13]

Figure 22: Field test site: Tusimice

Figure 23: Field test site: Teddington[4]

Besides the measuring device for the determination of particulate ambient air, a device for the determination of meteorological characteristics was installed at the cabinet / measuring test site. A continuous determination of ambient temperature, ambient pressure, relative humidity, wind velocity, and wind direction was made. Table 13 contains an overview on the most important meteorological data of the four test sites. Section 15 gives a detailed analysis of these results.

The following table is copied from Section 1 of the 2012 addendum to the TÜV Rheinland Report[3].

Table 13: Ambient conditions at the field test sites, expressed as daily averages

No.	Test site	Ambient temperature [°C]	Rel. Humidity [%]	Wind velocity [m/s]	No. of valid data pairs	No. ≥40
1	Cologne Parking Lot	4.7 -3.2 – 15.6	64.0 33.7 – 89.1	1.1 0.0 – 3.0	29	No
2	Titz-Rödingen	17.3 12.7 – 26.5	74.2 55.8 – 81.7	0.4 0.0 – 2.7	37	No
3	Cologne, Frankfurter Strasse	15.1 11.6 – 19.1	70.5 63.8 – 77.8	0.8 0.0 – 2.8	28	No
4	Steyregg	19.7 10.9 – 26.2	74.0 58.7 – 94.6	1.3 0.3 – 2.5	45	Yes
5	Graz	2.7 -5.9 – 13.3	73.8 33.9 - 100	0.6 0.0 – 3.1	45	Yes
6	Tusimice	2.7 -13.0 – 19.0	82.9 24.0 – 96.0	0.7 0.0 – 3.1	97 (J7860) 96 (J7863)	Yes
7	Teddington	10.3 5.8 – 14.9	74.0 51.9 – 91.8	1.1 0.1 – 3.5	40	Yes

10. Description of Equipment and Test Procedures

The original 2006 TÜV Rheinland Report[2] provides details on the three German tests. The details of the UK test are known. No information is given on the two Austrian and one Czech site in the 2012 Addendum to the TÜV Rheinland Report[3], and this information has been obtained by consultation the site operatives.

Equipment Deployed

The following equipment was used for each of the field tests:

- Air-conditioned Measurement cabinet of TÜV Rheinland for the two Smart Heated PM_{10} BAM-1020;
- Weather station for the determination of meteorological characteristics such as air temperature, air pressure, air humidity, wind velocity, wind direction and rainfall;
- Two reference samplers for PM_{10};
- Flow meters;
- Zero-filter for external zero point check;

The installation of the Cologne Parking Lot field test site was characterized by the following dimensions:

- Height of roof of cabinet: 2.7 m
- Height of sampling point for candidate / reference: 1.2 / 1.3 m above roof
- Height of weather vane: 4.5 m above ground

The installation of the Titz-Rödingen and Cologne Frankfurter Strasse field test sites were characterized by the following dimensions:

- Height of roof of cabinet: 2.7 m
- Height of sampling point for candidate / reference: 1.2 / 1.2 m above roof
- Height of weather vane: 4.5 m above ground

The installation of the Teddington field test site was characterized by the following dimensions:

- Height cabinet roof: 2.50 m;
- Height of the sampling for the Candidate:1.10 m above the cabinet roof and 3.61 m above ground;
- Height of the sampling for the Candidate: 0.5 m above the cabinet roof and 3.01 m above ground;
- Height of the wind vane: 2.5 m above ground

At Graz, Steyregg and Tusimice, the inlets of all samplers were approximately 3 to 3.5 m above ground level. At Tusimice, the Smart Heated PM_{10} BAM-1020s were installed in individual climate controlled cabinets.

Reference Method

Two PM_{10} reference devices were simultaneously operated during the testing with a volume flow of 2.3 m^3/h that was controlled and reported to ambient conditions. At Tusimice, only one reference method sampler was operated.

To determine the PM_{10} concentration, the laboratory performed a gravimetric determination of the amount of suspended particulate matter on the respective filters. The obtained result was then divided by the volume of air in m^3 and reported to ambient conditions.

The January 2010 version of the Guidance[9] stipulates that not more than 2.5 % of the paired values in total for each field test site may be identified and removed as outliers. Section 4.3 of the 2006 TÜV Rheinland Report[2] discusses how no outliers in the reference method data were identified for deletion using Grubbs' Test at the 99 % confidence interval in the German datasets. As there was only one reference method at Tusimice, and so it is not possible to delete outliers, the decision was taken by Bureau Veritas and TÜV Rheinland not to delete any outliers from any of the seven datasets in this study.

During the field tests, QA/QC procedures were periodically undertaken on the reference devices in accordance with the manufacturer's instructions. The instruments were leak checked, and the flow rates were checked.

The impaction plates of the PM_{10} sampling inlets have been cleaned periodically and have been prepared with silicon paste, which ensures a secure separation of the coarse particles on the impaction plate.

Candidate Method

Different candidate instruments were installed at different sites, and these have been discussed in Table 5. The candidate instruments were operated and maintained in accordance with the manufacturer's instructions.

The data were downloaded periodically and processed by the site operatives in order to calculate daily averages.

11. Data Availability of the Candidate Method

MCERTS for UK Particulate Matter[1] lists the following requirement for the Availability of the measuring system:

> *"The fraction of the total and consecutive monitoring time during all the field trials involved in the equivalence testing programme for which data of acceptable quality are collected. The times required for scheduled calibrations and maintenance shall not be included. The method for calculating this fractional time is given in Section 5.2 Eq.2. Availability defined here is the same as the minimum data capture requirements given in the data quality objectives in Directive 2008/50/EC for the relevant pollutant."*

Where Directive 2008/50/EC[14] defines a data capture of 90 %.

Section 6.1 - 5.2.18 of the 2006 TÜV Rheinland Report[2] discusses the availability based on hourly data for the three German tests. This was 99.7 % for each instrument when considering outages attributed to the instrument itself. Hourly data are not available for each of the seven sites, and instead only ratified 24 hour averages are available. The only site where data are absent for either candidate is Tusimice, where two days were unavailable for one candidate, and four for the other. It is not known whether this is for reasons due to an instrument fault, but assuming instrument faults as a worst case scenario, the availability based on daily data of the four sites where there are greater than 40 data pairs is 98.8 % as shown in Table 14.

Table 14: *Availability of Candidate Method data based on daily averages*

Site	Total Number of Instrument Days	Instrument Days Lost	Availability / %
Cologne Parking Lot	104	0	100.0
Titz - Rödingen	74	0	100.0
Cologne Frankfurter Strasse	56	0	100.0
Steyregg	102	0	100.0
Graz	100	0	100.0
Tusimice	214	6	97.2
Teddington	84	0	100.0
Total (all 7 datasets)	**734**	**6**	**99.2**
Total (only the 4 datasets with greater than 40 data pairs)	**500**	**6**	**98.8**

14 DIRECTIVE 2008/50/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2008 on ambient air quality and cleaner air for Europe
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF

Conclusion for UK Purposes

As discussed in Section 2, as all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter[1] (31st July 2012), it is not necessary to assess this criteria for the Smart Heated PM_{10} BAM-1020. However; in the interest of completeness, 98.8 % should be stated on the MCERTS certificate.

12. Field Test Uncertainty Calculations

12.1 Introduction

The MCERTS for UK Particulate Matter[1] uses the same methodology as that employed in the 2010 version of the GDE[9]. A series of five criteria must be fulfilled in order to prove equivalence.

1. Of the full dataset at least 20 % of the results obtained using the standard method shall be greater than the upper assessment threshold specified in 2008/50/EC for annual limit values *i.e.*: 28 µg/m³ for PM_{10} and currently 17 µg/m³ for $PM_{2.5}$.

2. The intra instrument uncertainty of the candidate must be less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³ or 18 µg/m³ for PM_{10} and $PM_{2.5}$ respectively.

3. The intra instrument uncertainty of the reference method must be less than 2.0 µg/m³.

4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and 30 µg/m³ for $PM_{2.5}$ for each individual candidate instrument against the average results of the reference method. For each of the following permutations, the expanded uncertainty must be less than 25 %:

   - Full dataset;
   - Datasets representing PM concentrations greater than or equal to 30 µg/m³ for PM_{10}, or concentrations greater than or equal to 18 µg/m³ for $PM_{2.5}$, provided that the subset contains 40 or more valid data pairs;
   - Datasets for each individual test site.

5. Preconditions for acceptance of the full dataset are that: the slope b is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$, and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept of all paired instruments together.

The fulfilment of the 5 criteria is checked in the following Sections:

Criteria 1 and 2 are discussed in Section 12.2.

Criteria 3,4 and 5 are discussed in Section 12.3.

Criterion 5 is further discussed in Section 12.4.

12.2 Determination of uncertainty between systems under test u_{bs}

In this Section, Criteria 1 and 2 are assessed, namely:

1. Of the full dataset at least 20 % of the results obtained using the standard method shall be greater than the upper assessment threshold specified in 2008/50/EC for annual limit values *i.e.*: 28 µg/m³ for PM_{10} and currently 17 µg/m³ for $PM_{2.5}$.

2. The intra instrument uncertainty of the candidate must be less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³ or 18 µg/m³ for PM_{10} and $PM_{2.5}$ respectively.

The following text is copied with minor alterations from Section 2 - 5.4.9 of the 2012 Addendum to the 2006 TÜV Rheinland Report[3].

Equipment

Not required for this minimum requirement.

Performance of test

The test was carried out in at in total seven different field tests campaigns. Different seasons and varying concentrations for PM_{10} were taken into consideration.

Of the complete data set, at least 20 % of the concentration values determined with the reference method, shall be greater than the upper assessment threshold according to 2008/50/EC. For PM_{10} the upper assessment threshold is at 28 µg/m³.

There have been 4 comparison campaigns (Steyregg, Graz, Tusimice, Teddington) each with at least 40 valid data pairs. Additionally the three comparison campaigns (Cologne Parking Lot, Titz-Rödingen, Cologne Frankfurter Strasse) from the original type approval[2] have been also evaluated, even if these comparisons contain less than 40 valid data pairs. Of the complete data set (7 comparisons, 320 valid data pairs), in total 35.3 % of the measured values are above the upper assessment threshold of 28 µg/m³ for PM_{10}.

Evaluation

The uncertainty between the candidates u_{bs} must be ≤ 2.5 µg/m³. An uncertainty of more than 2,5 µg/m³ between the two candidates is an indication that the performance of one or both systems is not sufficient and the equivalence cannot be declared.

The uncertainty is determined for:

- The complete data set;
- Each individual test site;
- One data set with measured values ≥ 30 µg/m³ for PM_{10} (Basis: averages reference measurement)
- One data set with measured values < 30 µg/m³ for PM_{10} (Basis: averages of reference measurement)

The in-between-instrument uncertainty u_{bs} is calculated from the differences of all 24-hour results of the simultaneously operated candidate systems according to the following equation:

$$u_{bs}^2 = \frac{\sum_{i=1}^{n}(y_{i,1} - y_{i,2})^2}{2n}$$

with $y_{i,1}$ and $y_{i,2}$ = results of the parallel measurements of individual 24h-values i
n = number of 24h-values

.

Assessment

The in-between-uncertainty between the candidates u_{bs} is with a maximum of 1.96 µg/m³ for PM_{10} below the required value of 2.5 µg/m³.

Detailed representation of the test results

Table 15 shows the calculated values for the uncertainty between systems under test u_{bs}. The graphical representation is shown in Figure 24 through to Figure 33.

Table 15: Uncertainty between systems under test u_{bs} for the candidates SN 4924 and SN 4925, measured component PM_{10}

Candidates	Test site	No. of values	Uncertainty u_{bs}
SN			µg/m³
Various	**All test sites**	**363**	**1.22**
Single test sites			
4924 / 4925	Cologne Parking Lot	52	1.22
4924 / 4925	Titz-Rödingen	37	0.86
4924 / 4925	Cologne Frankfurter Strasse	28	0.99
AUSTRIA 1 / AUSTRIA 2	Steyregg	51	0.75
AUSTRIA 1 / AUSTRIA 2	Graz	50	1.96
J7860 / J7863	Tusimice	103	1.18
17011 / 17022	Teddington	42	1.00
Classification via reference value			
Various	**Values ≥ 30 µg/m³**	**105**	**1.49**
Various	Values < 30 µg/m³	215	1.09

Figure 24: Results of the parallel measurements with the candidates, measured component PM_{10}, all test sites

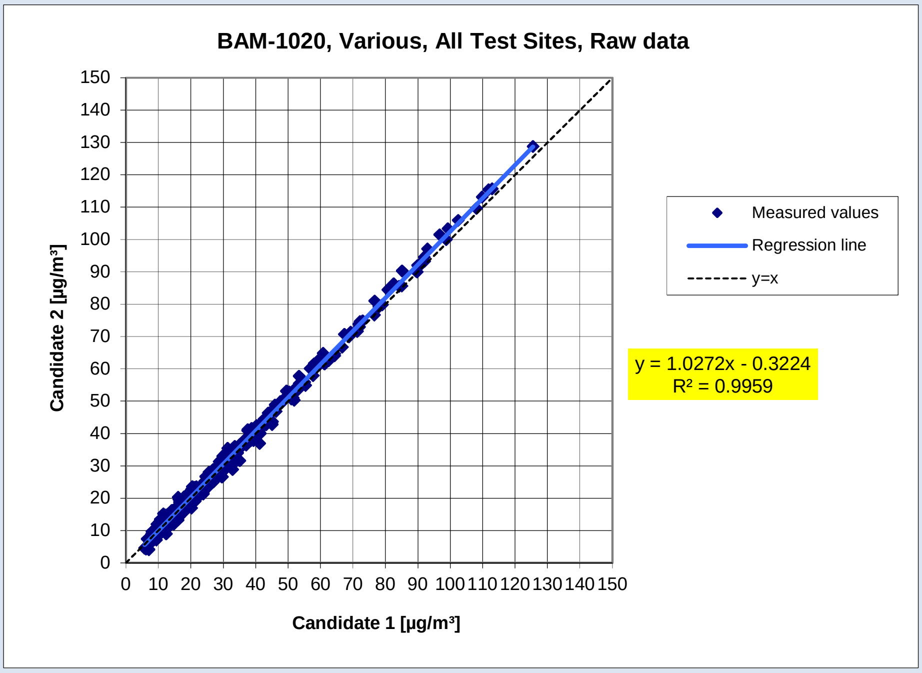


Figure 25: Results of the parallel measurements with the candidates, measured component PM_{10}, test site Cologne Parking Lot

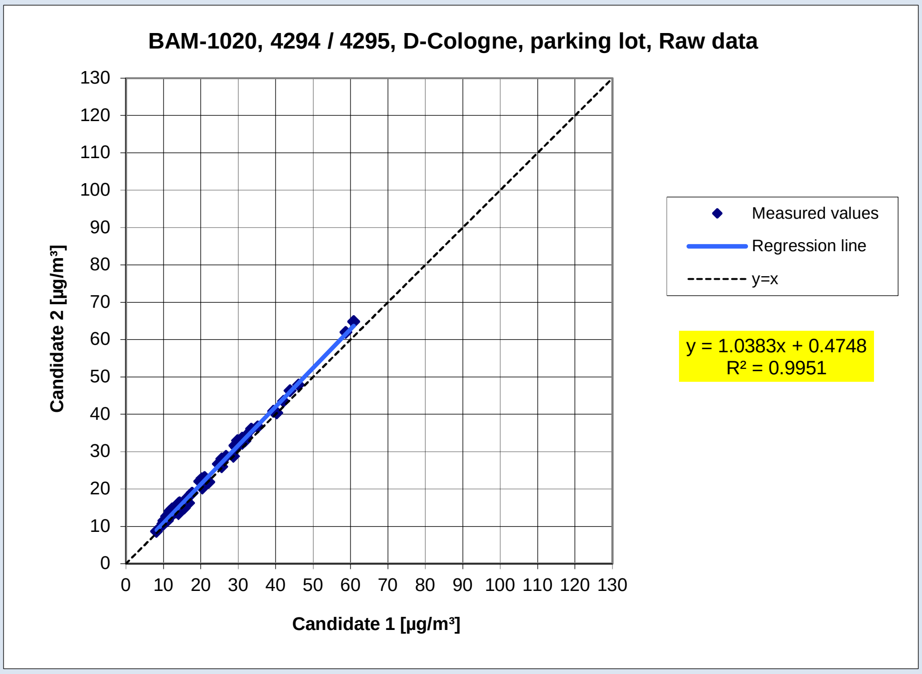


Figure 26: Results of the parallel measurements with the candidates, measured component PM_{10}, Test site Titz-Rödingen

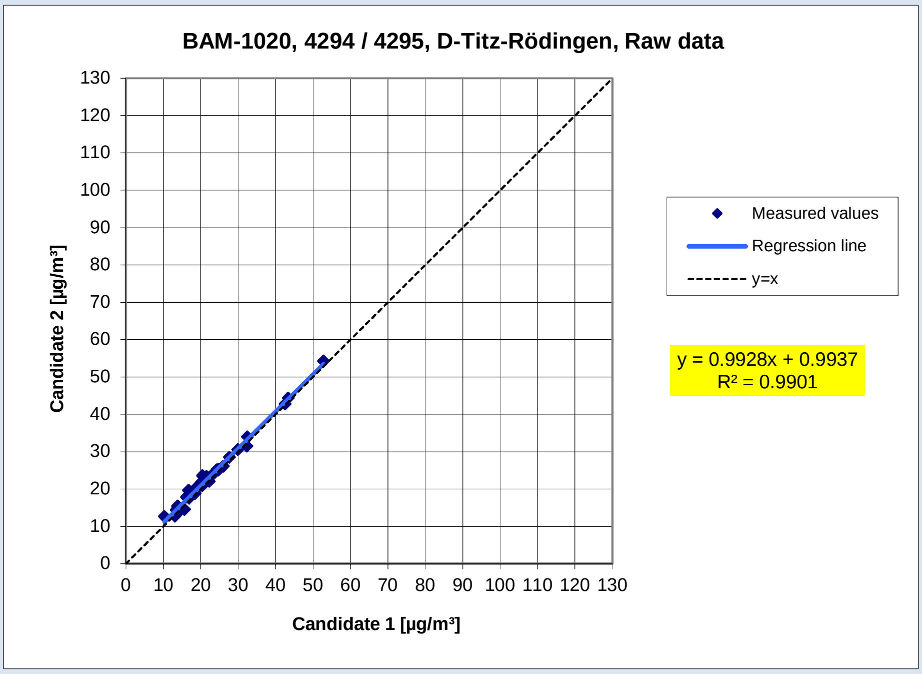


Figure 27: Results of the parallel measurements with the candidates measured component PM_{10}, Test site Cologne Frankurter Strasse

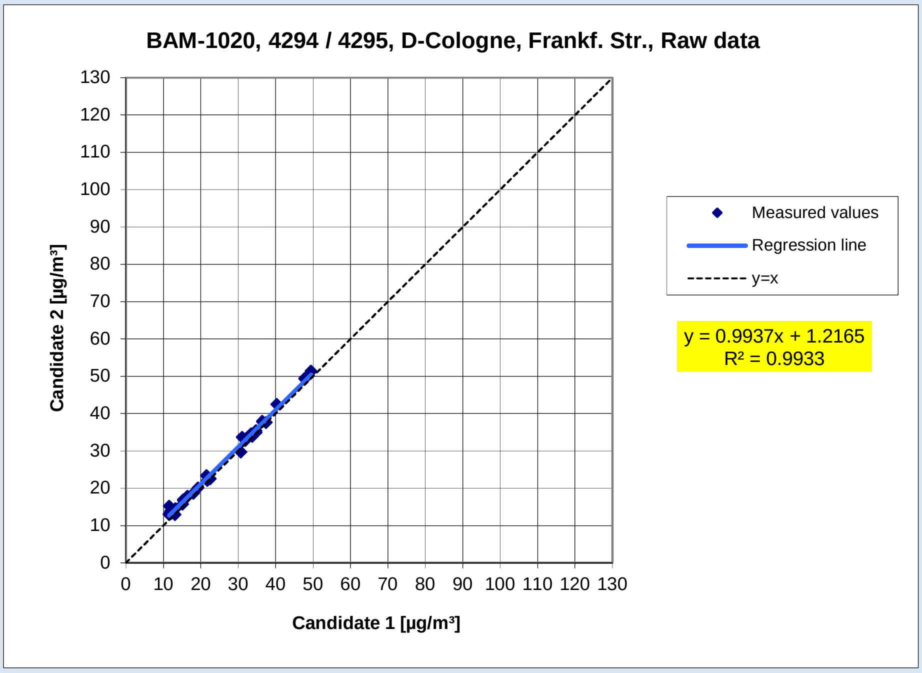


Figure 28: Results of the parallel measurements with the candidates, Measured component PM10, Test site Steyregg

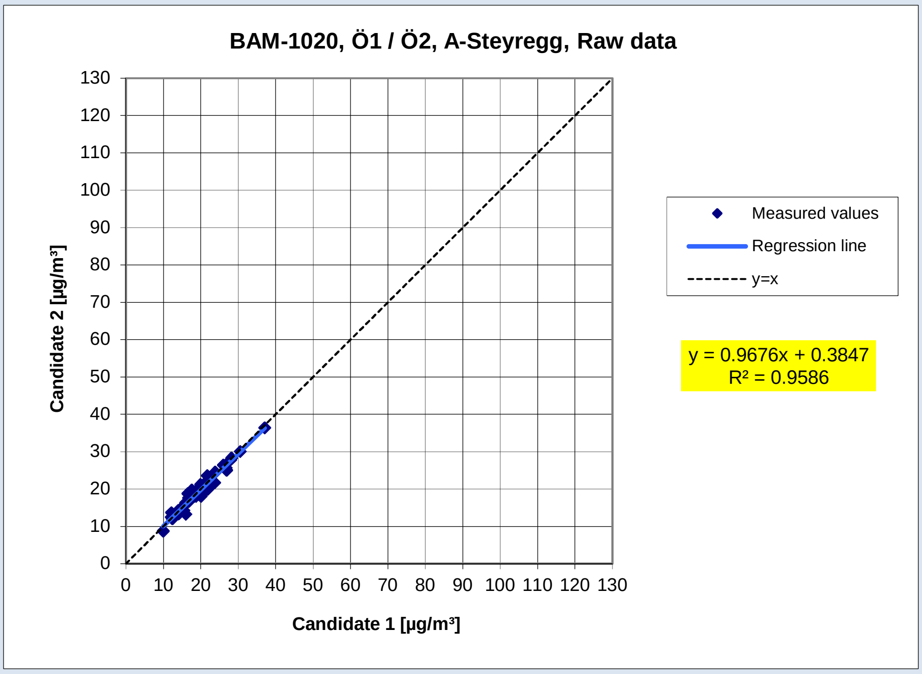


Figure 29: Results of the parallel measurements with the candidates, Measured component PM10, Test site Graz

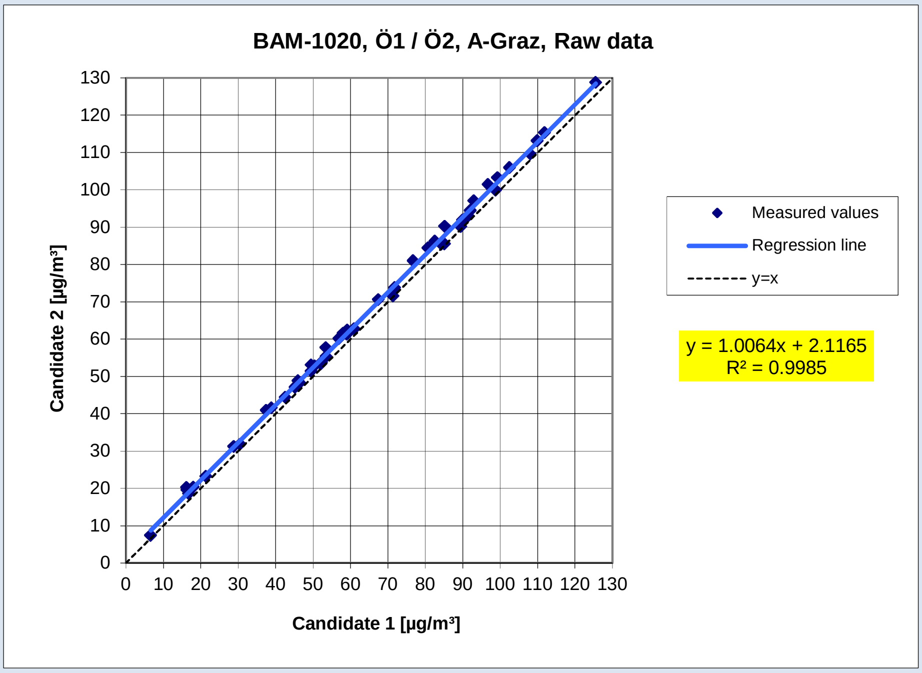


Figure 30: Results of the parallel measurements with the candidates, Measured component PM10, Test site Tusimice

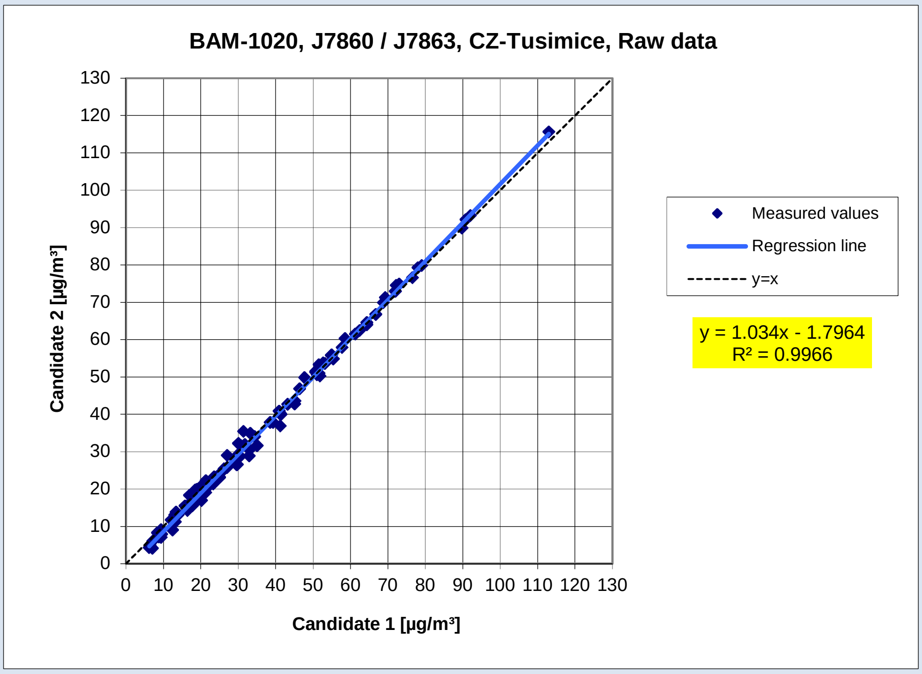


Figure 31: Results of the parallel measurements with the candidates, Measured component PM10, Test site Teddington

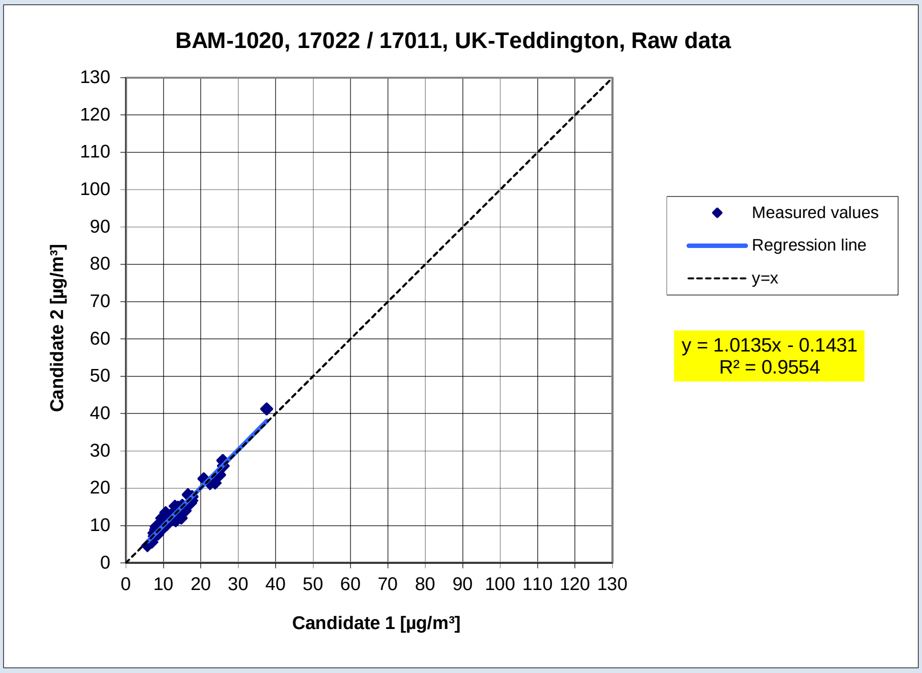


Figure 32: Results of the parallel measurements with the candidates, Measured component PM10, all test sites, values ≥ 30 µg/m³

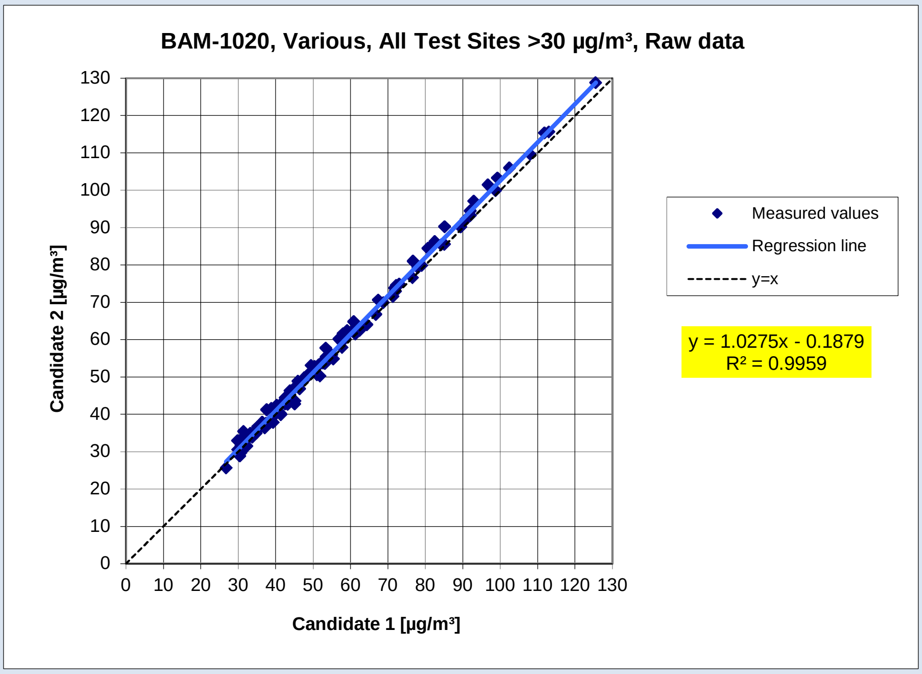
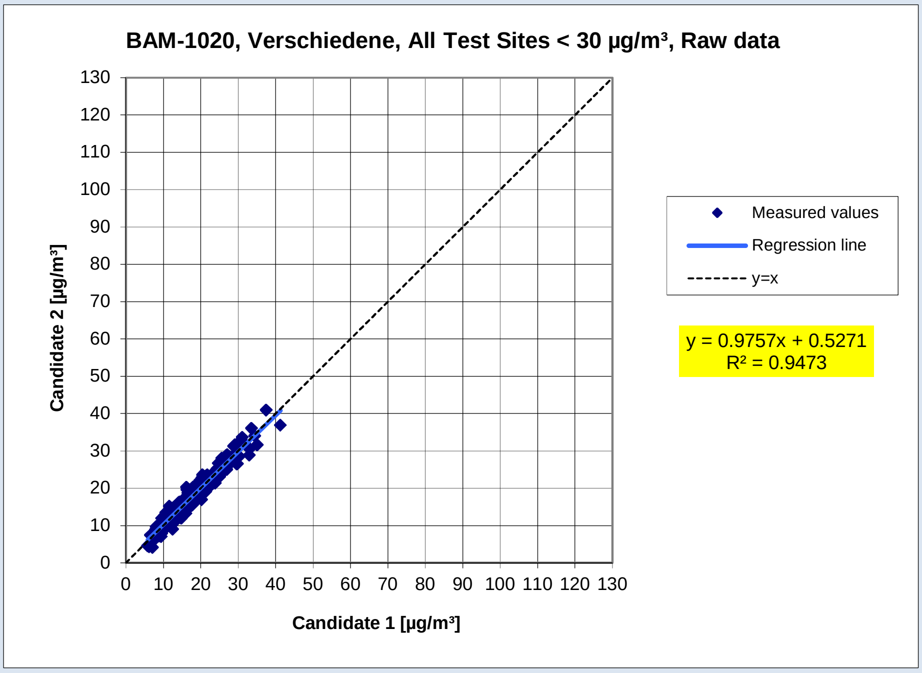


Figure 33: Results of the parallel measurements with the candidates, Measured component PM10, all test sites, values < 30 µg/m³



Conclusion for UK Purposes

It is noted that the conclusions of the 2012 Addendum to the 2006 TÜV Rheinland Report[3] consider data from all seven datasets, including the three where there are fewer than 40 data pairs. Table 21 (in section 12.5) shows the results of the equivalence test without correction for those field tests with greater than 40 data points. It is shown that 37.2% of data pairs were greater than 28 µg/m³ (shaded light blue) and that all of the between instrument uncertainties of the candidate method are less than 2.5 µg/m³ (shaded grey). Sections 12.4 and 12.5 discuss the need to slope correct in order for all datasets to have an expanded uncertainty below 25 %. Table 23 shows the results of slope correction. This again shows that criteria 1 and 2 are both fulfilled after the application of slope correction.

As at least 20 % of the results obtained using the standard method are greater than 28 µg/m³, criterion 1 is fulfilled. There is no requirement in MCERTS for UK Particulate Matter for this information to be placed upon the MCERTS certificate.

As the intra instrument uncertainty of the candidate method is less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³, criterion 2 is fulfilled. These three intra instrument uncertainties should be placed on the MCERTS certificate.

12.3 Calculation of the expanded uncertainty of the instruments

In this Section, Criteria 3,4 and 5 are assessed, namely:

3. The intra instrument uncertainty of the reference method must be less than 2.0 µg/m³.

4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and 30 µg/m³ for $PM_{2.5}$ for each individual candidate instrument against the average results of the reference method. For each of the following permutations, the expanded uncertainty must be less than 25 %:

    - Full dataset;
    - Datasets representing PM concentrations greater than or equal to 30 µg/m³ for PM_{10}, or concentrations greater than or equal to 18 µg/m³ for $PM_{2.5}$, provided that the subset contains 40 or more valid data pairs;
    - Datasets for each individual test site.

5. Preconditions for acceptance of the full dataset are that: the slope b is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$, and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept of all paired instruments together.

The Excel functions used to calculate the orthogonal regression was taken directly from the JRC Excel tool published in 2004 to calculate expanded uncertainties of PM equivalence datasets[15]. This tool has been superseded and is no longer available for download. The mathematics within the 2004 tool have been validated by both TÜV Rheinland and BV to give an identical result to the equations specified in GDE2010[9]. In CEN/TS16450:2013, the same orthogonal methodology is allowed, though a number of other orthogonal regression methods are now also permissible.

In all cases the uncertainty of the reference method was calculated for each individual dataset in accordance with GDE2010. At Tusimice there was only one reference method available, and so it was necessary to use the recommended default uncertainty of 0.67. At all other sites, there were two reference methods available and so the intra instrument uncertainty of the reference method was calculated.

The following text is copied with minor alterations from Section 3. 5.4.10 of the 2012 Addendum to the 2006 TÜV Rheinland Report[3].

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15 File: Test for EquivalenceV31004.xls formerly available to download from: http://ec.europa.eu/environment/air/quality/legislation/assessment.htm

Equipment

Not required for this minimum requirement.

Performance of Test

The test was carried out in field tests at in total seven different comparison campaigns during field test. Different seasons and varying concentrations for PM_{10} were taken into consideration.

There has been 4 comparison campaigns (Steyregg, Graz, Tusimice, Teddington) each with at least 40 valid data pairs. Additionally the three comparison campaigns (Cologne Parking Lot, Titz-Rödingen, Cologne Frankfurter Strasse) from the original type approval[2] have been also evaluated, even if these comparisons contain less than 40 valid data pairs.

Evaluation

The calculation of the in-between-instrument uncertainty u_{ref} of the reference devices is carried out prior to the calculation of the expanded uncertainty of the candidates.

The in-between-instrument uncertainty u_{ref} of the reference devices shall be ≤ 2 µg/m³. These results are discussed in the detailed description of results below.

A linear correlation $y_i = a + bx_i$ is assumed between the results of both methods in order to evaluate the comparability of the candidates y and the reference procedure x. The correlation between the average values of the reference devices and the candidates is established by orthogonal regression.

Regression is calculated for:

- All test sites
- Each test site separately
- 1 data set with measured values PM_{10} ≥ 30 µg/m³ (Basis: average value of reference measurement)

For further evaluation, the results of the uncertainty u_{c_s} of the candidates compared with the reference method are described with the following equation, which describes u_{CR} as a function of the PM concentration x_i:

$$u_{CR}^2(y_i) = \frac{RSS}{(n-2)} - u^2(x_i) + [a + (b-1)x_i]^2$$

With RSS = Sum of the (relative) residuals from orthogonal regression

$u(x_i)$ = random uncertainty of the reference procedure if value u_{bs}, which is calculated for using the candidates, can be used in this test

The sum of the (relative) residuals RSS is calculated by the following equation:

$$RSS = \sum_{i=1}^{n} (y_i - a - bx_i)^2$$

Uncertainty u_{c_s} is calculated for:

- All test sites
- Each test site separately
- 1 data set with measured values ≥ 30 µg/m³ (Basis: average values of the reference measurement)

Preconditions for acceptance of the full dataset are that:

- The slope b is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$

and

- The intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$

Where u(b) and u(a) are the standard uncertainties of the slope and intercept, respectively calculated as the square root of their variances. If these preconditions are not met, the candidate method may be calibrated according to GDE2010[9]. The calibration shall only be applied to the full dataset.

The combined uncertainty of the candidates $wc_{,CM}$ is calculated for each data set by combining the contributions according to the following equation:

$$w_{c,CM}^2(y_i) = \frac{u_{CR}^2(y_i)}{y_i^2}$$

For each dataset, the uncertainty $w_{c,CM}$ is calculated at the level of y_i = 50 µg/m³ for PM_{10}.

The expanded relative uncertainty of the results of the candidates is calculated for each data set by multiplication of $w_{c,CM}$ with a coverage factor k according to the following equation:

$$W_{CM} = k \cdot w_{CM}$$

In practice: k=2 for a large n

The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality of ambient air measurements according to 2008/50/EC[14]. Two results are possible:

1. $W_{CM} \leq W_{dqo}$ → Candidate method is accepted as equivalent to the standard method.

2. $W_{CM} > W_{dqo}$ → Candidate method is not accepted as equivalent to the standard method.

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 %[14].

Assessment

The expanded uncertainties (W_{CM}) without application of correction factors are below the defined expanded relative uncertainty W_{dqo} of 25 % for datasets except for the test site Graz (for candidate AUSTRIA 2) as well as for Teddington (for candidate 17011). It is necessary to check whether all test sites will be below the defined expanded relative uncertainty W_{dqo} of 25 % after the application of slope and/or intercept correction factors.

Table 16 shows an overview of the results of the equivalence check for the candidate BAM-1020 for PM_{10}. For reasons of clarity, this Table is spread across two pages. For the case, that a criterion is fulfilled or not, the text is represented in green or red colour.

The check of the five criteria from Section 12.1 resulted as follows:

Criterion 1: Greater than 20 % of the data are greater than 28 µg/m³.

Criterion 2: The intra instrument uncertainty of the candidates is smaller than 2.5 µg/m³.

Criterion 3: The intra instrument uncertainty of the reference is smaller than 2.0 µg/m³.

Criterion 4: Most of the expanded uncertainties are below 25 %, but this requirement is not fulfilled for the raw data set of Graz (Austria 2) and Teddington (17011).

Criterion 5: Several of the slopes and intercepts for the individual candidates are statistically significantly greater than allowed. Further, the slope and the intercept of the complete data set are statistically significantly greater than allowed.

Other: The evaluation of the All Data set for both candidates together shows that the AMS demonstrates a very good correlation with the reference method with a slope of 1.034 and an intercept of 0.843 with an expended uncertainty of 16.0 %.

Table 16: Overview of the equivalence calculations for the Smart Heated PM_{10} BAM-1020

Smart Heated PM_{10} BAM-1020	35.3% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	Reference	Candidate
All Paired Data	16.0	320	0.982	1.034 +/- 0.008	0.843 +/- 0.290	0.67	1.22
< 30 µg m³	24.7	215	0.826	1.119 +/- 0.032	-0.446 +/- 0.557	0.53	1.09
> 30 µg m³	17.7	105	0.971	1.042 +/- 0.017	0.141 +/- 1.031	0.91	1.49

4294	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Cologne, Parking Lot	29	0.960	0.948 +/- 0.036	2.202 +/- 0.950	10.13	34.5
	Titz - Rödingen	37	0.962	1.058 +/- 0.035	0.376 +/- 0.782	14.75	18.9
	Cologne, Frankfurter Str.	28	0.963	1.025 +/- 0.039	-1.293 +/- 1.083	8.07	42.9
Combined Datasets	< 30 µg m³	68	0.814	1.040 +/- 0.055	0.162 +/- 0.981	12.58	4.4
	> 30 µg m³	26	0.897	0.964 +/- 0.063	1.810 +/- 2.438	9.75	100.0
	All Data	94	0.953	0.987 +/- 0.022	1.048 +/- 0.563	9.16	35.3

4295	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Cologne, Parking Lot	29	0.970	0.990 +/- 0.033	2.681 +/- 0.862	12.53	34.5
	Titz - Rödingen	37	0.961	1.056 +/- 0.035	1.260 +/- 0.785	17.52	18.9
	Cologne, Frankfurter Str.	28	0.969	1.021 +/- 0.035	-0.154 +/- 0.994	8.10	42.9
Combined Datasets	< 30 µg m³	68	0.830	1.056 +/- 0.053	0.935 +/- 0.952	17.24	4.4
	> 30 µg m³	26	0.929	1.025 +/- 0.056	0.713 +/- 2.151	11.49	100.0
	All Data	94	0.960	1.004 +/- 0.021	1.735 +/- 0.528	11.41	30.9

Austria1	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.969	1.025 +/- 0.027	-0.202 +/- 1.848	20.89	82.2
	Steyregg	45	0.824	1.049 +/- 0.067	-1.750 +/- 1.392	9.31	8.9
Combined Datasets	< 30 µg m³	50	0.644	1.339 +/- 0.109	-6.789 +/- 2.135	42.75	2.0
	> 30 µg m³	40	0.960	1.057 +/- 0.034	-2.826 +/- 2.431	19.58	100.0
	All Data	90	0.983	1.039 +/- 0.015	-1.294 +/- 0.729	15.95	45.6

KEY

Light cyan	Criterion 1
Grey	Criterion 2
Peach	Criterion 3
Light yellow	Criterion 4
Light blue	Criterion 5
Orange-yellow	Other

Table 16 Continued. Overview of the equivalence calculations for the Smart Heated PM_{10} BAM-1020

Austria2	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.966	1.033 +/- 0.029	1.948 +/- 1.962	26.05	82.2
	Steyregg	45	0.793	1.035 +/- 0.072	-1.668 +/- 1.489	9.56	8.9
Combined Datasets	< 30 µg m³	50	0.557	1.492 +/- 0.130	-9.462 +/- 2.545	62.86	2.0
	> 30 µg m³	40	0.956	1.084 +/- 0.037	-2.296 +/- 2.635	22.65	100.0
	All Data	90	0.980	1.079 +/- 0.016	-1.702 +/- 0.818	19.84	45.6

J7860	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	59	0.906	1.172 +/- 0.047	1.204 +/- 0.839	40.46	6.8
	> 30 µg m³	38	0.974	1.002 +/- 0.027	3.154 +/- 1.548	17.67	100.0
	All Data (Tusimice)	97	0.984	0.999 +/- 0.013	3.739 +/- 0.492	18.45	43.3

J7863	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	58	0.913	1.158 +/- 0.045	0.159 +/- 0.812	33.73	6.9
	> 30 µg m³	38	0.978	1.032 +/- 0.025	1.948 +/- 1.450	17.98	100.0
	All Data (Tusimice)	96	0.987	1.035 +/- 0.012	2.035 +/- 0.461	18.18	43.8

17011	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.960	1.039 +/- 0.034	0.632 +/- 0.458	11.13	0.0
	> 30 µg m³	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.949	1.162 +/- 0.042	-0.766 +/- 0.602	29.99	2.5

17022	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.958	1.051 +/- 0.035	0.603 +/- 0.477	13.45	0.0
	> 30 µg m³	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.963	1.110 +/- 0.034	-0.050 +/- 0.488	22.28	2.5

KEY

- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

As not all of the expanded uncertainties are below 25 %, and not all of the uncertainties of slope and intercept are within the required limits, an additional evaluation after application of the respective correction factors / terms to the data sets has been carried out in Section 12.4:

a) Correction for intercept
b) Correction for slope
c) Correction for intercept and slope

The revised version of the Guide of January 2010 requires that when operating in networks, a candidate method needs to be tested annually at a number of sites and that the number of the instruments to be tested is dependent on the expanded measurement uncertainty of the device. The respective realization is the responsibility of the network operator or of the responsible authority of the member state.

However TÜV Rheinland and their UK partners recommend that the expanded uncertainty for the full data set is referred to for this, namely 16.0 %, which again would require an annual test at four measurement sites.

Detailed representation of the test results

Table 17 shows an overview on the uncertainties between the reference devices $u_{ref\ from}$ the field tests.

Table 17: Uncertainty between the reference devices uref for PM_{10}

Reference devices	Test site	No. of values	Uncertainty u_{bs}
Nr.			µg/m³
1 / 2	All test sites	320	0.67
1 / 2	Cologne Parking Lot	29	0.55
1 / 2	Titz-Rödingen	37	0.65
1 / 2	Cologne Frankfurter Strasse	28	1.02
1 / 2	Steyregg	45	0.53
1 / 2	Graz	45	0.82
1 / 2	Tusimice	96	-*
1 / 2	Teddington	40	0.25

* only one reference device in operation, for the evaluation the uncertainty for the complete data set of 0.67 µg/m³ is applied

The uncertainty between the reference devices uref is for all test sites < 2 µg/m³.

The datasets are show graphically in Figure 34 to Figure 50.

Figure 34: Reference vs. Candidate, Paired Data, All Test Sites

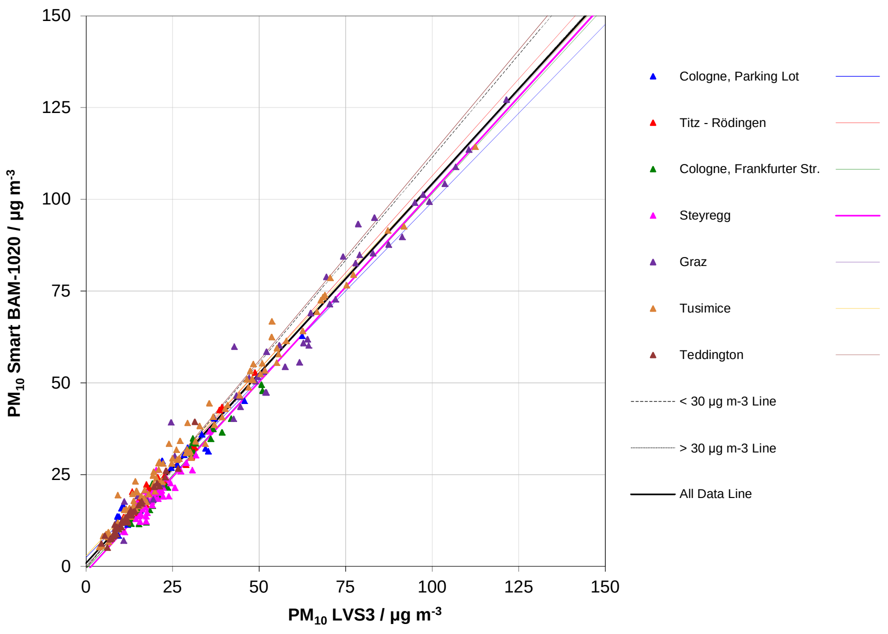


Figure 35: Reference vs. Candidate, SN 4924, Cologne Parking Lot

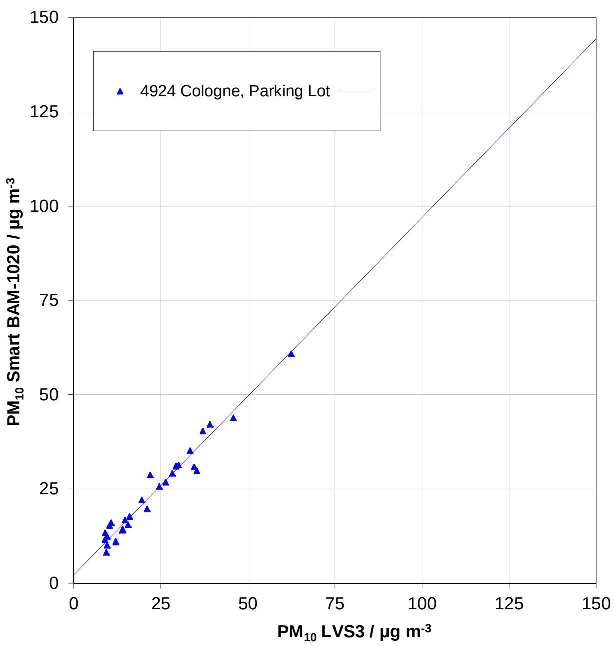


Figure 36: Reference vs. Candidate, SN4925, Cologne Parking Lot

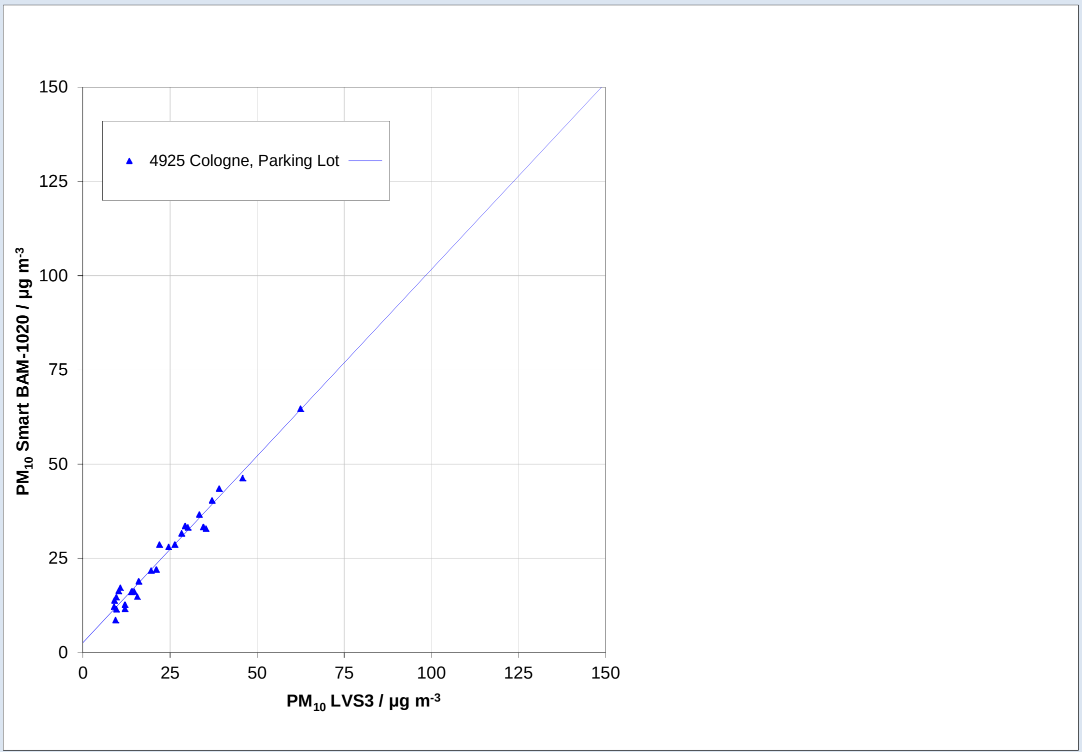


Figure 37: Reference vs. Candidate, SN 4924, Titz-Rödingen

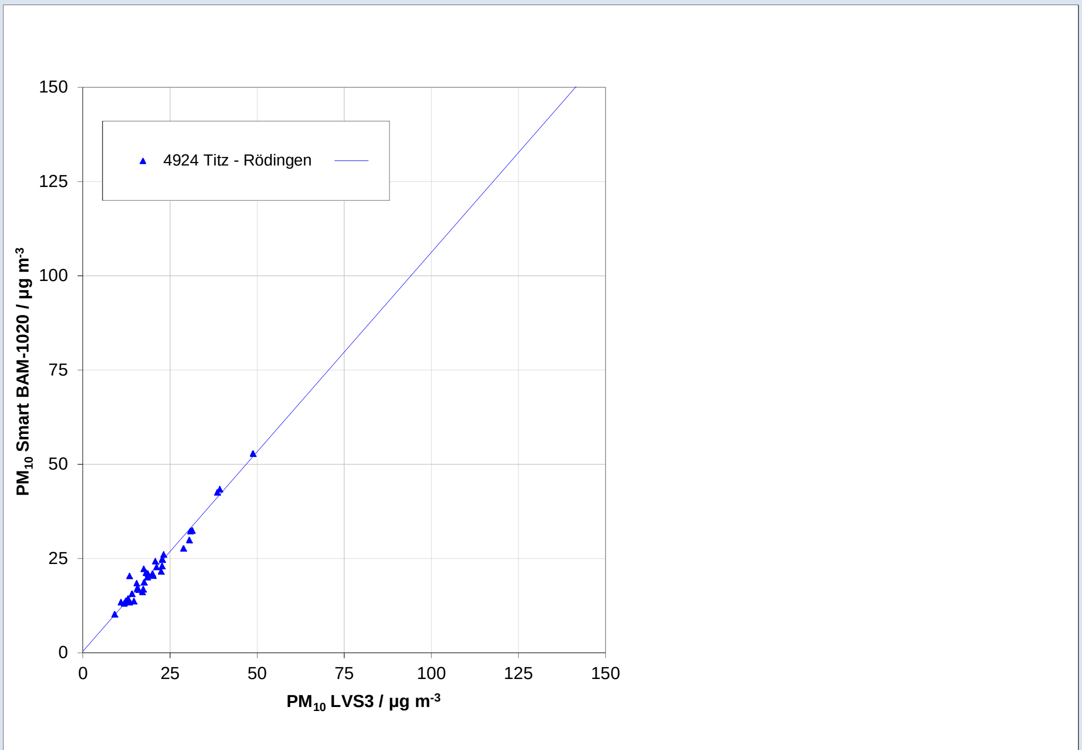


Figure 38: Reference vs. Candidate, SN4925, Titz-Rödingen

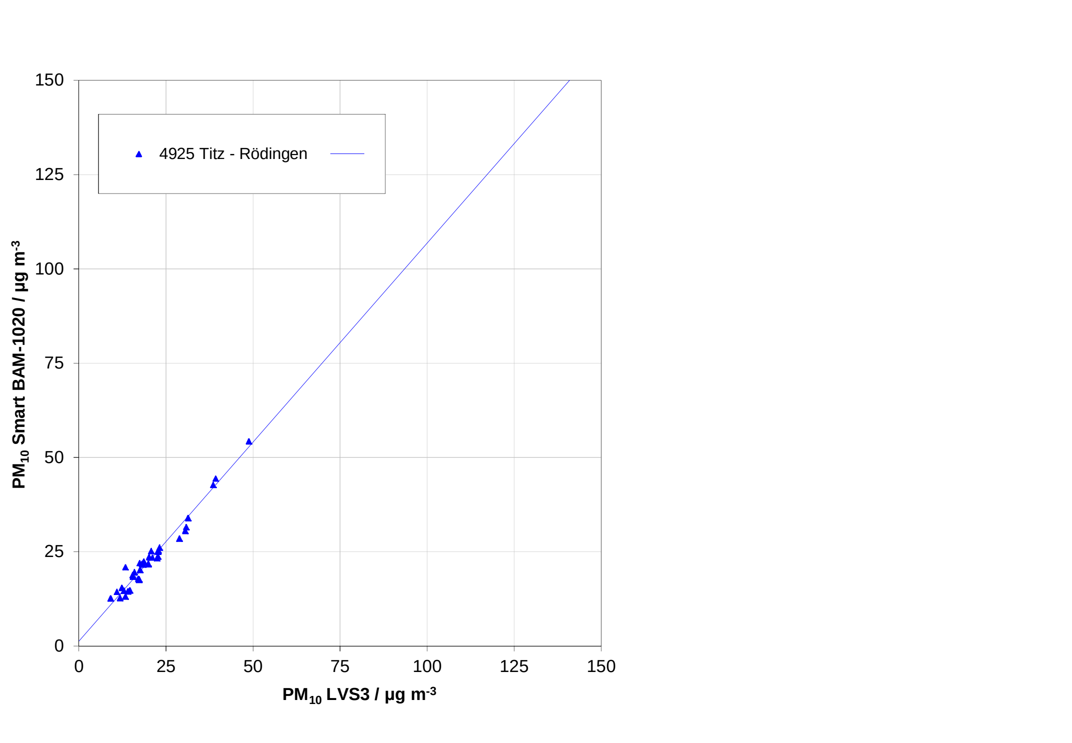


Figure 39: Reference vs. Candidate, SN 4924, Cologne Frankfurter Strasse

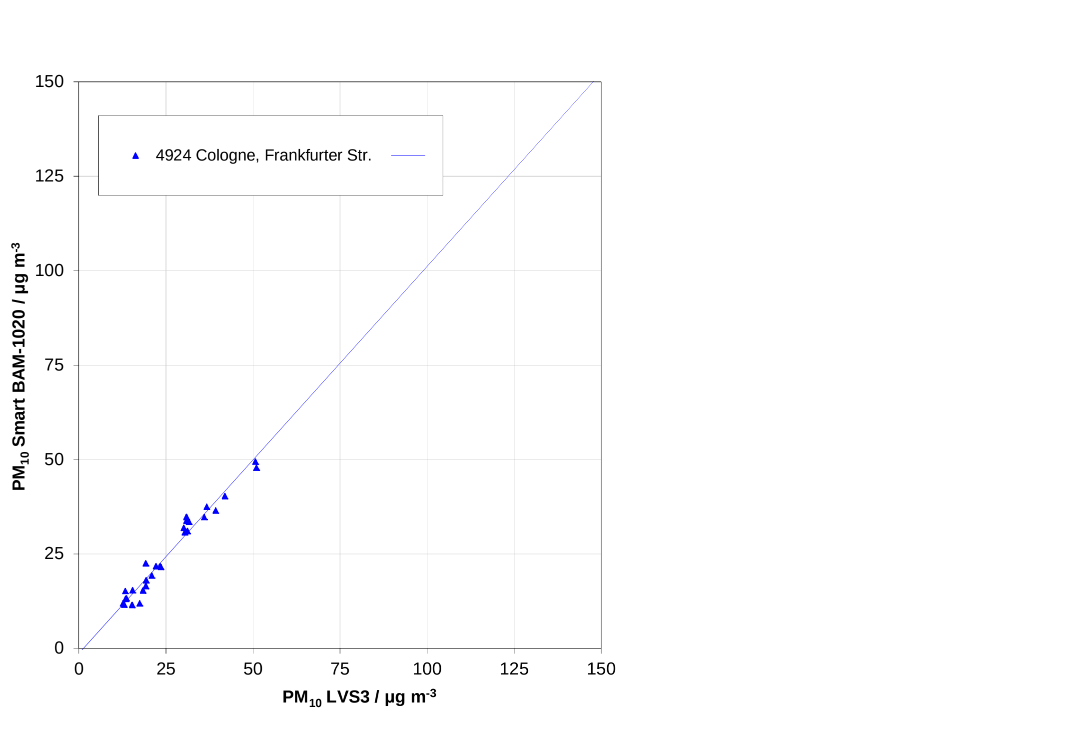


Figure 40: Reference vs. Candidate, SN 4925, Cologne Frankfurter Strasse

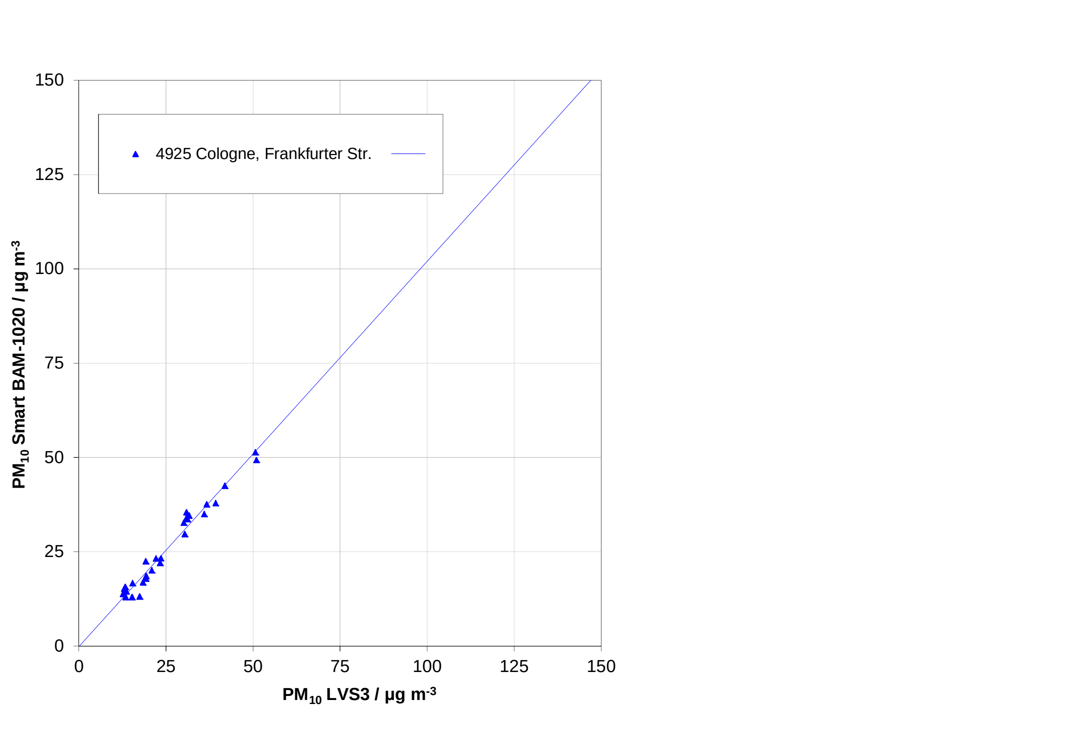


Figure 41: Reference vs. Candidate, Austria 1, Steyregg

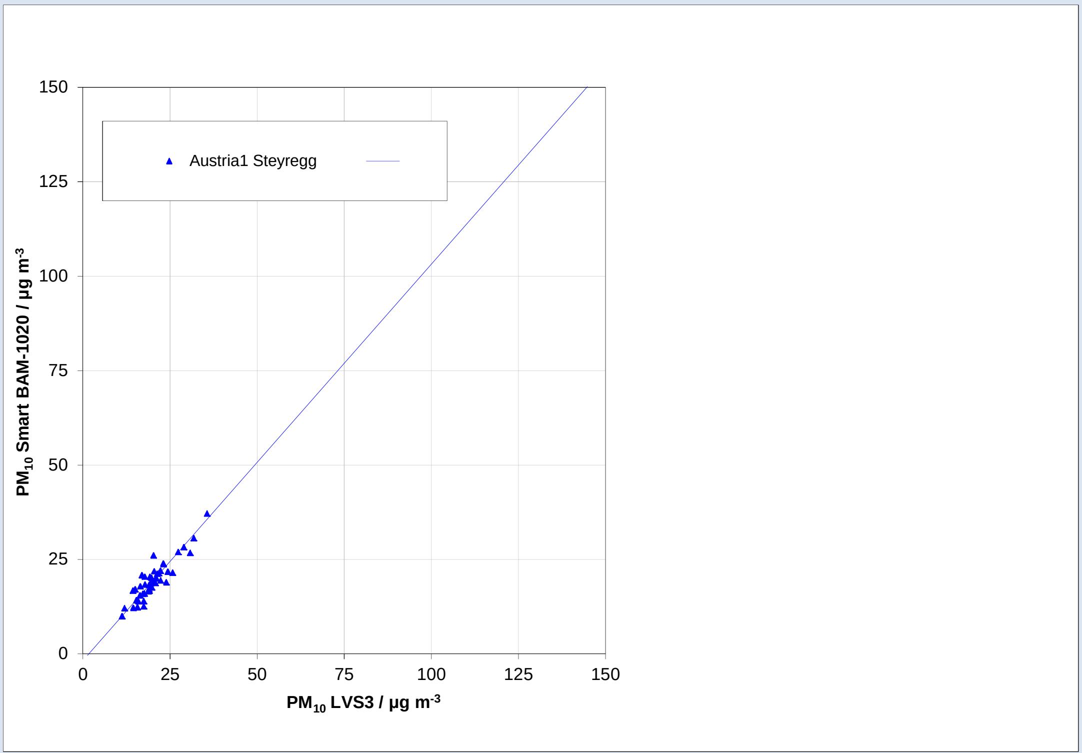


Figure 42: Reference vs. Candidate, Austria 2, Steyregg

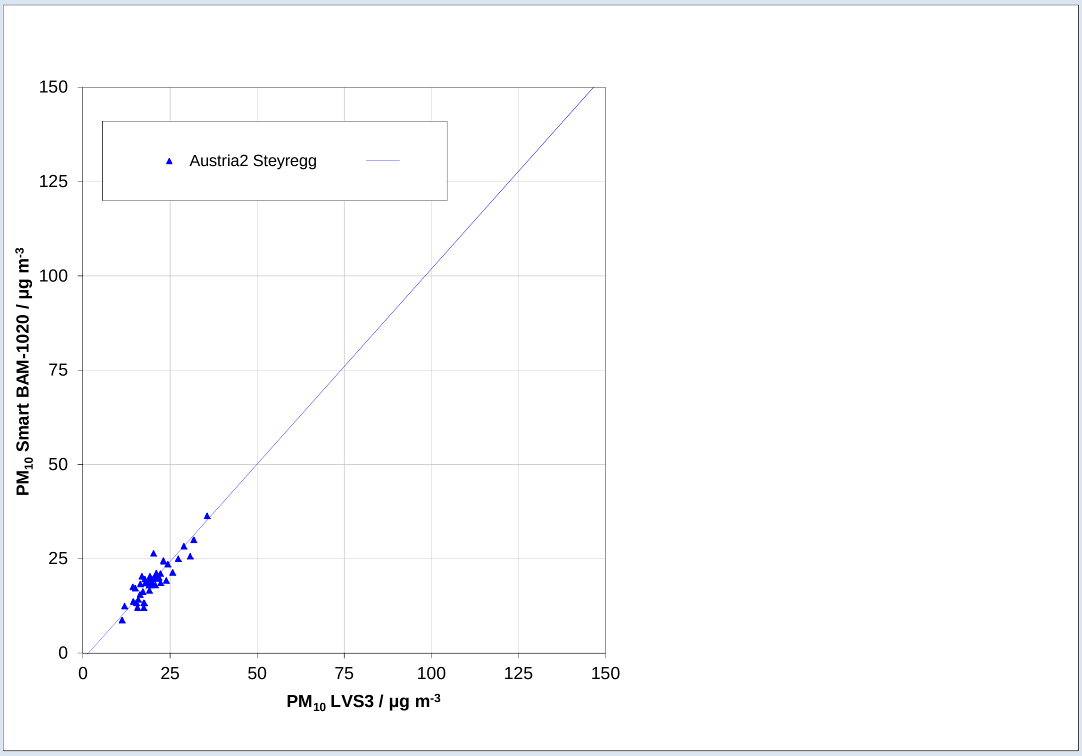


Figure 43: Reference vs. Candidate, Austria 1, Graz

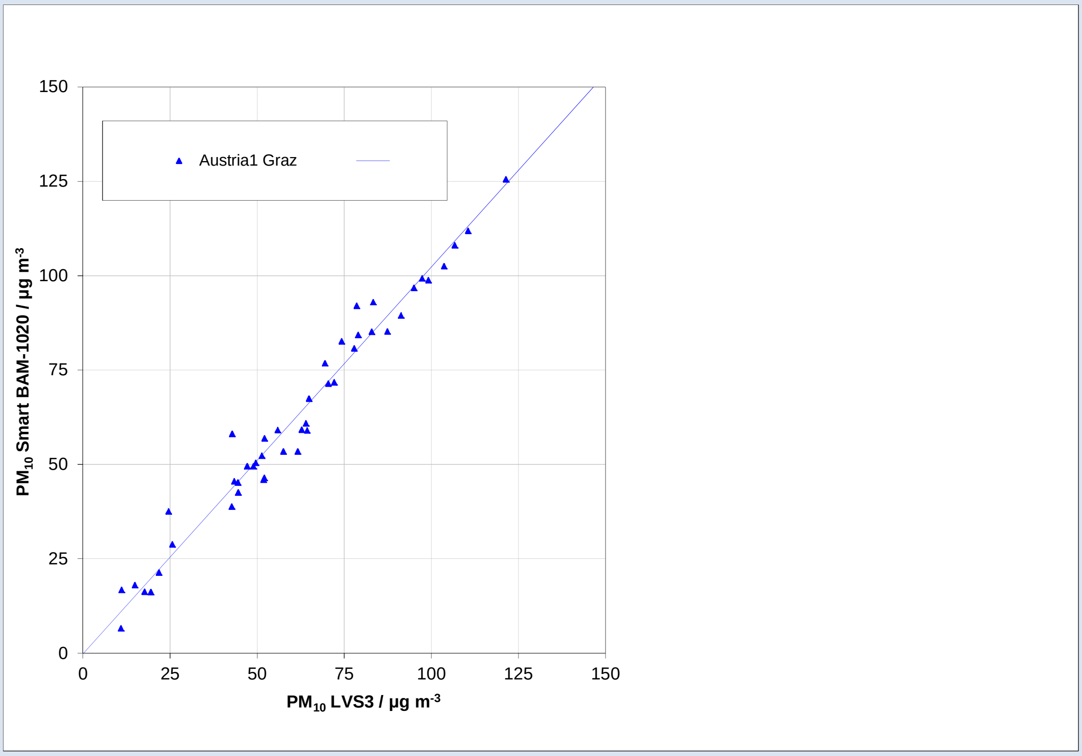


Figure 44: Reference vs. Candidate, Austria 2, Graz

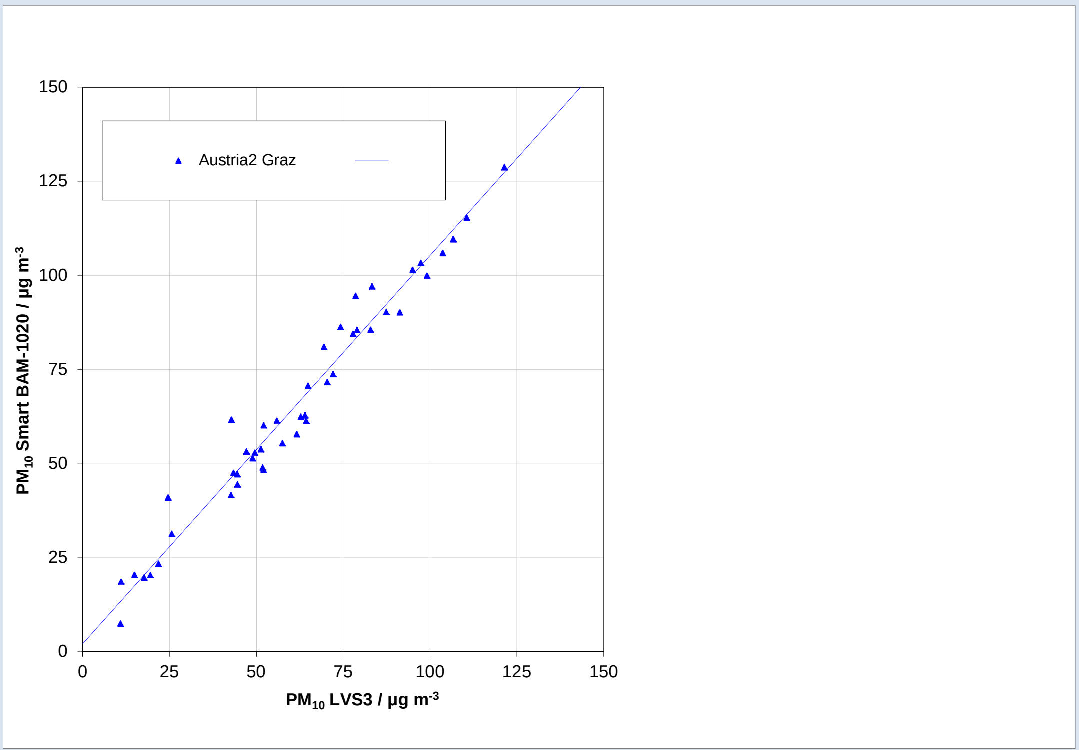


Figure 45: Reference vs. Candidate, J7860, Tusimice

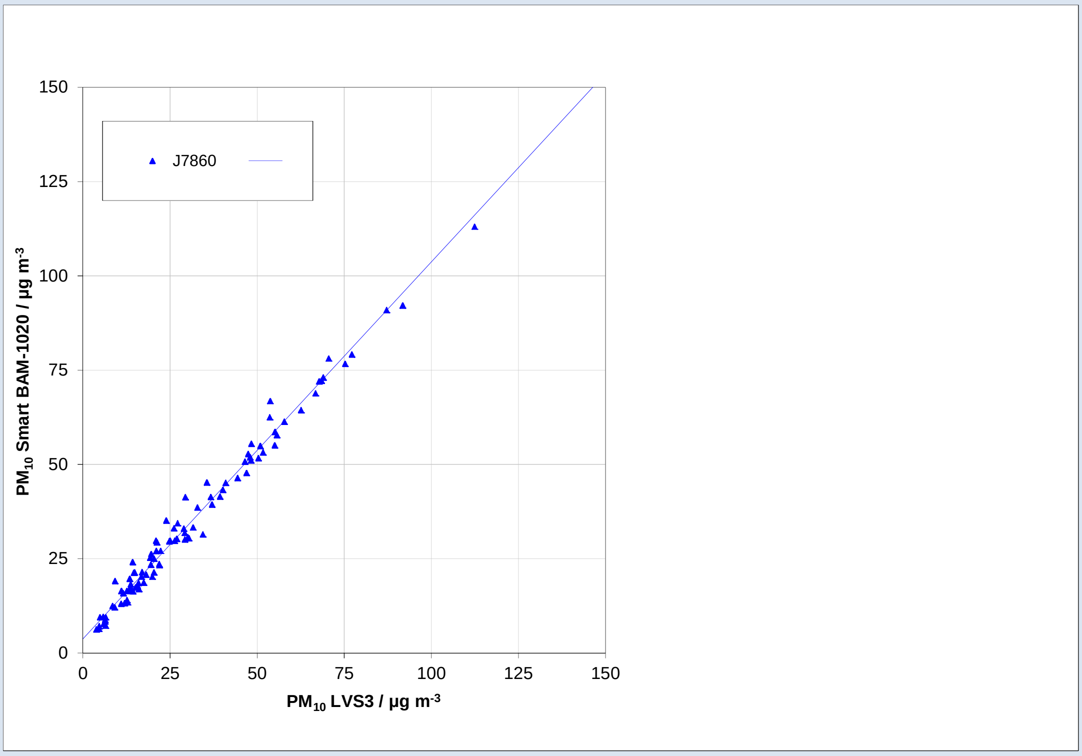


Figure 46: Reference vs. Candidate, J7863, Tusimice

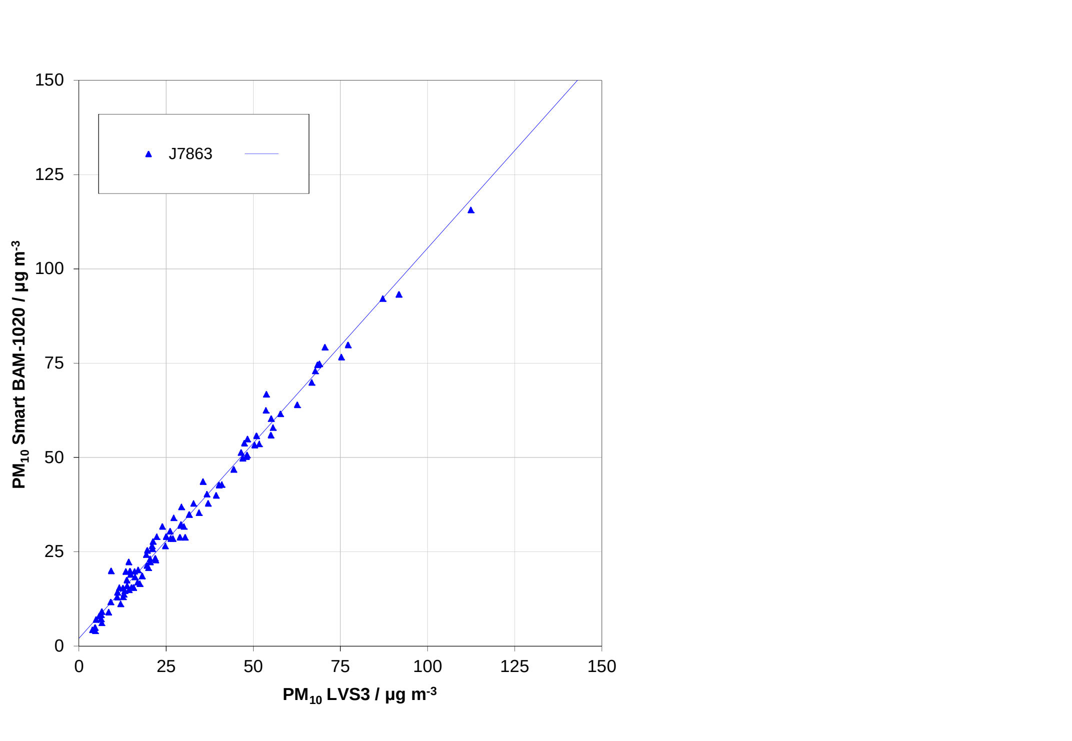


Figure 47: Reference vs. Candidate, SN 17011, Teddington

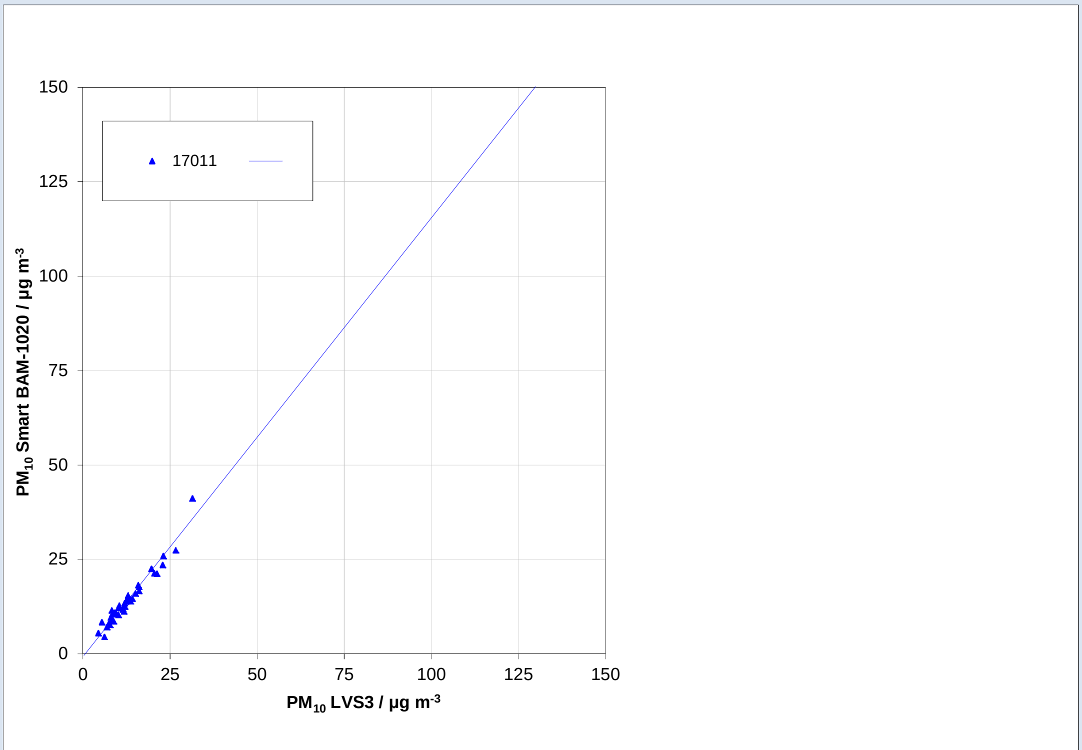


Figure 48: Reference vs. Candidate, SN 17022, Teddington

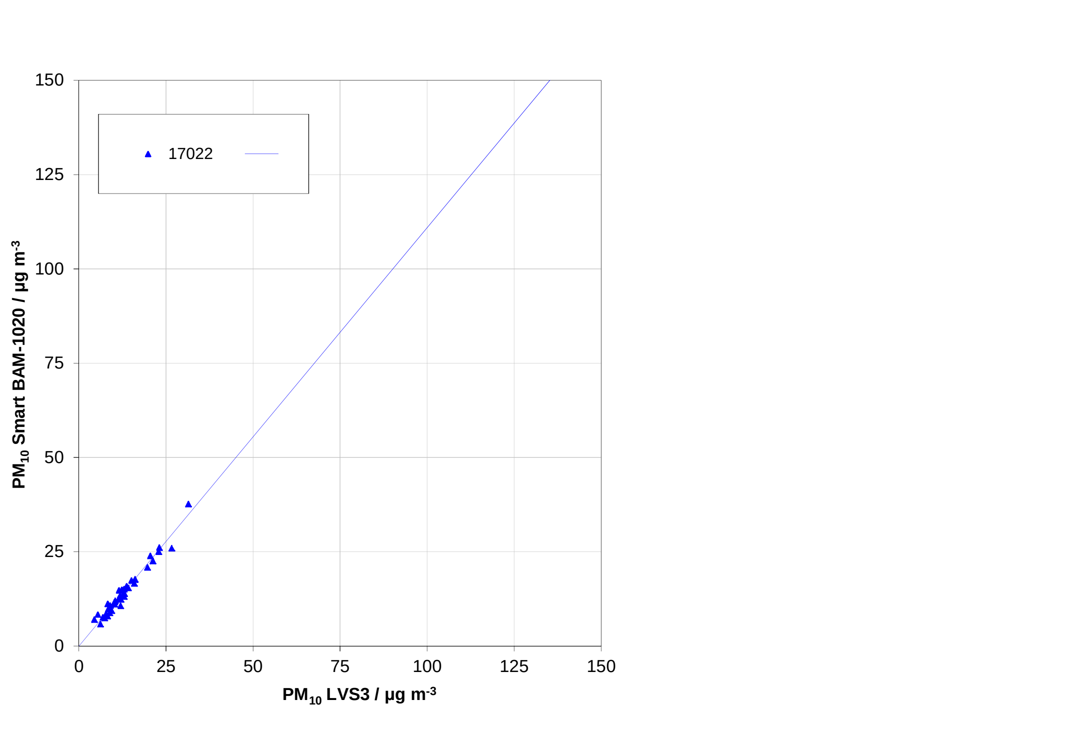


Figure 49: Reference vs. Candidate, All test sites, Values ≥ 30 µg/m³

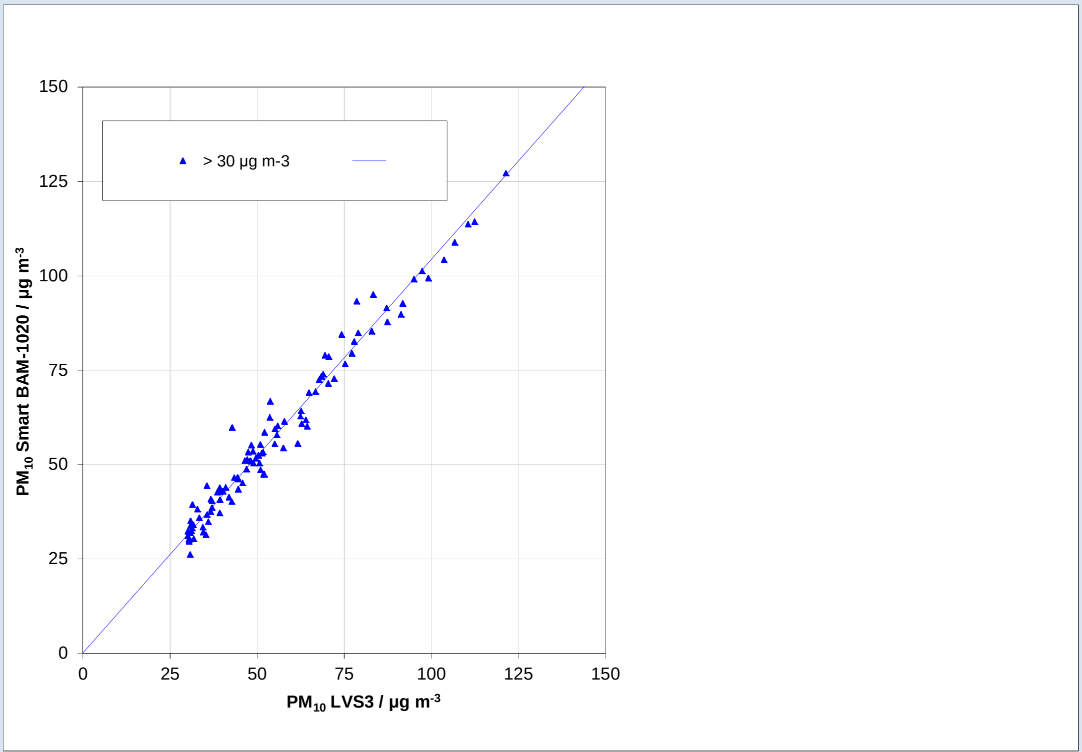
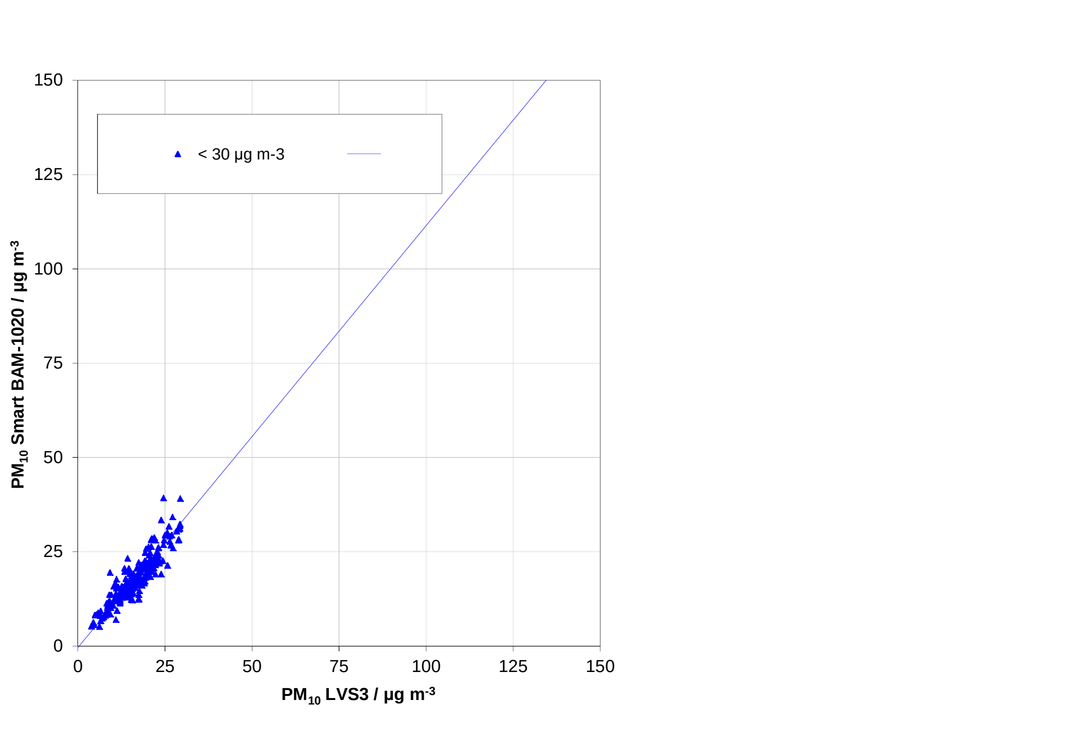


Figure 50: Reference vs. Candidate, All Test Sites, Values < 30 µg/m³



Conclusion for UK Purposes

It is noted that the conclusions of the 2012 Addendum to the 2006 TÜV Rheinland Report[3] consider data from all seven datasets, including the three where there are fewer than 40 data pairs. Table 21 (in section 12.5) shows the results of the equivalence test without correction for those field tests with greater than 40 data points. The calculation for the intra instrument uncertainty of the reference method is shaded pink. As the intra instrument uncertainty of the reference method is less than 2.0 µg/m³ for the 'All Data' dataset, criterion 3 is fulfilled. Further, the intra instrument uncertainty of the reference method is less than 2.0 µg/m³ for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³, though there is no requirement for this objective to be achieved. These three intra instrument uncertainties should be placed on the MCERTS certificate.

The required expanded uncertainties are not all less than 25%. The two expanded uncertainties that are above 25 % are:

- Instrument 17011 at Teddington, where the slope is being dominated by a single high data point. At sites with a larger number of high concentration data points (such as Tusimice), the slopes are lower than at Teddington, and it is probable that were more high concentration days observed at Teddington, then the slope would have been lower; and
- Instrument Austria 2 at Graz, where the intercept is high. It is noted that the intercept of Austria 1 at Graz was low, yet the slope of both instruments was close to 1. This highlights the need to precisely quantify analyser baseline performance and ensure that the instrument specific baseline correction factor programmed in to the instrument is correctly monitored and maintained.

All of the calculated expanded uncertainties should be shown on the MCERTS certificate. As such, criterion 4 is not fulfilled, and it is required to apply corrections for slope and/or intercept (Section 12.4 below). The expanded uncertainties of the datasets less than 30 µg/m³ were also calculated. These should also be shown on the MCERTS certificate, but there is no requirement that they be below 25 %.

12.4 Application of correction factors and terms

In this Section, Criterion 5 is assessed, namely:

5. Preconditions for acceptance of the full dataset are that: the slope b is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$, and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept of all paired instruments together.

The following text is copied with minor alterations from and Section 4 5.4.11 of the 2012 Addendum to the 2006 TÜV Rheinland Report[3].

Equipment

Not required for this minimum requirement.

Evaluation

If evaluation of the raw data according to Section 12.4 leads to a case where $W_{CM} > W_{dqo}$, which means that the candidate systems is not regarded equivalent to the reference method, it is permitted to apply a correction factor or term resulting from the regression equation obtained from the full data set. The corrected values shall satisfy the requirements for all data sets or subsets. Moreover, a correction factor may be applied even for $W_{CM} \leq W_{dqo}$ in order to improve the accuracy of the candidate systems.

Three different cases may occur:

a) Slope b not significantly different from 1: $|b-1| \leq 2u(b)$,
intercept a significantly different from 0: $|a| > 2u(a)$

b) Slope b significantly different from 1: $|b-1| > 2u(b)$,
intercept a not significantly different from 0: $|a| \leq 2u(a)$

c) Slope b significantly different from 1: $|b-1| > 2u(b)$
intercept a significantly different from 0: $|a| > 2u(a)$

With respect to a)

The value of the intercept a may be used as a correction term to correct all input values y_i according to the following equation.

$$y_{i,corr} = y_i - a$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u_{c\_s}^2(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + u^2(a)$$

with u(a) = uncertainty of the original intercept a, the value of which has been used to obtain $y_{i,corr}$.

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in the 2010 GDE[9].

With respect to b)

The value of the slope b may be used as a factor to correct all input values y_i according to the following equation.

$$y_{i,corr} = \frac{y_i}{b}$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u^2_{c\_s}(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + x_i^2 u^2(b)$$

with u(b) = uncertainty of the original slope b, the value of which has been used to obtain $y_{i,corr}$.

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in the 2010 GDE[9].

With respect to c)

The values of the slope b and of the intercept a may be used as correction terms to correct all input values y_i according to the following equation.

$$y_{i,corr} = \frac{y_i - a}{b}$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u^2_{c\_s}(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + x_i^2 u^2(b) + u^2(a)$$

with u(b) = uncertainty of the original slope b, the value of which has been used to obtain $y_{i,corr}$ and with u(a) = uncertainty of the original intercept a, the value of which has been used to obtain $y_{i,corr}$.

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in in the 2010 GDE[9].

The values for $u_{c\_s,corr}$ are used for the calculation of the combined relative uncertainty of the candidate systems after correction according to the following equation:

$$w^2_{c,CM,corr}(y_i) = \frac{u^2_{c\_s,corr}(y_i)}{y_i^2}$$

For the corrected data set, uncertainty is calculated at the daily limit value $w_{c,CM,corr}$ by taking as y_i the concentration at the limit value.

The expanded relative uncertainty $W_{CM,corr}$ is calculated according to the following equation:

$$W_{CM',corr} = k \cdot w_{CM,corr}$$

In practice: k=2 for large number of available experimental results

The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality of ambient air measurements according to 2008/50/EC[14].Two results are possible:

1. $W_{CM} \leq W_{dqo}$ → Candidate method is accepted as equivalent to the standard method.

2. $W_{CM} > W_{dqo}$ → Candidate method is not accepted as equivalent to the standard method.

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 %[14]

Assessment

The evaluation of the "All Data" dataset for both candidates together shows that the AMS demonstrates a very good correlation with the reference method with a slope of 1.034 and an intercept of 0.843 at an expended total uncertainty of 16.0 %.

However, since the expanded uncertainty for the raw datasets Graz (Austria 2) and Teddington (17011) are greater than 25 %, the application of correction factors / terms is inevitable for the demonstration of equivalence.

The January 2010 version of The Guidance is ambiguous with respect to which slope and intercept should be used to correct a candidate should it fail the test for equivalence. After communication with the convenor of the EC working group, which is responsible for setting up the Guide Mr. Theo Hafkenscheid), it was decided that the requirement of the November 2005 version of the Guidance are still valid, and that the slope and intercept from the orthogonal regression of all the paired data should be used.

The 2006 UK Equivalence Report[17] highlighted that this was a flaw in the mathematics required for equivalence as per the November 2005 version of The Guidance as it penalised instruments that were more accurate (Appendix E Section 4.2 therein). This same flaw is copied in the January 2010 version. It is the opinion of TŰV Rheinland and their UK partners that the BAM-1020 for PM_{10} is indeed being penalised by the mathematics for being accurate.

In this particular case, the slope for the "All Data" dataset is 1.034.

The intercept for the "All Data" dataset is 0.843

Thus an additional evaluation after application of the respective correction factors / terms to the data sets has been carried out for the following cases:

a) Correction for intercept

The data set is corrected for the intercept of 0.843. The evaluation shows, that after this correction the expanded uncertainty for the data set UK-Teddington (17011) is still greater than 25% (refer to Table 18). Thus the correction for the intercept only is not sufficient to demonstrate equivalence. Some of the uncertainties in the slope and intercept are still outside of the prescribed limits.

b) Correction for slope

Correction for slope correction the expanded uncertainty for all data sets is smaller than 25% (refer to Table 19). Thus equivalence can be demonstrated after slope correction The expanded measurement uncertainty improves from 16.0 % to 12.5 %. Some of the uncertainties in the slope and intercept are still outside of the prescribed limits.

c) Correction for intercept and slope

The data set is corrected for the intercept of 0.843 and for the slope of 1.034. The evaluation shows, that after this correction the expanded uncertainty for all data sets is smaller than 25% (refer to Table 20). Thus equivalence can be demonstrated after intercept and slope correction the expanded measurement uncertainty improves from 16.0 % to 12.1 %. Some of the uncertainties in the slope and intercept are still outside of the prescribed limits.

The correction for slope is regarded as sufficient, as the additional correction for the intercept only leads to marginal improvement of the data quality.

The version of the Guide of January 2010 requires that when operating in networks, a candidate method needs to be tested annually at a number of sites corresponding to the highest expanded uncertainty found during equivalence testing. These criteria are banded in 5 % steps. The respective realisation of this requirement is the responsibility of the network operator or of the responsible authority of the member state. However TÜV Rheinland and their UK partners recommend that the expanded uncertainty for the full paired “All Data” dataset, and is referred to as

- 16.0 % for the uncorrected dataset, which falls in the 15 to 20 % bracket;
- 14.2 % for the intercept corrected dataset, which falls in the 10 to 15 % bracket;
- 12.5 % for the slope corrected dataset, which falls in the 10 to 15 % bracket;
- 12.1 % for the dataset after correction for both slope and intercept, which falls in the 10 to 15 % bracket.

Assessment

The candidates fulfil the requirements on the data quality of ambient air quality measurements after slope correction. The correction furthermore leads to an additional significant improvement of the expanded uncertainties for the complete data set.

Detailed representation of the test results

Table 18 to Table 20 show the results of the evaluations of the equivalence tests after application of correction factors and terms on the complete data set.

Table 18: Summary of the results of the equivalence test after correction for intercept.

Smart Heated PM_{10} BAM-1020 Intercept Corrected	35.3% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	Reference	Candidate
All Paired Data	14.2	320	0.982	1.034 +/- 0.008	0.000 +/- 0.290	0.67	1.22
< 30 µg m^3	21.7	215	0.826	1.119 +/- 0.032	-1.288 +/- 0.557	0.53	1.09
> 30 µg m^3	16.3	105	0.971	1.042 +/- 0.017	-0.701 +/- 1.031	0.91	1.49

4294	Dataset	Orthogonal Regression				Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^3
Individual Datasets	Cologne, Parking Lot	29	0.960	0.948 +/- 0.036	1.359 +/- 0.950	11.22	34.5
	Titz - Rödingen	37	0.962	1.058 +/- 0.035	-0.466 +/- 0.782	11.91	18.9
	Cologne, Frankfurter Str.	28	0.963	1.025 +/- 0.039	-2.136 +/- 1.083	8.92	42.9
Combined Datasets	< 30 µg m^3	68	0.814	1.040 +/- 0.055	-0.680 +/- 0.981	10.58	4.4
	> 30 µg m^3	26	0.897	0.964 +/- 0.063	0.967 +/- 2.438	10.38	100.0
	All Data	94	0.953	0.987 +/- 0.022	0.206 +/- 0.563	9.30	35.3

4295	Dataset	Orthogonal Regression				Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^3
Individual Datasets	Cologne, Parking Lot	29	0.970	0.990 +/- 0.033	1.839 +/- 0.862	10.54	34.5
	Titz - Rödingen	37	0.961	1.056 +/- 0.035	0.417 +/- 0.785	14.52	18.9
	Cologne, Frankfurter Str.	28	0.969	1.021 +/- 0.035	-0.996 +/- 0.994	7.32	42.9
Combined Datasets	< 30 µg m^3	68	0.830	1.056 +/- 0.053	0.092 +/- 0.952	14.49	4.4
	> 30 µg m^3	26	0.929	1.025 +/- 0.056	-0.129 +/- 2.151	9.57	100.0
	All Data	94	0.960	1.004 +/- 0.021	0.892 +/- 0.528	9.53	30.9

Austria1	Dataset	Orthogonal Regression				Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^3
Individual Datasets	Graz	45	0.969	1.025 +/- 0.027	-1.045 +/- 1.848	20.50	82.2
	Steyregg	45	0.824	1.049 +/- 0.067	-2.593 +/- 1.392	8.95	8.9
Combined Datasets	< 30 µg m^3	50	0.644	1.339 +/- 0.109	-7.631 +/- 2.135	39.58	2.0
	> 30 µg m^3	40	0.960	1.057 +/- 0.034	-3.668 +/- 2.431	19.88	100.0
	All Data	90	0.983	1.039 +/- 0.015	-2.137 +/- 0.729	15.78	45.6

KEY

- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

Table 18 Continued: Summary of the results of the equivalence test after correction for intercept.

Austria2	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.966	1.033	+/-	0.029	1.106	+/-	1.962	24.39	82.2
	Steyregg	45	0.793	1.035	+/-	0.072	-2.511	+/-	1.489	10.09	8.9
Combined Datasets	< 30 µg m³	50	0.557	1.492	+/-	0.130	-10.304	+/-	2.545	59.63	2.0
	> 30 µg m³	40	0.956	1.084	+/-	0.037	-3.138	+/-	2.635	21.77	100.0
	All Data	90	0.980	1.079	+/-	0.016	-2.544	+/-	0.818	18.61	45.6

J7860	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	59	0.906	1.172	+/-	0.047	0.361	+/-	0.839	37.23	6.8
	> 30 µg m³	38	0.974	1.002	+/-	0.027	2.311	+/-	1.548	15.38	100.0
	All Data (Tusimice)	97	0.984	0.999	+/-	0.013	2.896	+/-	0.492	15.92	43.3

J7863	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	58	0.913	1.158	+/-	0.045	-0.684	+/-	0.812	30.54	6.9
	> 30 µg m³	38	0.978	1.032	+/-	0.025	1.105	+/-	1.450	15.50	100.0
	All Data (Tusimice)	96	0.987	1.035	+/-	0.012	1.193	+/-	0.461	15.54	43.8

17011	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.960	1.039	+/-	0.034	-0.210	+/-	0.458	8.21	0.0
	> 30 µg m³	1			+/-			+/-			100.0
	All Data (Teddington)	40	0.949	1.162	+/-	0.042	-1.608	+/-	0.602	26.73	2.5

17022	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.958	1.051	+/-	0.035	-0.240	+/-	0.477	10.40	0.0
	> 30 µg m³	1			+/-			+/-			100.0
	All Data (Teddington)	40	0.963	1.110	+/-	0.034	-0.893	+/-	0.488	19.05	2.5

KEY

- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

Table 19: Summary of the results of the equivalence test after correction for slope.

Smart Heated PM_{10} BAM-1020 Slope Corrected	35.3% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	Reference	Candidate
All Paired Data	12.5	320	0.982	1.000 +/- 0.008	0.824 +/- 0.280	0.67	1.18
< 30 µg m³	17.9	215	0.826	1.079 +/- 0.031	-0.372 +/- 0.538	0.53	1.06
> 30 µg m³	14.9	105	0.971	1.007 +/- 0.017	0.164 +/- 0.997	0.91	1.44

4294	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Cologne, Parking Lot	29	0.960	0.917 +/- 0.035	2.144 +/- 0.919	12.72	34.5
	Titz - Rödingen	37	0.962	1.023 +/- 0.034	0.378 +/- 0.756	9.03	18.9
	Cologne, Frankfurter Str.	28	0.963	0.990 +/- 0.037	-1.235 +/- 1.048	10.44	42.9
Combined Datasets	< 30 µg m³	68	0.814	1.003 +/- 0.053	0.219 +/- 0.949	8.97	4.4
	> 30 µg m³	26	0.897	0.931 +/- 0.061	1.815 +/- 2.358	11.57	100.0
	All Data	94	0.953	0.954 +/- 0.022	1.032 +/- 0.545	10.23	35.3

4295	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Cologne, Parking Lot	29	0.970	0.957 +/- 0.032	2.605 +/- 0.834	9.04	34.5
	Titz - Rödingen	37	0.961	1.021 +/- 0.034	1.233 +/- 0.760	11.24	18.9
	Cologne, Frankfurter Str.	28	0.969	0.988 +/- 0.034	-0.135 +/- 0.962	7.70	42.9
Combined Datasets	< 30 µg m³	68	0.830	1.018 +/- 0.052	0.961 +/- 0.921	11.33	4.4
	> 30 µg m³	26	0.929	0.990 +/- 0.054	0.737 +/- 2.080	8.24	100.0
	All Data	94	0.960	0.971 +/- 0.020	1.693 +/- 0.510	8.28	30.9

Austria1	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.969	0.991 +/- 0.027	-0.164 +/- 1.787	19.96	82.2
	Steyregg	45	0.824	1.012 +/- 0.065	-1.624 +/- 1.347	9.63	8.9
Combined Datasets	< 30 µg m³	50	0.644	1.285 +/- 0.105	-6.378 +/- 2.065	34.09	2.0
	> 30 µg m³	40	0.960	1.022 +/- 0.033	-2.687 +/- 2.351	20.01	100.0
	All Data	90	0.983	1.005 +/- 0.014	-1.240 +/- 0.705	15.78	45.6

KEY

- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

Table 19 Continued: Summary of the results of the equivalence test after correction for slope.

Austria2	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.966	0.998	+/-	0.028	1.920	+/-	1.898	22.33	82.2
	Steyregg	45	0.793	0.997	+/-	0.069	-1.531	+/-	1.441	11.48	8.9
Combined Datasets	< 30 µg m³	50	0.557	1.429	+/-	0.126	-8.879	+/-	2.462	52.84	2.0
	> 30 µg m³	40	0.956	1.048	+/-	0.036	-2.167	+/-	2.549	20.66	100.0
	All Data	90	0.980	1.043	+/-	0.016	-1.631	+/-	0.791	17.32	45.6

J7860	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	59	0.906	1.131	+/-	0.046	1.195	+/-	0.812	32.66	6.8
	> 30 µg m³	38	0.974	0.969	+/-	0.026	3.074	+/-	1.498	13.09	100.0
	All Data (Tusimice)	97	0.984	0.966	+/-	0.012	3.625	+/-	0.476	13.28	43.3

J7863	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	58	0.913	1.119	+/-	0.044	0.182	+/-	0.786	26.26	6.9
	> 30 µg m³	38	0.978	0.998	+/-	0.025	1.904	+/-	1.403	12.97	100.0
	All Data (Tusimice)	96	0.987	1.001	+/-	0.012	1.975	+/-	0.446	12.77	43.8

17011	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.960	1.004	+/-	0.033	0.620	+/-	0.443	5.53	0.0
	> 30 µg m³	1			+/-			+/-			100.0
	All Data (Teddington)	40	0.949	1.123	+/-	0.041	-0.728	+/-	0.583	22.58	2.5

17022	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.958	1.016	+/-	0.034	0.592	+/-	0.461	7.27	0.0
	> 30 µg m³	1			+/-			+/-			100.0
	All Data (Teddington)	40	0.963	1.073	+/-	0.033	-0.040	+/-	0.473	15.26	2.5

KEY

- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

Table 20: Summary of the results of the equivalence test, after correction for slope and intercept

Smart Heated PM_{10} BAM-1020 Slope and Intercept Corrected	35.3% > 28 µg m-3	Orthogonal Regression								Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			Reference	Candidate
All Paired Data	12.1	320	0.982	1.000	+/-	0.008	0.009	+/-	0.280	0.67	1.18
< 30 µg m³	15.5	215	0.826	1.079	+/-	0.031	-1.187	+/-	0.538	0.53	1.06
> 30 µg m³	14.9	105	0.971	1.007	+/-	0.017	-0.651	+/-	0.997	0.91	1.44

4294	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Individual Datasets	Cologne, Parking Lot	29	0.960	0.917	+/-	0.035	1.329	+/-	0.919	15.05	34.5
	Titz - Rödingen	37	0.962	1.023	+/-	0.034	-0.437	+/-	0.756	7.33	18.9
	Cologne, Frankfurter Str.	28	0.963	0.990	+/-	0.037	-2.050	+/-	1.048	12.87	42.9
Combined Datasets	< 30 µg m³	68	0.814	1.003	+/-	0.053	-0.596	+/-	0.949	9.11	4.4
	> 30 µg m³	26	0.897	0.931	+/-	0.061	1.000	+/-	2.358	13.74	100.0
	All Data	94	0.953	0.954	+/-	0.022	0.217	+/-	0.545	12.26	35.3

4295	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Individual Datasets	Cologne, Parking Lot	29	0.970	0.957	+/-	0.032	1.790	+/-	0.834	9.04	34.5
	Titz - Rödingen	37	0.961	1.021	+/-	0.034	0.418	+/-	0.760	8.91	18.9
	Cologne, Frankfurter Str.	28	0.969	0.988	+/-	0.034	-0.950	+/-	0.962	9.54	42.9
Combined Datasets	< 30 µg m³	68	0.830	1.018	+/-	0.052	0.146	+/-	0.921	9.59	4.4
	> 30 µg m³	26	0.929	0.990	+/-	0.054	-0.078	+/-	2.080	8.55	100.0
	All Data	94	0.960	0.971	+/-	0.020	0.878	+/-	0.510	8.65	30.9

Austria1	Dataset	Orthogonal Regression								Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b			Intercept (a) +/- u_a			W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.969	0.991	+/-	0.027	-0.979	+/-	1.787	20.64	82.2
	Steyregg	45	0.824	1.012	+/-	0.065	-2.439	+/-	1.347	11.48	8.9
Combined Datasets	< 30 µg m³	50	0.644	1.285	+/-	0.105	-7.193	+/-	2.065	31.13	2.0
	> 30 µg m³	40	0.960	1.022	+/-	0.033	-3.502	+/-	2.351	21.30	100.0
	All Data	90	0.983	1.005	+/-	0.014	-2.055	+/-	0.705	16.94	45.6

KEY

- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

Table 20 Continued: Summary of the results of the equivalence test, after correction for slope and intercept

Austria2	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.966	0.998 +/- 0.028	1.105 +/- 1.898	21.51	82.2
	Steyregg	45	0.793	0.997 +/- 0.069	-2.346 +/- 1.441	13.69	8.9
Combined Datasets	< 30 µg m³	50	0.557	1.429 +/- 0.126	-9.694 +/- 2.462	49.76	2.0
	> 30 µg m³	40	0.956	1.048 +/- 0.036	-2.982 +/- 2.549	20.80	100.0
	All Data	90	0.980	1.043 +/- 0.016	-2.446 +/- 0.791	17.28	45.6

J7860	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	59	0.906	1.131 +/- 0.046	0.380 +/- 0.812	29.59	6.8
	> 30 µg m³	38	0.974	0.969 +/- 0.026	2.259 +/- 1.498	11.97	100.0
	All Data (Tusimice)	97	0.984	0.966 +/- 0.012	2.810 +/- 0.476	11.73	43.3

J7863	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	58	0.913	1.119 +/- 0.044	-0.633 +/- 0.786	23.28	6.9
	> 30 µg m³	38	0.978	0.998 +/- 0.025	1.089 +/- 1.403	11.54	100.0
	All Data (Tusimice)	96	0.987	1.001 +/- 0.012	1.160 +/- 0.446	11.08	43.8

17011	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.960	1.004 +/- 0.033	-0.195 +/- 0.443	4.58	0.0
	> 30 µg m³	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.949	1.123 +/- 0.041	-1.543 +/- 0.583	19.51	2.5

17022	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.958	1.016 +/- 0.034	-0.223 +/- 0.461	5.30	0.0
	> 30 µg m³	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.963	1.073 +/- 0.033	-0.855 +/- 0.473	12.29	2.5

KEY

- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

12.5 Further Discussion for UK Purposes

The German Certification Committee required that the three German datasets be included, even though there are fewer than 40 data pairs in each of the three datasets. For UK purposes it is required to discount the three German datasets that contain fewer than 40 data pairs. Table 21 shows the uncorrected data for the remaining datasets after the removal of the three German datasets.

Table 21: Summary of the results of the equivalence test without correction for those field tests with greater than 40 data points.

Smart Heated PM_{10} BAM-1020 for datasets with greater than 40 data pairs	37.2% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	Reference	Candidate
All Paired Data	17.4	226	0.983	1.035 +/- 0.009	0.947 +/- 0.369	0.59	1.29
< 30 µg m³	28.3	147	0.827	1.143 +/- 0.039	-0.730 +/- 0.682	0.43	1.14
> 30 µg m³	19.6	79	0.966	1.033 +/- 0.022	0.894 +/- 1.402	0.84	1.58

Austria1	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.969	1.025 +/- 0.027	-0.202 +/- 1.848	20.89	82.2
	Steyregg	45	0.824	1.049 +/- 0.067	-1.750 +/- 1.392	9.31	8.9
Combined Datasets	< 30 µg m³	50	0.644	1.339 +/- 0.109	-6.789 +/- 2.135	42.75	2.0
	> 30 µg m³	40	0.960	1.057 +/- 0.034	-2.826 +/- 2.431	19.58	100.0
	All Data	90	0.983	1.039 +/- 0.015	-1.294 +/- 0.729	15.95	45.6

Austria2	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.966	1.033 +/- 0.029	1.948 +/- 1.962	26.05	82.2
	Steyregg	45	0.793	1.035 +/- 0.072	-1.668 +/- 1.489	9.56	8.9
Combined Datasets	< 30 µg m³	50	0.557	1.492 +/- 0.130	-9.462 +/- 2.545	62.86	2.0
	> 30 µg m³	40	0.956	1.084 +/- 0.037	-2.296 +/- 2.635	22.65	100.0
	All Data	90	0.980	1.079 +/- 0.016	-1.702 +/- 0.818	19.84	45.6

J7860	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	59	0.906	1.172 +/- 0.047	1.204 +/- 0.839	40.46	6.8
	> 30 µg m³	38	0.974	1.002 +/- 0.027	3.154 +/- 1.548	17.67	100.0
	All Data (Tusimice)	97	0.984	0.999 +/- 0.013	3.739 +/- 0.492	18.45	43.3

J7863	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	58	0.913	1.158 +/- 0.045	0.159 +/- 0.812	33.73	6.9
	> 30 µg m³	38	0.978	1.032 +/- 0.025	1.948 +/- 1.450	17.98	100.0
	All Data (Tusimice)	96	0.987	1.035 +/- 0.012	2.035 +/- 0.461	18.18	43.8

17011	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.960	1.039 +/- 0.034	0.632 +/- 0.458	11.13	0.0
	> 30 µg m³	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.949	1.162 +/- 0.042	-0.766 +/- 0.602	29.99	2.5

17022	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.958	1.051 +/- 0.035	0.603 +/- 0.477	13.45	0.0
	> 30 µg m³	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.963	1.110 +/- 0.034	-0.050 +/- 0.488	22.28	2.5

KEY
- Criterion 1
- Criterion 2
- Criterion 3
- Criterion 4
- Criterion 5
- Other

Table 21 shows that not all of the expanded uncertainties are below 25 %, and as the slope and intercept of various datasets are statistically significant, it is necessary to investigate correction by each of slope, intercept, and both slope and intercept together. Table 16 showed that when all seven field tests were considered the slope was 1.034, whereas when considering only the four field tests where there were greater than 40 data pairs, Table 21 shows that the slope is 1.035.

Table 22 shows the data for the remaining datasets after the removal of the three German datasets and with correction for intercept by subtracting 0.947. Not all of the critical expanded uncertainties are below 25 %.

Table 22: Summary of the results of the equivalence test for those field tests with greater than 40 data points. Data have been corrected by subtracting 0.947.

Smart Heated PM_{10} BAM-1020 for datasets with greater than 40 data pairs corrected by subtracting 0.947	37.2% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	Reference	Candidate
All Paired Data	15.4	226	0.983	1.035 +/- 0.009	0.000 +/- 0.369	0.59	1.29
< 30 µg m^{3}	25.0	147	0.827	1.143 +/- 0.039	-1.677 +/- 0.682	0.43	1.14
> 30 µg m^{3}	17.9	79	0.966	1.033 +/- 0.022	-0.053 +/- 1.402	0.84	1.58

Austria1	Dataset	Orthogonal Regression				Limit Value of 50 µg m^{3}	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^{3}
Individual Datasets	Graz	45	0.969	1.025 +/- 0.027	-1.149 +/- 1.848	20.51	82.2
	Steyregg	45	0.824	1.049 +/- 0.067	-2.697 +/- 1.392	9.03	8.9
Combined Datasets	< 30 µg m^{3}	50	0.644	1.339 +/- 0.109	-7.735 +/- 2.135	39.20	2.0
	> 30 µg m^{3}	40	0.960	1.057 +/- 0.034	-3.773 +/- 2.431	19.97	100.0
	All Data	90	0.983	1.039 +/- 0.015	-2.241 +/- 0.729	15.83	45.6

Austria2	Dataset	Orthogonal Regression				Limit Value of 50 µg m^{3}	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^{3}
Individual Datasets	Graz	45	0.966	1.033 +/- 0.029	1.001 +/- 1.962	24.22	82.2
	Steyregg	45	0.793	1.035 +/- 0.072	-2.615 +/- 1.489	10.26	8.9
Combined Datasets	< 30 µg m^{3}	50	0.557	1.492 +/- 0.130	-10.409 +/- 2.545	59.23	2.0
	> 30 µg m^{3}	40	0.956	1.084 +/- 0.037	-3.243 +/- 2.635	21.71	100.0
	All Data	90	0.980	1.079 +/- 0.016	-2.648 +/- 0.818	18.51	45.6

J7860	Dataset	Orthogonal Regression				Limit Value of 50 µg m^{3}	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^{3}
Combined Datasets	< 30 µg m^{3}	59	0.906	1.172 +/- 0.047	0.257 +/- 0.839	36.84	6.8
	> 30 µg m^{3}	38	0.974	1.002 +/- 0.027	2.207 +/- 1.548	15.15	100.0
	All Data (Tusimice)	97	0.984	0.999 +/- 0.013	2.792 +/- 0.492	15.65	43.3

J7863	Dataset	Orthogonal Regression				Limit Value of 50 µg m^{3}	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^{3}
Combined Datasets	< 30 µg m^{3}	58	0.913	1.158 +/- 0.045	-0.788 +/- 0.812	30.15	6.9
	> 30 µg m^{3}	38	0.978	1.032 +/- 0.025	1.001 +/- 1.450	15.24	100.0
	All Data (Tusimice)	96	0.987	1.035 +/- 0.012	1.088 +/- 0.461	15.26	43.8

17011	Dataset	Orthogonal Regression				Limit Value of 50 µg m^{3}	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^{3}
Combined Datasets	< 30 µg m^{3}	39	0.960	1.039 +/- 0.034	-0.315 +/- 0.458	7.91	0.0
	> 30 µg m^{3}	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.949	1.162 +/- 0.042	-1.713 +/- 0.602	26.34	2.5

17022	Dataset	Orthogonal Regression				Limit Value of 50 µg m^{3}	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m^{3}
Combined Datasets	< 30 µg m^{3}	39	0.958	1.051 +/- 0.035	-0.344 +/- 0.477	10.07	0.0
	> 30 µg m^{3}	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.963	1.110 +/- 0.034	-0.997 +/- 0.488	18.67	2.5

KEY

- Criterion 1 (light cyan)
- Criterion 2 (grey)
- Criterion 3 (peach)
- Criterion 4 (light yellow)
- Criterion 5 (light blue)
- Other (orange)

Table 23 shows the data for the remaining datasets after the removal of the three German datasets and with correction for slope by dividing by 1.035. All of the critical expanded uncertainties are below 25 %.

Table 23: Summary of the results of the equivalence test for those field tests with greater than 40 data points. Data have been corrected by dividing by 1.035.

Smart Heated PM_{10} BAM-1020 for datasets with greater than 40 data pairs corrected by dividing by 1.035	37.2% > 28 µg m-3	Orthogonal Regression								Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b)	+/-	u_b	Intercept (a)	+/-	u_a	Reference	Candidate
All Paired Data	13.8	226	0.983	1.000	+/-	0.009	0.924	+/-	0.356	0.59	1.24
< 30 µg m^3	21.1	147	0.827	1.101	+/-	0.038	-0.645	+/-	0.659	0.43	1.10
> 30 µg m^3	16.5	79	0.966	0.998	+/-	0.021	0.900	+/-	1.355	0.84	1.53

Austria1	Dataset	Orthogonal Regression								Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b)	+/-	u_b	Intercept (a)	+/-	u_a	W_{CM} / %	% > 28 µg m^3
Individual Datasets	Graz	45	0.969	0.990	+/-	0.027	-0.163	+/-	1.786	19.99	82.2
	Steyregg	45	0.824	1.011	+/-	0.065	-1.620	+/-	1.345	9.75	8.9
Combined Datasets	< 30 µg m^3	50	0.644	1.284	+/-	0.105	-6.366	+/-	2.063	33.86	2.0
	> 30 µg m^3	40	0.960	1.021	+/-	0.033	-2.683	+/-	2.349	20.07	100.0
	All Data	90	0.983	1.004	+/-	0.014	-1.239	+/-	0.704	15.84	45.6

Austria2	Dataset	Orthogonal Regression								Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b)	+/-	u_b	Intercept (a)	+/-	u_a	W_{CM} / %	% > 28 µg m^3
Individual Datasets	Graz	45	0.966	0.997	+/-	0.028	1.920	+/-	1.896	22.26	82.2
	Steyregg	45	0.793	0.996	+/-	0.069	-1.527	+/-	1.439	11.63	8.9
Combined Datasets	< 30 µg m^3	50	0.557	1.427	+/-	0.126	-8.862	+/-	2.460	52.56	2.0
	> 30 µg m^3	40	0.956	1.047	+/-	0.036	-2.164	+/-	2.547	20.65	100.0
	All Data	90	0.980	1.042	+/-	0.016	-1.629	+/-	0.791	17.31	45.6

J7860	Dataset	Orthogonal Regression								Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b)	+/-	u_b	Intercept (a)	+/-	u_a	W_{CM} / %	% > 28 µg m^3
Combined Datasets	< 30 µg m^3	59	0.906	1.130	+/-	0.046	1.194	+/-	0.811	32.44	6.8
	> 30 µg m^3	38	0.974	0.968	+/-	0.026	3.072	+/-	1.496	13.02	100.0
	All Data (Tusimice)	97	0.984	0.965	+/-	0.012	3.621	+/-	0.476	13.18	43.3

J7863	Dataset	Orthogonal Regression								Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b)	+/-	u_b	Intercept (a)	+/-	u_a	W_{CM} / %	% > 28 µg m^3
Combined Datasets	< 30 µg m^3	58	0.913	1.118	+/-	0.044	0.182	+/-	0.785	26.06	6.9
	> 30 µg m^3	38	0.978	0.997	+/-	0.025	1.903	+/-	1.402	12.88	100.0
	All Data (Tusimice)	96	0.987	1.000	+/-	0.012	1.974	+/-	0.445	12.67	43.8

17011	Dataset	Orthogonal Regression								Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b)	+/-	u_b	Intercept (a)	+/-	u_a	W_{CM} / %	% > 28 µg m^3
Combined Datasets	< 30 µg m^3	39	0.960	1.003	+/-	0.033	0.620	+/-	0.443	5.48	0.0
	> 30 µg m^3	1			+/-			+/-			100.0
	All Data (Teddington)	40	0.949	1.122	+/-	0.041	-0.727	+/-	0.582	22.39	2.5

17022	Dataset	Orthogonal Regression								Limit Value of 50 µg m^3	
		n_{c-s}	r^2	Slope (b)	+/-	u_b	Intercept (a)	+/-	u_a	W_{CM} / %	% > 28 µg m^3
Combined Datasets	< 30 µg m^3	39	0.958	1.015	+/-	0.034	0.592	+/-	0.461	7.17	0.0
	> 30 µg m^3	1			+/-			+/-			100.0
	All Data (Teddington)	40	0.963	1.072	+/-	0.033	-0.040	+/-	0.472	15.08	2.5

KEY	
(light cyan)	Criterion 1
(grey)	Criterion 2
(light orange)	Criterion 3
(light yellow)	Criterion 4
(light blue)	Criterion 5
(gold)	Other

Table 24 shows the data for the remaining datasets after the removal of the three German datasets and with correction for slope and intercept by subtracting 0.947 then dividing by 1.035. All of the critical expanded uncertainties are below 25 %.

Table 24: Summary of the results of the equivalence test for those field tests with greater than 40 data points. Data have been corrected by subtracting 0.947 and then by dividing by 1.035.

Smart Heated PM_{10} BAM-1020 for datasets with greater than 40 data pairs corrected by subtracting 0.947 then dividing by 1.035	37.2% > 28 µg m-3	Orthogonal Regression				Between Instrument Uncertainties	
	W_{CM} / %	n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	Reference	Candidate
All Paired Data	13.4	226	0.983	1.000 +/- 0.009	0.009 +/- 0.356	0.59	1.24
< 30 µg m³	18.3	147	0.827	1.101 +/- 0.038	-1.560 +/- 0.659	0.43	1.10
> 30 µg m³	16.3	79	0.966	0.998 +/- 0.021	-0.015 +/- 1.355	0.84	1.53

Austria1	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.969	0.990 +/- 0.027	-1.078 +/- 1.786	20.83	82.2
	Steyregg	45	0.824	1.011 +/- 0.065	-2.535 +/- 1.345	11.94	8.9
Combined Datasets	< 30 µg m³	50	0.644	1.284 +/- 0.105	-7.281 +/- 2.063	30.54	2.0
	> 30 µg m³	40	0.960	1.021 +/- 0.033	-3.598 +/- 2.349	21.59	100.0
	All Data	90	0.983	1.004 +/- 0.014	-2.154 +/- 0.704	17.23	45.6

Austria2	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Individual Datasets	Graz	45	0.966	0.997 +/- 0.028	1.005 +/- 1.896	21.42	82.2
	Steyregg	45	0.793	0.996 +/- 0.069	-2.442 +/- 1.439	14.18	8.9
Combined Datasets	< 30 µg m³	50	0.557	1.427 +/- 0.126	-9.777 +/- 2.460	49.11	2.0
	> 30 µg m³	40	0.956	1.047 +/- 0.036	-3.079 +/- 2.547	20.89	100.0
	All Data	90	0.980	1.042 +/- 0.016	-2.544 +/- 0.791	17.36	45.6

J7860	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	59	0.906	1.130 +/- 0.046	0.279 +/- 0.811	29.02	6.8
	> 30 µg m³	38	0.974	0.968 +/- 0.026	2.157 +/- 1.496	11.89	100.0
	All Data (Tusimice)	97	0.984	0.965 +/- 0.012	2.706 +/- 0.476	11.58	43.3

J7863	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	58	0.913	1.118 +/- 0.044	-0.733 +/- 0.785	22.74	6.9
	> 30 µg m³	38	0.978	0.997 +/- 0.025	0.988 +/- 1.402	11.41	100.0
	All Data (Tusimice)	96	0.987	1.000 +/- 0.012	1.059 +/- 0.445	10.90	43.8

17011	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.960	1.003 +/- 0.033	-0.295 +/- 0.443	4.78	0.0
	> 30 µg m³	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.949	1.122 +/- 0.041	-1.642 +/- 0.582	18.96	2.5

17022	Dataset	Orthogonal Regression				Limit Value of 50 µg m³	
		n_{c-s}	r^2	Slope (b) +/- u_b	Intercept (a) +/- u_a	W_{CM} / %	% > 28 µg m³
Combined Datasets	< 30 µg m³	39	0.958	1.015 +/- 0.034	-0.323 +/- 0.461	5.21	0.0
	> 30 µg m³	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.963	1.072 +/- 0.033	-0.955 +/- 0.472	11.81	2.5

KEY

- Criterion 1 (light cyan)
- Criterion 2 (grey)
- Criterion 3 (peach)
- Criterion 4 (light yellow)
- Criterion 5 (light blue)
- Other (orange)

In summary, after application of the respective correction factors / terms to the data sets has been carried out for the following cases:

a) Correction for intercept

The data set is corrected for the intercept of 0.947. The evaluation shows, that after this correction the expanded uncertainty for the data set UK-Teddington (17011) is still greater than 25% (refer to Table 22). Thus the correction for the intercept only is not sufficient to demonstrate equivalence. Some of the uncertainties in the slope and intercept are still outside of the prescribed limits.

b) Correction for slope

Correction for slope correction the expanded uncertainty for all data sets is smaller than 25% (refer to Table 23). Thus equivalence can be demonstrated after slope correction The expanded measurement uncertainty improves from 17.4 % to 13.8 %. Some of the uncertainties in the slope and intercept are still outside of the prescribed limits.

c) Correction for intercept and slope

The data set is corrected for the intercept of 0.947 and for the slope of 1.035. The evaluation shows, that after this correction the expanded uncertainty for all data sets is smaller than 25% (refer to Table 24). Thus equivalence can be demonstrated after intercept and slope correction the expanded measurement uncertainty improves from 17.4 % to 13.4 %. Some of the uncertainties in the slope and intercept are still outside of the prescribed limits.

The correction for slope is regarded as sufficient, as the additional correction for the intercept only leads to marginal improvement of the data quality.

As previously discussed when considering all seven datasets, The version of the Guide of January 2010 requires that when operating in networks, a candidate method needs to be tested annually at a number of sites corresponding to the highest expanded uncertainty found during equivalence testing. These criteria are banded in 5 % steps. The respective realisation of this requirement is the responsibility of the network operator or of the responsible authority of the member state. However it is recommended that the expanded uncertainty for the full paired "All Data" dataset, and is referred to as:

- 17.4 % for the uncorrected dataset, which falls in the 15 to 20 % bracket;
- 15.4 % for the intercept corrected dataset, which falls in the 15 to 20 % bracket;
- 13.8 % for the slope corrected dataset, which falls in the 10 to 15 % bracket;
- 13.4 % for the dataset after correction for both slope and intercept, which falls in the 10 to 15 % bracket.

Conclusion for UK Purposes

For UK purposes it is required to discount the three German datasets that contain fewer than 40 data pairs.

When considering only those 4 datasets with greater than 40 data pairs, the required expanded uncertainties were not all below 25 % prior to correction, and it is necessary to correct the instrument for slope and/or intercept.

Correction for slope by dividing by 1.035 was shown to be essential in order to reduce all of the expanded uncertainties to below the data quality objective of 25 %.

Correction for intercept is shown to be only marginally beneficial. Intercept correction is not required in order to make the instrument equivalent, but it is essential that thorough and frequent on-going QA/QC procedures are employed (as prescribed in EN12341:2014[5] and CEN/TS16450[6]) including to precisely quantify analyser baseline performance and ensure that the instrument specific baseline correction factor programmed in to the instrument is correctly monitored and maintained.

The MCERTS certificate should show the range of required expanded uncertainties for each of the following permutations:

- No Correction;
- Correction for Slope;
- Correction for Intercept;
- Correction for Slope and Intercept.

It should be clearly and unequivocally stated on the certificate that correction for slope is required in order for the instrument to be deemed equivalent. By following this approach, Criterion 5 is fulfilled.

13. Discussion on the number of Reference Methods Used

As all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter[1] (31st July 2012), there is no requirement that two collocated reference methods are used for each field test.

In six of the seven field tests, two reference method instruments were used, and as such the field tests go beyond the requirements of MCERTS for UK Particulate Matter.

14. Discussion on the number of UK Field Tests

As all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter[1] (31st July 2012), there is a requirement for there to be only at least one UK field test.

The Smart Heated PM_{10} BAM-1020 had one UK test, and as such meets the requirements of MCERTS for UK Particulate Matter.

PARTICULATE MATTER POLLUTION CLIMATE EVALUATION

15. Pollution Climate Calculations

15.1 Introduction

MCERTS for UK Particulate Matter[1] sets out a mechanism for proving whether field campaigns from other Member States are at a similar Pollution Climate to the UK. This is based upon an extensive study of the existing pollution climate within the UK[16].

The methodology centres on a number of parameters. Primary of these is that it is required to prove that the geometric mean of the PM_{10} or $PM_{2.5}$ concentrations during individual campaigns are within the range prescribed in Table 25 below for a specific site type. There is also the requirement that at least 6 calendar months of data should be available, though allowances are made for instruments that were tested before MCERTS for UK Particulate Matter was published.

Table 25: Range of geometric mean concentrations for each site type in the UK calculated using 2007-2010 PM_{10} data, with this data factored to estimate the $PM_{2.5}$ geometric mean ranges.

Site Type	Geometric Mean PM_{10} Range (µg m^{-3})	Geometric Mean $PM_{2.5}$ Range (µg m^{-3})
Background (urban or suburban)	11.9 – 25.7	8.4 - 18.1
Traffic	10.9 – 42.3	7.7 - 29.8
Rural	4.3 – 18.1	3.0 - 12.8
Industrial	13.8 – 24.6	9.7 - 17.4

Additionally there is a requirement that at least one of the field tests of at least 40 data pairs has at least 10 % of days where there was a high percentage, and at least one of the field tests of at least 40 data pairs has at least 10 % of days where there was a low percentage of:

- Wind Speed;
- Ambient Temperature; and
- Ambient Dew Point.

Further, there is a requirement that at least one of the field tests of at least 40 data pairs has at least 5 % of days where there was a high percentage, and at least one of the field tests of at least 40 data pairs has at least 5 % of days where there was a low percentage of:

- Semi Volatile PM component.

The low and high thresholds are summarised in Table 26. For wind speed, different requirements are placed on whether the anemometer was mounted at a height of 10 m, 5 m or 2.5 m above ground level and as to whether the measurements were undertaken in a rural or urban area.

16 Characterising the PM climate in the UK for Equivalence Testing, D Green & G Fuller, King's College London Environmental Research Group, June 2012
uk-air.defra.gov.uk/reports/cat13/1207190952_DefraCharacterisingThePMClimateInTheUKForEquivalenceTestingV3.pdf

Table 26: Low and high thresholds and the requisite number of daily means for PM_{10} and $PM_{2.5}$ equivalence tests to be carried out outside these thresholds, whichever is appropriate (as a percentage of the number of measurements within one comparison) for semi-volatile PM mass concentrations and for selected meteorological conditions.

Threshold	Semi-volatile / Nitrate (µg m-3)		Wind speed (m/s)							Ambient Temperature (ºC)		Ambient Dew Point (ºC)	
			Threshold										
			10 metres		5 metres		2.5 metres						
	Threshold	%	Urban	Rural	Urban	Rural	Urban	Rural	%	Threshold	%	Threshold	%
Low	3.2	5	2.9	6	0.7	5.1	0.3	4.2	10	7.6	10	3.9	10
High	6.3	5	5.2	12.4	1.2	10.6	0.6	8.8	10	16.1	10	10.8	10

All of the concentration and meteorological data measured in the field tests for this study are given in Appendix E.

15.2 Geometric Mean Calculations

As has been discussed in Section 2, the Smart Heated PM_{10} BAM-1020 instruments were tested at the following sites:

- The parking lot of The National Physical Laboratory (NPL) in Teddington in the UK (Urban Background);
- The parking lot of the TÜV Rheinland facility in Cologne, Germany (Urban Background);
- An area east of Cologne, Germany near the village of Titz-Rödingen (Rural);
- A roadside location in the suburb Köln-Mülheim, approximately 3km away from Cologne city centre, Germany called Cologne Frankfurter Strasse (Traffic);
- A site close to a busy road in a suburban area of Graz, Austria called Graz (Described by TÜV Rheinland both as Urban Background and Traffic).
- A site on the outskirts of Steyregg, Austria called Steyregg (Suburban)
- An industrial area of the Czech Republic near the German border called Tusimice (Industrial).

The results of the geometric mean calculations are summarised in Table 27. Where criteria are met they are shaded green, and where they are not met they are shaded red. In order to prevent weighting the calculations to specific days of the year: for each day of the year if more than one year's worth of reference method data was available, then the geometric mean of all available years was taken for this day. The geometric mean was then calculated for the entire year using these geometric means for each day of the year.

At the two Austrian sites of Graz and Steyregg, PM_{10} reference method data have been collected since 2000, and there has been very good data coverage. In line with the requirements of the Defra MCERTS Guidance, data have only been used from a 3 year period encompassing the period when the Smart BAM 1020s were tested (2007-9). Steyregg was shown to be of a similar pollution climate to the UK. Graz is described by TÜV Rheinland both as Urban Background and Traffic. It has a pollution climate slightly greater than that prescribed for an Urban Background site, but is comfortably within the range prescribed traffic sites, and as such can also be shown to be of a similar pollution climate to the UK.

At the site in The Czech Republic (Tusimice), beta attenuation data are collected and reported to the EC and uploaded on to Airbase. 2008 to 2010 data are available and these have been used for the pollution climate calculations. For the period when the field test was conducted (2010), the reference method data have also been considered in the pollution climate calculations. Tusimice was shown to be of a similar pollution climate to the UK.

The UK site in Teddington is only used for research purposes, though there have been 281 unique calendar days over which data have been collected, which is greater than the required 188 days. Teddington was shown to have a pollution climate within the range ascribed to the UK.

The three German sites (Cologne Parking Lot, Titz-Rödingen and Cologne Frankfurter Strasse) are only used for research purposes. Cologne Parking Lot has greater than 188 unique calendar days over which data have been collected, and was shown to be of a similar pollution climate to the UK. Titz-Rödingen and Cologne Frankfurter Strasse each have fewer than 188 unique calendar days over which data have been collected. In order to demonstrate that the area around Cologne is within the prescribed range, a Nord-Rhein Westphalia (NRW) network site for which three years of PM_{10} reference method data are available (Cologne-Chorweiler in a suburban area to Cologne) is also presented. This site is within the prescribed range of 130 km to all Cologne-Bonn area field test sites, and as such, the data from all sites in the Cologne area are shown to have a similar pollution climate to the UK. Further evidence can be found in the extensive study of the UK Pollution Climate, where data from the Cologne area were proven to be of a similar pollution climate to the UK[16]. For the 122 days of available data, the geometric mean for Cologne Frankfurter Strasse was shown to be of a similar pollution climate to the UK. The geometric mean for Titz-Rödingen is above that expected for a rural site in the UK, though it should be noted that here were only 52 days' worth of data used in these calculations, which is considerably less than the required 188. While Titz-Rödingen has been classified as a rural site by TÜV Rheinland, as it is a rural area of Nord Rhein Westphalia (NRW), it is within 20 miles on several sides of the urban conurbation comprising Cologne, Dusseldorf and many less significant cities, with a total population of 10 million people. As such, the site would not be classified as rural relative to those sites designated rural in the UK networks from which the geometric mean for rural sites was calculated. It is however too rural to be classed as suburban. $PM_{2.5}$ data for Titz-Rödingen are also included in Table 27.for reference, and these are shown to lie within the accepted range for a rural site with the same pollution climate as the UK. As such, Cologne Parking Lot, Titz-Rödingen and Cologne Frankfurter Strasse have been demonstrated to be of a similar pollution climate to the UK.

Table 27: Site Name, Country, Site Classification, number of days, number of calendar days, prescribed range and geometric mean for reference method measurements of PM_{10} made in each site employed for the testing of the Smart Heated PM_{10} BAM-1020. calculations for Cologne Chorwelier are also shown.

Site	Country	Classification	PM_{10}					
			Days	Calendar Days	Allowed Range			Geometric Mean
Cologne, Parking Lot	Germany	Urban Background	400	228	11.9	to	25.7	22.6
Titz-Roedingen	Germany	Rural	52	52	4.3	to	18.1	21.0
Cologne Frankf. Str.	Germany	Traffic	121	121	10.9	to	42.3	21.0
Cologne-Chorweiler	Germany	Suburban	889	365	11.9	to	25.7	22.6
Graz (2007-9 only)	Austria	Traffic	1095	366	10.9	to	42.3	27.3
Steyregg (2007-9 only)	Austria	Suburban	1085	366	11.9	to	25.7	21.3
Teddington	UK	Urban Background	502	281	11.9	to	25.7	15.6
Tusimice	Czech Republic	Industrial	1089	366	13.8	to	24.6	21.1
Site	**Country**	**Classification**	**$PM_{2.5}$**					
			Days	**Calendar Days**	**Allowed Range**			**Geometric Mean**
Titz-Roedingen	Germany	Rural	47	47	3.0	to	12.8	12.2

15.3 Semi Volatile, Wind Speed, Ambient Temperature and Ambient Dew Point Calculations

Ambient temperature, relative humidity and wind speed measurements were typically obtained from meteorological stations collocated with the instruments. For the test at Tusimice in the Czech Republic, ambient temperature and wind speed data were obtained from Destnice, which is 26 km Northwest of Tusimice.

For the test at Tusimice, ambient dew points were taken from the meteorological station at Destnice. For all other sites, ambient dew points were calculated from the ambient temperature and the relative humidity. It is recognised that during periods of 100 % relative humidity this will lead to an underestimation of the ambient dew point, and therefore the percentage of days with the ambient dew point higher than the prescribed threshold may in actuality be greater. In all cases, the wind speed data are assumed to be urban rather than rural. The reason for this is that MCERTS for UK Particulate Matter calculations of rural wind speed were performed on data obtained from anemometers in coastal locations. Conversely, all of the sites employed in the field tests were non-coastal and exhibited a large degree of surface roughness.

Semi volatile components were obtained by a variety of methods outlined below:

- Cologne Parking Lot; Titz-Rödingen and Cologne Frankfurter Strasse: These three studies were conducted in 2006: the ammonium nitrate component was calculated on the day of the year as the average of the 2009, 10 and 11 ammonium nitrate data obtained by ions analysis of reference method filters collected at the NRW site at Cologne Chorweiler.
- Graz and Steyregg: At both of these sites, the average volatile fraction data from 2 collocated FDMSs was used.
- Teddington: The average volatile fraction data from the AURN sites at Teddington and Bloomsbury was used.
- Tusimice: ammonium nitrate data were obtained by ions analysis of reference method filters collected in Prague, which is 62 km to the East of Tusimice.

For those sites listed above where ammonium nitrate concentration obtained from the analysis of reference method filters at Cologne Chorweiler and Prague, these remote sites are significantly within the 130 km distance restriction imposed upon the use of volatile fraction data from remote sites. In recognition that both ammonium and nitrate ions can form compounds with nitrate and ammonium respectively (e.g. ammonium sulphate or sodium nitrate), the ammonium nitrate calculation was taken as whichever was the lower of:

1. assuming all ammonium ions were a part of ammonium nitrate; and
2. assuming all nitrate ions were a part of ammonium nitrate.

For nearly all days, the lower value for ammonium nitrate was obtained by assuming all nitrate was held in ammonium nitrate.

The results are summarised in Table 28 where criteria are met they are shaded green, and where they are not met they are shaded red. As discussed in Section 15.1, there is the requirement that for each instrument type, at least one site of at least 40 data pairs must meet the high threshold for each criteria, and at least one site of at least 40 data pairs must meet the low threshold for each criteria. Regardless of whether the three datasets with fewer than 40 data pairs are considered, for the Smart Heated PM_{10} BAM-1020, at least one site meets the lower threshold and at least one site meets the higher threshold for each of Wind Speed, Ambient Temperature, Ambient Dew Point and Semi Volatile. As such, the Wind Speed, Ambient Temperature, Ambient Dew Point and Semi Volatile criteria are fully met for the Smart Heated PM_{10} BAM-1020.

15.4 Conclusions

The geometric mean calculations for each of the three test sites are met. Further, in all cases, at least one site meets the lower threshold and at least one site meets the higher threshold for each of Wind Speed, Ambient Temperature, Ambient Dew Point and Semi Volatiles. As such, the pollution climate criteria are fully met for the Smart Heated PM_{10} BAM-1020.

This information should be referenced on the MCERTS Certificate, but there is no requirement to give any detailed information as to the specific findings of the Pollution Climate calculations.

Table 28: Wind Speed, Ambient Temperature, Ambient Dew Point and Semi Volatile calculations for the Smart Heated PM_{10} BAM-1020 for all seven sites as well as just those sites with greater than 40 data pairs.

Smart Heated PM_{10} BAM-1020	Wind Speed				Temperature			Dew Point			Semi Volatile		
	Category	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %
Cologne, Parking lot	5 m urban	29	24.1	27.6	29	72.4	0.0	29	82.8	0.0	29	0.0	86.2
Titz - Rödingen	5 m urban	37	81.1	13.5	37	0.0	91.9	37	0.0	83.8	37	91.9	2.7
Cologne, Frankfurter Str.	5 m urban	28	60.7	32.1	28	0.0	71.4	28	0.0	46.4	28	50.0	10.7
Steyregg	10 m urban	51	100.0	0.0	51	0.0	96.1	51	0.0	90.2	51	64.7	0.0
Graz	10 m urban	41	100.0	0.0	41	85.4	0.0	41	95.1	0.0	50	18.0	36.0
Tusimice	10 m urban	95	98.9	0.0	96	54.2	13.5	96	54.2	10.4	97	20.6	44.3
Teddington	2.5 m urban	40	10.0	77.5	40	2.5	15.0	40	20.0	5.0	40	55.0	2.5

PM_{10} Smart Heated BAM	Wind Speed				Temperature			Dew Point			Semi Volatile		
	Category	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %	Count	Lower / %	Higher / %
Steyregg	10 m urban	51	100.0	0.0	51	0.0	96.1	51	0.0	90.2	51	64.7	0.0
Graz	10 m urban	41	100.0	0.0	41	85.4	0.0	41	95.1	0.0	50	18.0	36.0
Tusimice	10 m urban	95	98.9	0.0	96	54.2	13.5	96	54.2	10.4	97	20.6	44.3
Teddington	2.5 m urban	40	10.0	77.5	40	2.5	15.0	40	20.0	5.0	40	55.0	2.5

CONCLUSIONS

16. Discussion Relative to Data Quality Objectives

Air Quality Directive 2008/50/EC[14] has two data quality objectives for Particulate Matter. One is that the uncertainty is below 25 %, and the other is that the minimum data capture is 90 %. The mechanisms to prove these are set out in GDE2010[9] and MCERTS for UK Particulate Matter[1], and these mechanisms have been followed herein.

The uncertainty was demonstrated to be below 25 % in Section 12.3. The minimum data capture was demonstrated to be above 90 % in Section 11. As such, the data quality objectives have been fully achieved.

17. Overall Conclusions

The Smart Heated PM_{10} BAM-1020 fully meets the requirements set out in MCERTS for UK Particulate Matter [1]. The pollution climate calculations (Section 15) show that the requirements for the sites to be of a similar pollution climate to the UK, and for there to be a suitable range of wind speed, temperature, dew point and volatile components are all met. The field test sites utilised cover urban background, suburban, rural, industrial and traffic locations. We propose, therefore, that this instrument is suitable for use at urban background, suburban, rural, industrial and traffic locations within the UK.

The Executive Summary summarise the findings in relation to MCERTS for UK Particulate Matter[1]. The text has been agreed by the UK certification committee and is repeated on the MCERTS certificate. Below is a summary of the rationale behind these decisions.

A measurement range of 0 to 1000 µg/m³ is recommended in the TÜV Rheinland Report[2] as a "default setting of the analogue output for European conditions". It is recommended that this is also adopted for UK purposes.

Details of the instruments used at each test site were given in Section 1.3. The Smart Heated PM_{10} BAM-1020 has previously been certified by Sira under the MCERTS certification scheme, but not under MCERTS for UK Particulate Matter. Sira have certified all Smart Heated PM_{10} BAM-1020 instruments fitted with Software Version 3236-02 3.2.1b onwards and serial number D0001 (*i.e.* 1st January 2004) onwards. Software Version 3236-02 3.2.1b was chosen as being used in the three original German tests (discussed herein) upon which that certification was based. The serial number of D0001 corresponds to the earliest instrument produced with the same build specification as the instruments used in those tests (E4924 and E4925). TÜV Rheinland have audited all subsequent versions of the software that have been released, and the list of their approval can be found in the TÜV Rheinland Certificate of 22nd March 2013[10]. A subsequent TÜV Confirmation dated 6th August 2013 on changes regarding certificate 0000037055 states that the currently approved software version as 3236-07 5.1.1 for instruments without a touch screen display, and 3236-77 V5.2.0 for instruments with a touch screen display[11].

It is recommended that the certification is retained as instruments from serial number D0001 onwards with Software Version 3236-02 3.2.1b onwards. It is further recommended that every effort should be made by operators of the instruments to install the latest approved version of the instrument firmware suitable for the particular model being operated.

For the UK and Czech datasets the instruments were equipped with the combined pressure and temperature sensor (BX-596), whereas for the German and Austrian datasets the instruments were fitted with ambient temperature sensor (BX-592) (Section 1.3). The difference is that with the BX-596 you get additional control with the changes of the barometric pressure during the hour, while the BX-592 configuration uses the barometric pressure at the beginning of each cycle to control the flow. The Smart Heated $PM_{2.5}$ BAM-1020 TÜV Rheinland Report[4] and allows for the $PM_{2.5}$ instrument to be configured with either sensor, and it is recommended that that approach is also adopted in the UK for the Smart Heated PM_{10} BAM-1020.

The Test for the Constancy of Volumetric Flow was discussed in Section 8.1. As the highest deviation from the nominal value is 2.5%, it is this value that should be transferred to the MCERTS certificate. This is less than the required ± 3%. The flow rate tests were done under flow conditions at a variety of filter loadings as opposed to 0%, 50 % and 80% of the mass load as prescribed in MCERTS for UK Particulate Matter[1]. The variable filter load is not a requirement in Technical Specification CEN/TS16450[6].

The Leak Test procedure was discussed in Section 8.2. As the greatest leak detected is 0.6%, it is this value that should be transferred to the MCERTS certificate. This is less than the required 1%.

The maintenance interval was discussed in Section 8.3. The maintenance interval is defined by necessary maintenance procedures and is 4 weeks, and this is this value that should be transferred to the MCERTS certificate. This is greater than the required ≥ 2 weeks.

A series of intensive laboratory tests was undertaken by TÜV Rheinland that go beyond the requirements set out in MCERTS for UK Particulate Matter. It is not required to report the results of these tests on the MCERTS certificate.

MCERTS for UK Particulate Matter[1] requires that there should be a total of at least four field tests of at least 40 data points at locations. As all of the field tests were conducted before the publication of MCERTS for UK Particulate Matter (31st July 2012), allowances are made for the scope of the field tests:

1. It is not necessary that all the field test sites have a similar pollution climate similar to that of the UK, though these calculations were presented in Section 15. It was shown that the pollution climate criteria are fully met for the Smart Heated PM_{10} BAM-1020. This information should be referenced on the MCERTS Certificate, but there is no requirement to give any detailed information as to the specific findings of the Pollution Climate calculations;
2. There is a requirement for there to be only at least one UK field test. The Smart Heated PM_{10} BAM-1020 had one UK test, and as such meets this requirement. This information should be included on the MCERTS certificate;
3. There is no requirement that two collocated reference methods are used for each field test. Two reference methods were used in all the tests except for Tusimice, and so it was necessary to use the recommended default uncertainty of 0.67 at this site. This information should be included on the MCERTS certificate;
4. There is no requirement for there to be at least 90 % data availability, though these calculations were presented in Section 11, where it was shown that the availability of all the candidate instruments was greater than 90 %. This information should be included on the MCERTS certificate.

While the German certification process required the inclusion of the three datasets with fewer than 40 data pairs each, for UK purposes, it is required that all of the datasets have at least 40 data pairs. As such, this report discusses the results of considering both all seven datasets, and just the four datasets where there are greater than 40 data pairs.

The field test data were discussed in Section 12. MCERTS for UK Particulate Matter[1] use the same methodology as that employed in the 2010 version of the GDE[9]. A series of five criteria must be fulfilled in order to prove equivalence.

1. Of the full dataset at least 20 % of the results obtained using the standard method shall be greater than the upper assessment threshold specified in 2008/50/EC for annual limit values *i.e.*: 28 µg/m³ for PM_{10} and currently 17 µg/m³ for $PM_{2.5}$.
2. The intra instrument uncertainty of the candidate must be less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³ or 18 µg/m³ for PM_{10} and $PM_{2.5}$ respectively.
3. The intra instrument uncertainty of the reference method must be less than 2.0 µg/m³.
4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and 30 µg/m³ for $PM_{2.5}$ for each individual candidate instrument against the average results of the reference method. For each of the following permutations, the expanded uncertainty must be less than 25 %:
   - Full dataset;
   - Datasets representing PM concentrations greater than or equal to 30 µg/m³ for PM_{10}, or concentrations greater than or equal to 18 µg/m³ for $PM_{2.5}$, provided that the subset contains 40 or more valid data pairs;
   - Datasets for each individual test site.
5. Preconditions for acceptance of the full dataset are that: the slope b is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$, and the intercept a is insignificantly different from 0:

$|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept of all paired instruments together.

As at least 20 % of the results obtained using the standard method are greater than 28 µg/m³, criterion 1 is fulfilled. There is no requirement in MCERTS for UK Particulate Matter for this information to be placed upon the MCERTS certificate.

As the intra instrument uncertainty of the candidate method is less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³, criterion 2 is fulfilled. These three intra instrument uncertainties should be placed on the MCERTS certificate.

As the intra instrument uncertainty of the reference method is less than 2.0 µg/m³ for the all data dataset, criterion 3 is fulfilled. Further, the intra instrument uncertainty of the reference method is less than 2.0 µg/m³ for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³, though there is no requirement for this objective to be achieved. These three intra instrument uncertainties should be placed on the MCERTS certificate.

The required expanded uncertainties are not all less than 25%. The two expanded uncertainties that are above 25 % are:

- Instrument 17011 at Teddington, where the slope is being dominated by a single high data point. At sites with a larger number of high concentration data points (such as Tusimice), the slopes are lower than at Teddington, and it is probable that were more high concentration days observed at Teddington, then the slope would have been lower; and
- Instrument Austria 2 at Graz, where the intercept is high. It is noted that the intercept of Austria 1 at Graz was low, yet the slope of both instruments was close to 1. This highlights the need to precisely quantify analyser baseline performance and ensure that the instrument specific baseline correction factor programmed in to the instrument is correctly monitored and maintained.

All of the calculated expanded uncertainties should be shown on the MCERTS certificate. As such, criterion 4 is not fulfilled, and it is required to apply corrections for slope and/or intercept (Section 12.4 below). The expanded uncertainties of the datasets less than 30 µg/m³ were also calculated. These should also be shown on the MCERTS certificate, but there is no requirement that they be below 25 %.

As the required expanded uncertainties were not all below 25 % prior to correction, it is necessary to correct the instrument for slope and/or intercept. Correction for slope was shown to be essential in order to reduce all of the expanded uncertainties to below the data quality objective of 25 %. It has been shown that the requirement to correct the instrument for slope by dividing by 1.035.

Correction for intercept is shown to be only marginally beneficial. Intercept correction is not required in order to make the instrument equivalent, but it is essential that thorough and frequent on-going QA/QC procedures are employed (as prescribed in EN12341:2014[5] and CEN/TS16450[6]) including to precisely quantify analyser baseline performance and ensure that the instrument specific baseline correction factor programmed in to the instrument is correctly monitored and maintained.

The MCERTS certificate should show the range of required expanded uncertainties for each of the following permutations:

- No Correction;
- Correction for Slope;
- Correction for Intercept;
- Correction for Slope and Intercept.

It should be clearly and unequivocally stated on the certificate that correction for slope is required in order for the instrument to be deemed equivalent. By following this approach, Criterion 5 is fulfilled.

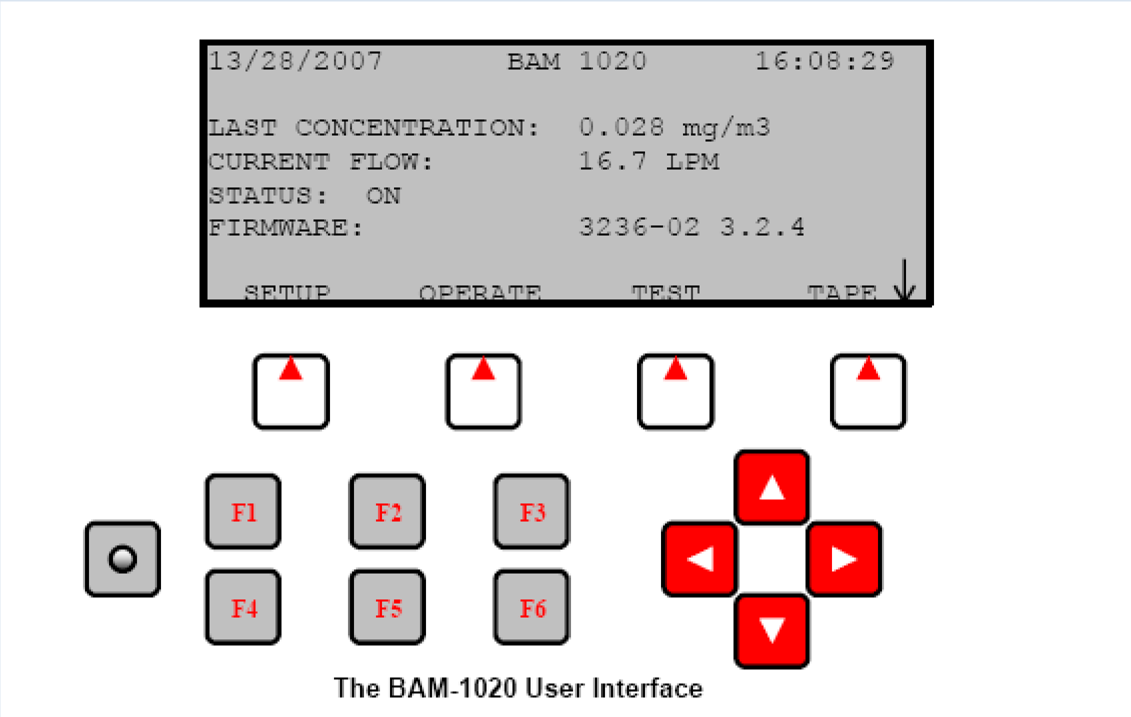
APPENDICES

A. Operating Procedures

The $PM_{2.5}$ version of the Smart Heated BAM-1020 was certified in 2010 in Germany, and as such represents a more up to date study than the original 2006 Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[2]. Further, no operating procedures were discussed in the 2012 addendum to the Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[3]. The following text is, therefore, copied with minor alterations from Section 3.3 of the Smart Heated $PM_{2.5}$ BAM-1020 TÜV Rheinland[4].

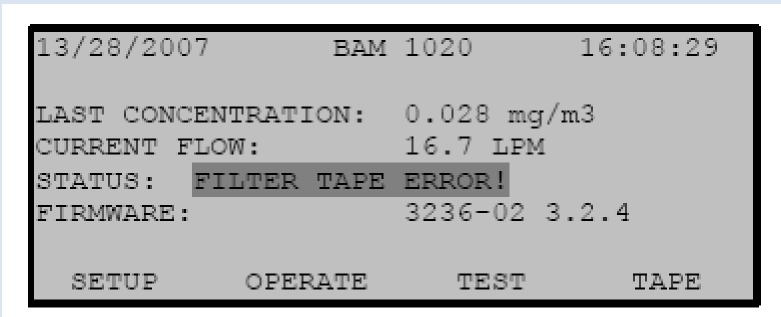
The handling of the measuring systems is done *via* a soft keypad in combination with a display at the front of the instrument. The user is able to get stored data, to change parameters and to perform several tests to control the functional capability of the measuring system.

Figure 51: *Display and soft keypad of Smart Heated BAM-1020*



The main screen of the user display can be found on the top level – here the actual time and date, the last 1h-concentration value, the actual flow rate, the firmware version as well as the status of the instrument are displayed.

Figure 52: *Main screen of user display*

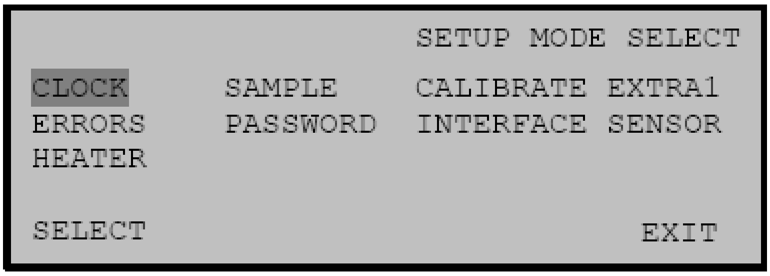


Via the function keys F1 to F6, different functions can be easily called from the top level. For example it is possible, to access actual information on the last concentration values as well as measured values from other sensors (such as ambient temperature), error messages and on stored data for the measurements of the last ten days.

Starting from the top level, one can furthermore access on the following sub-menus *via* soft key:

1. Menu “SETUP” (Press soft key “SETUP”): The configuration and setting of parameters of the measuring system is done in the menu “SETUP”. The user can do settings for parameters like for instance date/time, sampling time, measuring range, flow rate, output of measured values (actual or standard conditions), change of password, interfaces, external sensors and sample heater.

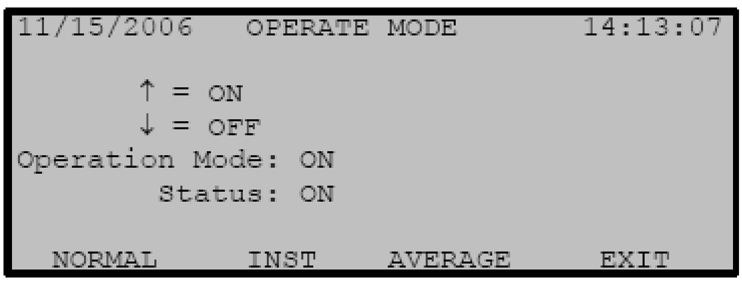
Figure 53: Menu “SETUP”



The SETUP Menu

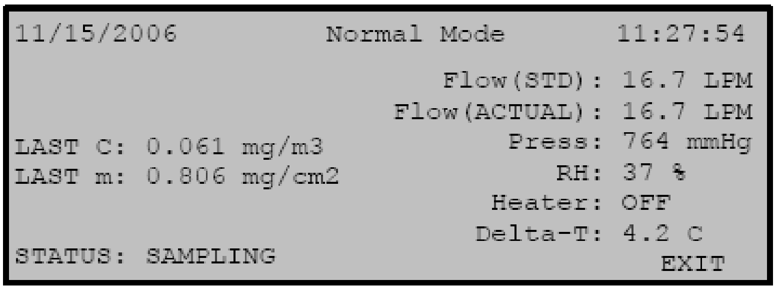
2. Menu “OPERATION” (Press soft key “OPERATION”): In the menu “OPERATION”, it is possible to call up information during the operation of the measuring system. As long as the operating mode is switched to “ON”, the measuring system will be in operation according the settings. An interruption of the ongoing measurement can be done either by switching the operating mode to “OFF”, by calling up the menus “SETUP”, “TEST” or “TAPE” during the ongoing operation or in case of a severe malfunction (e.g. filter tape breakage).

Figure 54 Menu “OPERATION”



The OPERATE Menu

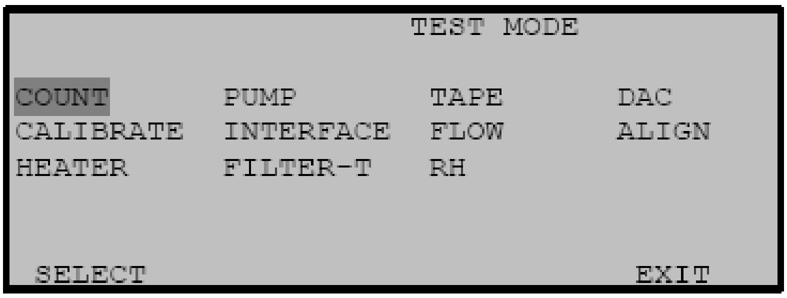
Figure 55: Screenshot "NORMAL"



The NORMAL Menu

3. Menu "TEST" (Press soft key "TEST"): In the menu "TEST", the user can perform several tests for checking the hardware and components, e.g. a check of the radiometric measurement (reference foil test), a check of the flow rate or a calibration of temperature and pressure sensors as well as of the flow rate is possible.

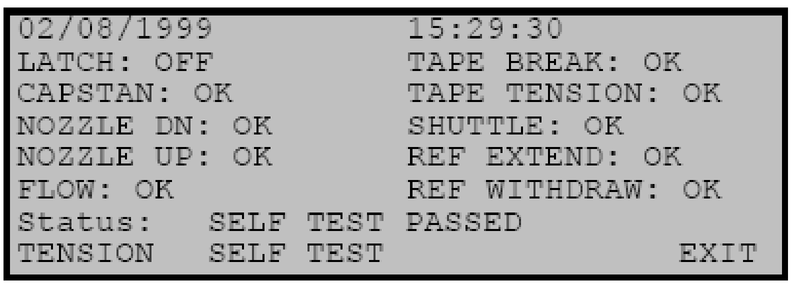
Figure 56: Menu "TEST"



The TEST Menu

4. Menu "TAPE" (Press soft key "TAPE"): In the menu "TAPE", it is possible to start at any time (while aborting the on-going measurement) an extensive self-test of the measuring system. In this self-test, which takes around 4 minutes, several mechanical parts (e.g. the filter transport system) are tested on functional capability and the flow rate and the condition of the filter tape (tension, crack of tape) are checked. In case of irregularities or unallowable deviations, an error message "FAIL" is displayed and a specific search for the problem can start. If the self-test can be performed without problems, the status "SELFTEST PASSED" is displayed and the operation can start. The performance of this test is generally recommended after each restart of the measurement following an abort, or after changing of the filter tape.

Figure 57: Screen shot "TAPE/SELF TEST"



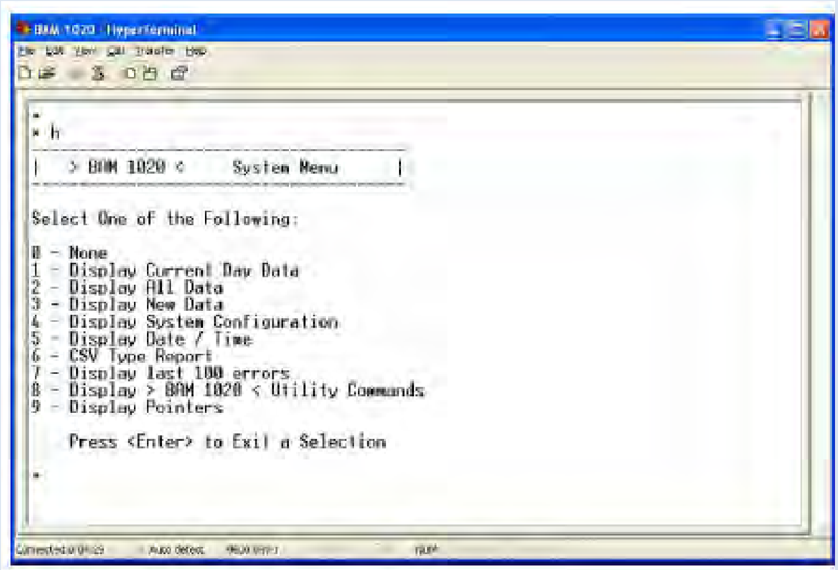
Self-Test Status Screen

Besides direct communication *via* keys/display, there are numerous possibilities to communicate *via* different analogue outputs, relais (status and alarm messages) as well *via* RS-232 interfaces. The RS232-interfaces allow for connection with a printer, PC or modem. The communication with the instrument can be done for instance with the software HyperTerminal.

The serial interface #1 serves for data transfer and transmission of the instrument status. This interface together with a modem is often used for remote control.

The following system menu is available.

Figure 58: Communication via serial interface #1 – system menu



During the test work, the measured data have been remotely downloaded once a week. They are suitable for further data integration to daily mean values in an external spreadsheet.

Figure 59: Example of downloaded data

Station	10																					
Time	Conc(ug/m3)	Qtot(m3)	BP(mmH)	WS(MPS)	WS(MPS)	RH(%)	Delta(C)	AT(C)	Stab(ug)	Ref(ug)	E	U	M	I	L	R	N	F	P	D	C	T
2/9/2009 8:00	16	0.701	749.4	5.9	0.7	16	22.3	1.9	-0.8	827.2	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 9:00	18	0.701	749.7	5.9	0.7	17	21.8	2.5	-1.9	830.2	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 10:00	9	0.701	749.5	5.9	0.7	18	20.7	3	-3.5	830.2	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 11:00	9	0.701	749.8	5.9	0.7	18	19.4	3.5	-2.9	828	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 12:00	8	0.701	749.9	5.9	0.7	19	17.7	4.5	-0.7	828.9	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 13:00	7	0.701	749.6	5.9	0.7	20	16.3	5.9	-1.2	828.5	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 14:00	11	0.7	749.5	5.9	0.7	20	16.1	6.3	-3	828.4	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 15:00	12	0.7	749.2	5.9	0.7	20	16.5	5.9	0	826.5	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 16:00	11	0.7	748.8	5.9	0.7	20	16.5	5.9	-3.8	824.5	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 17:00	13	0.701	748.1	5.8	0.7	20	17.1	4.9	1.9	829.3	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 18:00	15	0.701	747.3	5.8	0.7	21	17.3	4.2	-0.2	828	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 19:00	20	0.701	746.8	5.8	0.7	22	17	3.9	0.7	831.3	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 20:00	18	0.7	745.9	5.8	0.7	24	17.1	3.1	-3.2	827.3	0	0	0	0	0	0	0	0	0	0	0	0
2/9/2009 21:00	17	0.701	744.2	5.7	0.7	25	17	2.5	-0.4	828.5	0	0	0	0	0	0	0	0	0	0	0	0

Conc(µg(m³)): *concentration value in µg/m³ reported to ambient conditions*
Qtot(m³): *total sample volume in m³ (here at 42 min sampling time)*
BP(mm-Hg): *ambient pressure in mm-Hg*
WS (MPS): *wind speed, not active in this case*
RH(%): *relative humidity below the filter tape in % - used for control of the sample heater*
Delta(C): *ambient temperature minus the temperature at filter tape – used for control of the sample heater, not active in this case*
AT(C): *ambient temperature in °C*
Stab(µg): *result of the internal zero measurement in µg of I_1 and I_{1x}*
Ref(µg): *result of the internal reference foil measurement in µg/cm² of I_2*
E, U, M, I, L, R, N, F, P, D, C, T: *Status messages (relais)*

Via the system menu number 4 – Display System Configuration, it is furthermore possible to display and print out the actual parameter setting of the BAM-1020 for the purpose of information and diagnosis (refer to Figure 60)

Figure 60: Typical print out of the parameter setting of BAM-1020

BAM 1020 Settings Report
2/18/2009 9:40

Station ID	10
Firmware	3236-07 5.0.1
K	0.933
BKGD	-0.0014
usw	0.3
ABS	0.828
Range	1
Offset	-0.015
Clamp	-0.015
Conc Units	ug/m3
Conc Type	ACTUAL
Count Time	8
Cv	1.01
Qo	0
Flow Type	ACTUAL
Flow Setpt	16.7
Std Temp	25
High Flow Alarm	20
Low Flow Alarm	10
Heat Mode	AUTO
Heat OFF (%)	6
RH Ctrl	YES
RH SetPt	45
RH Log	YES
DT Ctrl	NO
DT SetPt	99
DT Log	YES
BAM Sample	42
MET Sample	60
Cycle Mode	STANDARD
Fault Polarity	NORM
Reset Polarity	NORM
Maintenance	OFF

EUMILRNFPDCT
0

AP	150
Baud Rate	9600
Printer Report	2
e3	0
e4	15

Channel	1	2	3	4	5	6
Sensor ID	255	2	255	255	255	35
Channel ID	255	254	255	255	255	254
Name	BP	WS	WS	RH	Delta	AT
Units	mmH	MPS	MPS	%	C	C
Prec	1	1	1	0	1	1
FS Volts	2.5	1	1	0.5	2.5	2.5
Mult	300	44.7	44.7	32	-147.1	95
Offset	525	0	0	-26	95.8	-40
Vect/Scalar	S	S	S	S	S	S
Inv Slope	N	N	N	N	N	N

Calibration	Offset	Slope
Flow	0.089	0.973
AT	0	
BP	0	
RH	-0.213	
FT	0	

The serial interface #2 serves only as a printer output and can be connected to a printer or a PC. It offers the possibility of continuous recording of actual information on the measurements.

For external check of the zero point of the measuring system and for determination of the background value BKGD (offset correction for concentration values) according to the manual Chapter 7.7, a zero filter (BX-302, Zero Filter Calibration Kit) is mounted at the device inlet. The use of this filter allows the provision of particle-free air.

Figure 61: Zero filter BX-302 during field application

With the available valve, it is also possible to check the tightness of the measuring system with the zero filter BX-302 according to the manual chapter 5.3.

For the audit of the inlet flow rate according to the manual chapter 5.6, an adapter BX-305 (Flow Inlet Adapter Kit) is available. As this kit is compliant in manufacture to the zero filter kit BX-802 except for the HEPA-filter itself, it is also possible to check the tightness of the measuring system with its available valve according to the manual chapter 5.3.

B. Filter Weighing Procedures

B.1 German Test Sites (Cologne Parking Lot, Cologne Frankfurter Strasse, Titz – Rödingen.)

The following text is copied with minor alterations from Sections 4.3 and 5 of the 2006 Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[2].

The following filters have been used during the suitability test:

Table 29: Used filter materials

Measuring instrument	Filter material, type	Manufacturer
Reference sampler LVS3 respectively SEQ47/50	Quartz fiber, ∅ 50mm	Whatman
Classifying sampler GS 050	Quartz fiber, ∅ 50mm	Whatman

The clean filters for the reference and classifying samplers have been conditioned in the weighing room for at least 48h with a temperature of 20 ± 1 °C and a constant relative humidity. The weighing process has taken place on a balance of the company Sartorius, model MC 210P, which has an absolute resolution of 10µg. The filters for the reference sampler have been inserted in the filter holders and have been carried to and from the cabinet in filter containers. Sampled filters have been carried back to the laboratory in their sampling heads and have been taken out of them in the weighing room.

The sampled filters have been treated in the weighing room the same way than the clean ones.

According to EN12341:1998[7], the following devices have been used during the field test:

1. as reference sampler: Small Filter Device Low Volume Sampler LVS3 (field test site Cologne Parking Lot)
   Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
   Date of manufacture: 2000
   PM_{10}-sampling inlet

   as well as

   Filter Changer SEQ47/50, indoor version, (since test sites Titz-Rödingen and Cologne Frankfurter Strasse)
   Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
   Date of manufacture: 2005
   PM_{10}-sampling inlet

During the test, two reference samplers have been used in parallel with a controlled flow rate of 2.3 m³/h. The accuracy of the flow rate control is less than 1 % of the nominal flow rate under real operating conditions.

Since the field test site "Titz-Rödingen", two reference systems of the type Filter Changer SEQ47/50 have been used. The systems have been installed as indoor version, which means, that the central unit of the filter changer is installed inside the cabinet and the connection to the sampling inlet is realized with a sampling tube. The sampling tube is installed in a cladding tube, made of aluminum and purged with ambient air.

The filter changer is technically based on the small filter device LVS3 and because of its shape and manufacture, it complies on principle with the reference sampler according to EN12341:1998[7]. The mechanism of filter change together with the clean and collect filter storage system allows a continuous 24-h-sampling over a period up to 15 days.

The sampling air for the LVS3 as well as for the SEQ47/50 is drawn through the sampling inlet with a rotary slide valve vacuum pump. The flow rate of the sampled air is measured between filter and vacuum pump via a measuring orifice. The inlet air is flowing from the pump to the air outlet, while passing a separator for the abrasion of the rotary slide valve.

After finished sampling, the measurement electronics show the sampled air intake volume in standard or actual-m³, respectively stores the measured data in the internal buffer (SEQ47/50).

The PM_{10} concentration has been determined by dividing the gravimetrically determined dust amount on the filter by the associated sampled air volume in in ambient m³.

B.2 UK Test Site (Teddington)

The original 2006 Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[2] predates the UK test in Teddington. Further, no reference method procedures were discussed in the 2012 addendum to the Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[3]. The following text is, therefore, copied with minor alterations from Appendix 2 of the Smart Heated $PM_{2.5}$ BAM-1020 TÜV Rheinland[4].

NPL (National Physical Laboratory) were subcontracted to weigh filters manually for the field study. In line with EN14907 filters were kept in the weighing room for less than 28 days; the glove box used for weighing was maintained at (20 ± 1) °C and (50 ± 5) %; and filters were weighed twice before and after sampling. Table 30 summarizes the conditioning and weighing timescales utilised:

Table 30: Conditioning and weighing timescales

Pre Sampling	Post Sampling
Condition minimum of 48 hours Weigh Filters Condition 24 hours Weigh Filters	Condition 48 hours Weigh Filters Condition 24 hours Weigh Filters

At the start of each weighing session the balance was exercised to remove mechanical stiffness, and then calibrated. At the start and end of each batch of filters, a 50 and 200 mg check weight were weighed. In line with the recommendations of the UK PM Equivalence Report[17], filters were weighed relative to a 100 mg check weight, and not a tare filter, as the latter was shown to lose mass over time. Four filters were weighed between check weights, as the balance drift over time had been shown to be small.

The **Check weight Mass (CM)** of the filter was calculated for each weighing session using **E B.1** below:

$$CM = \frac{\left(m_{check,Beg} + m_{check,End}\right)}{2} \qquad \textbf{E B.1}$$

Where:

$M_{check,bef}$ = Mass of check weight weighed immediately prior to sample filter.

$M_{check,aft}$ = Mass of check weight weighed immediately after sample filter.

The **Relative Mass (RM)** of the filter was calculated for each weighing session using **E B.2** below:

$$RM = m_{filter} - CM \qquad \textbf{E B.2}$$

Where:

m_{filter} = Mass of sample filter

17 D. Harrison, R. Maggs (2006), UK Equivalence Programme for Monitoring of Particulate Matter. http://uk-air.defra.gov.uk/reports/cat05/0606130952_UKPMEquivalence.pdf

Particulate Mass (PM) is calculated using the following equation in accordance with EN14907.

$$PM = \left(\frac{RM_{End1} + RM_{End2}}{2}\right) - \left(\frac{RM_{Beg1} + RM_{Beg2}}{2}\right) \qquad \textbf{E B.3}$$

Where:

Pre1 denotes weighing session 1 prior to sampling

Pre2 denotes weighing session 2 prior to sampling

Post1 denotes weighing session 1 after sampling

Post2 denotes weighing session 2 after sampling

Pre Spread (S_{Pre}), Post Spread (S_{Post}) and Blank Spread (S_{Blank}) were calculated using the following equations:

$$S_{Pre} = RM_{Anf1} - RM_{Anf2} \qquad \textbf{E B.4}$$

$$S_{Post} = RM_{End1} - RM_{End2} \qquad \textbf{E B.5}$$

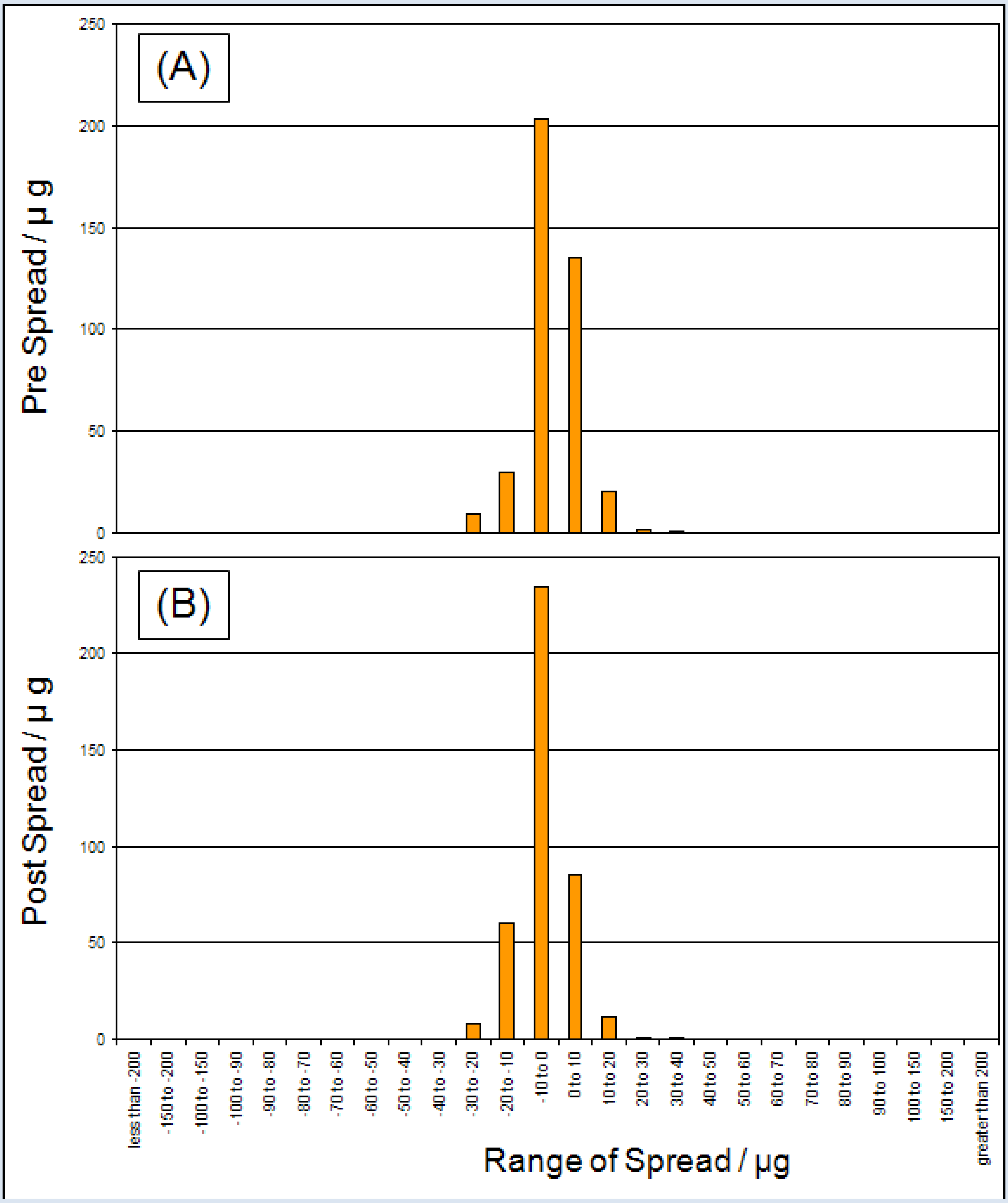
$$S_{Blank} = \left(\frac{CM_{End2} + CM_{End1}}{2}\right) - \left(\frac{CM_{Anf2} + CM_{Anf1}}{2}\right) \qquad \textbf{E B.6}$$

As with the UK PM Equivalence Report[17], it was not possible to weigh all filters within the 15 day timeframe suggested in EN14907. However, as filters were removed immediately from the reference samplers and placed in the refrigerator, it was not necessary to determine if $T_{Ambient}$ exceeded 23 ºC. It is felt that as 15 days was impractical for a relatively small scale field study, it is less likely to be attainable if this methodology were adopted by a National or Regional network, and as such, the methodology employed herein is representative of how the reference samplers would be operated in practice.

Analysis of Protocols Employed

The distributions of pre and post weight for all Emfab filters weighed relative to the tare filter and check weight are shown in Figure 62. If filters lose relative mass between weightings, then the distribution will be shifted to the right, whereas if there is a gain in the relative mass the distribution will shift to the left. EN14907 states that unsampled filters should be rejected if the difference between the masses of the two pre weightings is greater than 40 µg. Similarly, EN14907 states that sampled filters should be rejected if the difference between the masses of the two post weightings is greater than 60 µg. Filters were not rejected based on these criteria. The observed distributions of repeat mass measurements are considered unlikely to have had a significant effect on the results.

*Figure 62: Distribution for Emfab filters of (**A**) Pre spread weighed relative to the check weight and (**B**) Post spread weighed relative to the check weight.*



B.3 Austrian Test Sites (Graz and Steyregg)

The following text is copied with minor alterations from Sections 2.3 and 2.4 of the Umweltbundesamt of Austria Report on the equivalence testing of the Grimm 180 Candidate Instrument[13], which was collocated with the Smart Heated PM_{10} BAM-1020.

The measurements in Graz and Steyregg were executed in collaboration between the Umweltbundesamt and the monitoring network operators of the Austrian Federal States. The Umweltbundesamt operates the national EU reference laboratory for air pollutants and has significant experience in monitoring PM. A temperature and humidity controlled room for a micro balance has been operated since 1999. The personnel of the department for air quality & energy are also Austrian representatives in international scientific committees (e.g. CEN/TC264/WG15) and direct Austrian standardization groups for immission measurements respectively research groups for quality management of immission measurements in Austria.

Both High Volume and Low-Volume Reference Samplers were operated at each site. A very good conformity of both methods was observed. The sampling time was in each case 23 hours in order to enable the daily filter change and visual inspection of the deployed measuring devices. These operations were done either from 7 a.m. until 8 a.m. ory from 8 a.m. until 9 a.m. So the daily mean values for the candidate devices were calculated for the same period of time over 23 hours.

The filters were conditioned, weighed and separately packed into plastic Petri dishes. Filter holders were stored inside the temperature and humidity controlled room in which the micro balance was situated. Filters were stamped in order to aid identification. For example, “KF1 09 001” means “Kleinfiltergerät” (small filter device;) Number 1, year 2009, day 001, means January 1st 2009. The transport from and to the measurement location took place inside a cooling box with cooling elements during summertime in order to guarantee keeping the temperature limits for filter storing and transport according to EN 14907. Previous to the usage of the filter at the measurement location they have been stored inside an air-conditioned container.

The temperature and humidity controlled room at Umweltbundesamt is climatically controlled to (20° C ± 1° C und 50 % rH ± 5 %). Data are being captured *via* certified sensors and subsequently saved in the environmental monitoring network database of the Umweltbundesamt as half hour averages. The data are being controlled by a technician on weekdays. Weighing is halted if the temperature or humidity criteria are breached.

A microbalance type Mettler Toledo MT5 with a resolution of 1 µg was used to weigh the filters. This balance is maintained and calibrated annually by a certified institute. Prior to every weighing series, the proper functionality of the microbalances is controlled using a reference weight. During the measurement for this equivalence test no noteworthy aberrations were detected. The determination of the filter mass was executed according to the Austrian guideline EN 14907 and as such there was double weighing of the PM_{10} filters both before and after sampling. Filters which could not keep the set limits of mass difference for repeat determination were discarded.

The flows of the sampler were calibrated prior to every measurement campaign using a transfer standard and during each field test they were inspected at least twice. The aberrations were in each case below the measurement inaccuracy of the used calibration medium. Thus no correction of the volumes was undertaken. The pressure and temperature sensors have been inspected regularly with for this process appropriate transfer standards. The aberrations were in each case below the measurement inaccuracy of the used calibration medium. Thus no correction of the pressure or temperature values were undertaken.

The cleaning and recharging of the impact plate with silicone grease happened weekly. The air tightness of the air intake system has also been tested at this time. The cleaning of the filter nozzles was undertaken as required.

B.4 Czech Test Site (Tusimice)

The following information was obtained by consultation with the site operatives.

- The reference sampler was the LVS3 device as manufactured by Derenda;
- The filter media were 47 mm Glass Fibre manufactured by Whatman;
- Manual filter exchanges were undertaken at 7.00 am Central European Time;
- Immediately after sampling the filters were taken to the site shelter and were put to slides with the identification of filters and the corresponding data sheets. The slides were stored at 20 °C;
- Filters were periodically transported to the CHMI Testing laboratory No.1460 which has accreditation according to ISO17025:2005 by the Czech Accreditation Institute;
- Weighing was undertaken done according to EN14907, and filters were weighed twice before and twice after sampling. A Metler Toledo MX5 (sensitivity 1 µg). The weighing room was maintained at a temperature of 20 °C and an RH of 50%.

C. ISO17025 Accreditations

Figure 63: ISO17025 Accreditation deed of TÜV Rheinland Energie und Umwelt GmbH

DAkkS
Deutsche
Akkreditierungsstelle

Deutsche Akkreditierungsstelle GmbH

Beliehene gemäß § 8 Absatz 1 AkkStelleG i.V.m. § 1 Absatz 1 AkkStelleGBV
Unterzeichnerin der Multilateralen Abkommen
von EA, ILAC und IAF zur gegenseitigen Anerkennung

Akkreditierung

Die Deutsche Akkreditierungsstelle GmbH bestätigt hiermit, dass die

TÜV Rheinland Energie und Umwelt GmbH

mit ihrer

Messstelle für Immissionsschutz (Environmental Protection)
Am Grauen Stein, 51105 Köln

und ihrer unselbständigen Messstelle

Robert-Koch-Straße 27, 55129 Mainz

die Kompetenz nach DIN EN ISO/IEC 17025:2005 besitzt, Prüfungen in folgenden Bereichen durchzuführen:

Bestimmung (Probenahme und Analytik) von anorganischen und organischen gas- oder partikelförmigen Luftinhaltsstoffen im Rahmen von Emissions- und Immissionsmessungen; Probenahme von luftgetragenen polyhalogenierten Dibenzo-p-Dioxinen und Dibenzofuranen bei Emissionen und Immissionen; Probenahme von faserförmigen Partikeln bei Emissionen und Immissionen; Ermittlung von gas- oder partikelförmigen Luftinhaltsstoffen mit kontinuierlich arbeitenden Messgeräten; Bestimmung von Geruchsstoffen in Luft; Kalibrierungen und Funktionsprüfungen kontinuierlich arbeiten-der Messgeräte für Luftinhaltsstoffe einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Eignungsprüfungen von automatisch arbeitenden Emissions- und Immissionsmesseinrichtungen einschließlich Systemen zur Datenauswertung und Emissionsfern-überwachung; Feuerraummessungen; Ermittlung der Emissionen und Immissionen von Geräuschen; Ermittlung von Geräuschen und Vibrationen am Arbeitsplatz;
Modul Immissionsschutz

Die Akkreditierungsurkunde gilt nur in Verbindung mit dem Bescheid vom 13.05.2011 mit der Akkreditierungsnummer D-PL-11120-02 und ist gültig bis 31.01.2013. Sie besteht aus diesem Deckblatt, der Rückseite des Deckblatts und der folgenden Anlage mit insgesamt 32 Seiten.

Registrierungsnummer der Urkunde: **D-PL-11120-02-00**

Berlin, 13.05.2011

i. V. Valbuena
Andrea Valbuena
Abteilungsleiterin

Deutsche Akkreditierungsstelle GmbH

Standort Berlin
Spittelmarkt 10
10117 Berlin

Standort Frankfurt am Main
Gartenstraße 6
60594 Frankfurt am Main

Standort Braunschweig
Bundesallee 100
38116 Braunschweig

Die auszugsweise Veröffentlichung der Akkreditierungsurkunde bedarf der vorherigen schriftlichen Zustimmung der DAkkS Deutsche Akkreditierungsstelle GmbH. Ausgenommen davon ist die separate Weiterverbreitung des Deckblattes durch die umseitig genannte Konformitätsbewertungsstelle in unveränderter Form.

Es darf nicht der Anschein erweckt werden, dass sich die Akkreditierung auch auf Bereiche erstreckt, die über den durch die DAkkS bestätigten Akkreditierungsbereich hinausgehen.

Die Akkreditierung erfolgte gemäß des Gesetzes über die Akkreditierungsstelle (AkkStelleG) vom 31. Juli 2009 (BGBl. I S. 2625) sowie der Verordnung (EG) Nr. 765/2008 des Europäischen Parlaments und des Rates vom 9. Juli 2008 über die Vorschriften für die Akkreditierung und Marktüberwachung im Zusammenhang mit der Vermarktung von Produkten (Abl. L 218 vom 9. Juli 2008, S. 30).
Die DAkkS ist Unterzeichnerin der Multilateralen Abkommen zur gegenseitigen Anerkennung der European co-operation for Accreditation (EA), des International Accreditation Forum (IAF) und der International Laboratory Accreditation Cooperation (ILAC). Die Unterzeichner dieser Abkommen erkennen ihre Akkreditierungen gegenseitig an.

Der aktuelle Stand der Mitgliedschaft kann folgenden Webseiten entnommen werden:
EA: www.european-accreditation.org
ILAC: www.ilac.org
IAF: www.iaf.nu

Figure 64: ISO17025 Accreditation deeds of NPL (excerpts).

Schedule of Accreditation
issued by
United Kingdom Accreditation Service
21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK

UKAS TESTING
0002

Accredited to ISO/IEC 17025:2005

NPL Management Ltd

Issue No: 047 **Issue date:** 22 October 2012

Hampton Road **Teddington** **Middlesex** **TW11 0LW**	**Contact: Customer Helpline** **Tel: +44 (0)20 8943 7070** **Fax: +44 (0)20 8943 6184** **E-Mail: measurement_services@npl.co.uk** **Website: www.npl.co.uk**

Testing performed by the Organisation at the locations specified below

Locations covered by the organisation and their relevant activities

Laboratory locations:

Location details		Activity	Location code
Address Hampton Road Teddington Middlesex TW11 0LW	**Local contact** Mr Tahir Maqba Customer Services Manager Tel: +44 (0)20 8943 6796 Fax: +44 (0)20 8943 6184 E-Mail: tahir.maqba@npl.co.uk Website: www.npl.co.uk	**Support Functions:** Quality System Quality Audit Administration **Testing:** Mechanical, metallurgical, physical and chemical testing **Sampling and Testing:** Stack Emissions Testing	A
Address University of Huddersfield Queensgate Huddersfield Building T4/04 HD1 3DH	**Local contact** Lisa Leonard Tel: +44 (0) 20 8943 8716 Fax: +44 (0) 208 614 0482 E-mail: lisa.leonard@npl.co.uk Website: http://www.npl.co.uk/huddersfield	**Testing:** Dimensional testing	D

Site activities performed away from the locations listed above:

Location details	Activity	Location code
Customers' premises/sites	Sampling and analysis	B
Customer Sites requiring Stack Emissions Testing	Stack Emissions Testing	C

Assessment Manager: TSS

Page 1 of 16

UKAS TESTING 0002 Accredited to ISO/IEC 17025:2005	**Schedule of Accreditation** issued by **United Kingdom Accreditation Service** 21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK **NPL Management Ltd** **Issue No:** 047 **Issue date:** 22 October 2012
Testing performed by the Organisation at the locations specified	

Materials/Products tested	Type of test/Properties measured/Range of measurement	Standard specifications/ Equipment/Techniques used	Location Code
WORKPLACE AND AMBIENT ATMOSPHERIC POLUTANTS, AND OTHER GAS SAMPLES (cont'd)	Chemical Tests (cont'd)		
Volatile organic compounds using pumped sorbent tubes	0.0001 to 200 ml/m^3 (ppm v/v) for some individual species	Documented in-house method based on MDHS 60 and 72 and ISO standard TC/146/SC2/N142 using Gas Chromatography with a FID end point QPDQM/B/527	A
	Physical Tests		
Volatile organic compounds using sorbent sampler tubes	0.0001 to 200 ml/m^3 (ppm v/v) for some individual species with opinions and interpretations based on NIST research library	Documented in-house method based on BS EN ISO 16017-1&2, UK HSE MDHS 63, 72 & 80 using an automated thermal desorber gas chromatogram with a mass spectrometer and optional simultaneous flame ionisation detector (ATD/GC/MS-FID)	A
Total mercury from glass adsorption tubes containing gold-coated silica	Total mercury	Thermal desorption-atomic fluorescence spectroscopy. Documented in-house method QPAS/B/544 in accordance with BS EN 15852:2010	A
Weight of suspended particulate matter	25 ug to 7 mg equivalent to 1 µg/m^3 for a 1 m^3/hour sampler to 120 µg/m^3 for a 2.3 m^3/hour sampler	Documented in-house method based on BS EN 14907:2005	A
Pumped and diffusive sorbent tubes	C2 to C10 hydrocarbons, Nitrogen dioxide Nitrogen monoxide Sulphur dioxide Volatile organic compounds	Documented in-house methods QPDQM/B/522, 523, 525, 526, 527	B

Assessment Manager: TSS Page 9 of 16

Schedule of Accreditation

issued by

United Kingdom Accreditation Service

21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK

UKAS CALIBRATION 0478 Accredited to ISO/IEC 17025:2005	**NPL Management Ltd** **Issue No:** 058 **Issue date:** 28 November 2012	
	Hampton Road **Teddington** **Middlesex** **TW11 0LW**	**Contact: Customer Helpline** **Tel: +44 (0)20 8943 7070** **Fax: +44 (0)20 8943 6184** **E-Mail: measurement_services@npl.co.uk** **Website: www.npl.co.uk**
Calibration performed by the Organisation at the locations specified below		

Locations covered by the organisation and their relevant activities

Laboratory locations:

Location details		Activity	Location code
Address National Physical Laboratory Hampton Road Teddington Middlesex TW11 0LW	**Local contact** Mr Tahir Maqba, Customer Services Manager Tel: +44 (0)20 8943 6796 Fax: +44 (0)20 8943 6184 Email: tahir.maqba@npl.co.uk	Calibration Acoustics, Chemical, Dimensional, Electromagnetic, Fibre optics, Flow, Force, Humidity, Mass, Optical, Pressure, Radiological, Temperature, Time and Frequency, Ultrasonics	Teddington
Address Wraysbury Reservoir Coppermill Road Wraysbury Middlesex TW19 5NW	**Local contact** Mr G Hayman Tel: +44 (0)20 8943 7172 Email: gary.hayman@npl.co.uk	Calibration Underwater Acoustics	Wraysbury

Site activities performed away from the locations listed above:

Location details	Activity	Location code
Customers' sites or premises The customers' site or premises must be suitable for the nature of the particular calibrations undertaken and will be the subject of contract review arrangements between the laboratory and the customer.	Calibration Time and Frequency Humidity Chemical *(Environmental air quality monitoring instruments)*	Customers' sites

Assessment Manager: JWC Page 1 of 52

UKAS CALIBRATION 0478 Accredited to ISO/IEC 17025:2005	**Schedule of Accreditation** issued by **United Kingdom Accreditation Service** 21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK **NPL Management Ltd** **Issue No:** 058 **Issue date:** 28 November 2012

Calibration performed by the Organisation at the locations specified

Measured Quantity Instrument or Gauge	Range	Calibration and Measurement Capability (CMC) Expressed as an Expanded Uncertainty (k = 2)	Remarks	Location Code
INSTRUMENTS FOR AIR QUALITY MONITORING				Customers' sites
Analyser Calibration	NOx 200 ppb to 2 ppm SO_2 150 ppb to 1 ppm O_3 30 ppb to 1 ppm CO 0.5 ppm to 45 ppm	4.0 %	Two point (zero and span) calibration. An assessment of uncertainty due to analyser repeatability and linearity is also undertaken.	
Determination of on site standard concentration	NOx 200 ppb to 2 ppm (NO and NO_2) SO_2 150 ppb to 1 ppm CO 0.5 ppm to 45 ppm	4.0 %		
NO_2 molybdenum converter efficiency test	100 ppb to 250 ppb NO_2	1.5 %	Reaction of NO with O_3	
Sample system collection efficiency	NO_2 50 ppb to 150 ppb SO_2 50 ppb to 150 ppb O_3 50 ppb to 150 ppb CO 6 ppm to 12 ppm	1.5 % absolute 1.0 % absolute 1.5 % absolute 1.0 % absolute		
Analyser span noise test	Range as analyser calibration	2.0 ppb		
Analyser zero noise test	NOx, NO, SO_2, O_3, CO	1.0 ppb		
Particulate analyser calibration	0 $mg.m^{-3}$ to 1 $mg.m^{-3}$	1.5 %	Using 4 pre-weighed masses	
Particulate analyser flow rate test	1 slm to 10 slm 10 slm to 40 slm	1.5 % 2.0 %	Volumetric and mass flow	
BINARY GAS MIXTURES				
Nitric oxide in nitrogen	200 nmol/mol to 2 μmol/mol	3.0 % relative		

END

Assessment Manager: JWC

Page 51 of 52

Figure 65: ISO17025 Accreditation deeds of The Austrian Environment Agency.

bmw
Bundesministerium für Wirtschaft, Familie und Jugend

Bestätigung der Akkreditierung

Das Bundesministerium für Wirtschaft, Familie und Jugend bestätigt, dass die

Umweltbundesamt GmbH

Spittelauer Lände 5, 1090 Wien

ÖKD Nr.: 30

Datum der Erstakkreditierung: 29. Juli 2009

ÖKD

als Kalibrierstelle akkreditiert ist und die Anforderungen des Maß- und Eichgesetzes, BGBl.Nr. 152/1950, zuletzt geändert durch BGBl. I Nr. 115/2010, der Kalibrierdienstverordnung, BGBl.Nr. 42/1994, zuletzt geändert durch BGBl. II Nr. 490/2001, des Akkreditierungsgesetzes, BGBl.Nr. 468/1992, zuletzt geändert durch BGBl. I Nr. 85/2002, und der ÖVE/ÖNORM EN ISO/IEC 17025:2007 erfüllt.

Der detaillierte Umfang der Akkreditierung ist dem jeweils gültigen Bescheid zu entnehmen.

Die akkreditierten Fachgebiete sind in der Liste der akkreditierten Stellen unter

www.bmwfj.gv.at/technikundvermessung/akkreditierung

veröffentlicht.

Wien, am 13.02.2012

Dipl.-Ing. Gerald Freistetter

Abteilung I/11 - Akkreditierungsstelle
1011 Wien | Stubenring 1 | Tel.: +43 (0)1 711 00 - 8235 | Fax: +43 (0)1 711 00 93 - 8235 | DVR 0037257
E-Mail: post@i11.bmwfj.gv.at | **www.bmwfj.gv.at/akkreditierung**

Figure 66: Letter attesting to the ISO17025 Accreditation of CHMI.

CZECH HYDROMETEOROLOGICAL INSTITUTE

Na Sabatce 17, 143 06 Praha 4 – Komorany, Czech Republic

To whom it may concern

Subject: certification

Prague, 5.12.2012

We declare that our Ambient Air Monitoring Network and Laboratories as Imission Monitoring (IM) department-system by CHMI is designated as National Reference Laboratory (NRL) for air pollution by MoE CR and IM is accredited according to EN ISO/IEC 17025:2005.

Jiri Novak

Head of Imission Monitoring system
Czech Hydrometeorological Institute

D. Maintenance Procedures

The $PM_{2.5}$ version of the Smart Heated BAM-1020 was certified in 2010 in Germany, and as such represents a more up to date study than the original 2006 Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[2]. Further, no operating procedures were discussed in the 2012 addendum to the Smart Heated PM_{10} BAM-1020 TÜV Rheinland Report[3]. The following text is, therefore, copied with minor alterations from Section 8 of the Smart Heated $PM_{2.5}$ BAM-1020 TÜV Rheinland[4].

Works in the maintenance interval (1 month)

The following procedures are required to be undertaken at regular intervals:

- Regular visual inspection / telemetric monitoring
- Check, if device status is o.k.
- Check, if there are no error messages
- Check, if there are no contaminations
- Check of the instrument functions according to the instructions of the manufacturer
- Check of the filter stock
- Maintenance of the sampling head according to the instructions of the manufacturer specifications
- Every 4 weeks: plausibility check of temperature, pressure sensors, if necessary re-calibration
- Every 4 weeks: leak check
- Every 4 weeks: check of the flow rate, if necessary re-calibration

Each measurement cycle, the measuring systems carry out an internal check of the zero point (zero measurement) as well as of the sensitivity (measurement with reference foil). The results of these checks can be used for the continuous check of the stability of the radiometric measurement. Apart from that follow the manufacturer's directions and recommendations.

Further maintenance works

The following works are necessary in addition to the regular works in the maintenance interval:

- Replacement of filter tape after approx. 2 months (measurement cycle: 60 min). After the replacement, it is strongly advised to perform a self-test according to chapter 3.5 of the manual.
- According to the manufacturer, the calibration of the flow rate should be performed every 2 months.
- The muffler at the pump should be replaced semiannually.
- The sensors for the ambient temperature, air pressure, filter temperature and filter rH have to be checked every 6 months according to the manual.
- Once a year, a 72 h BKGD-test with the help of the zero filter kit BX-302 according to the manual point 7.7 should be performed.
- Once a year the carbon vanes of the vacuum pump (only rotary vane pump) have to be checked and replaced if necessary during an annual base maintenance.
- During the annual base maintenance, it is also to pay attention to the cleaning of the sampling tube.

Further details are provided in the user manual.

E. Field Test Data

Table 31: Site; Start Date, LVS3 Concentration; CM concentration; Ambient Temperature; RH; Ambient Dew Point; and Volatile Components used.

Site	Start Date	Reference 1 / µg m^{-3}	Reference 2 / µg m^{-3}	Candidate 1 / µg m^{-3}	Candidate 2 / µg m^{-3}	Average Ambient Temp / °C	Average RH/ %	Average Ambient Dew Point / ºC	Average WS / ms^{-1}	Average Volatile / µg m^{3}	Notes
Cologne, Parking Lot	11/02/2006	35.2	35.5	29.8	32.9	1.9	82.9	-0.7	0.0	8.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	12/02/2006			25.7	26.0	2.5	65.3	-3.3	0.7	8.3	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	13/02/2006	33.4	35.7	30.9	33.3	4.1	61.0	-2.8	1.0	7.7	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	14/02/2006					5.4	79.7	2.1	1.4	12.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	15/02/2006	12.5	11.7	10.9	12.7	7.1	84.8	4.7	1.4	14.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	16/02/2006	9.8	9.4	10.1	11.5	7.2	75.8	3.2	0.9	9.3	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	17/02/2006	9.6	9.2	8.2	8.7	6.6	66.7	0.9	1.1	11.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	18/02/2006			14.0	13.3	5.4	80.2	2.2	0.2	16.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	19/02/2006			10.4	11.5	6.9	69.2	1.7	0.8	12.7	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	20/02/2006	9.2	10.0	12.4	14.7	3.2	82.6	0.5	1.0	10.7	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	21/02/2006	14.0	13.8	14.1	16.1	4.0	72.2	-0.6	1.0	7.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	22/02/2006	16.0	16.1	17.7	18.9	1.8	60.9	-4.9	1.4	9.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	23/02/2006			20.5	20.3	0.5	50.9	-8.5	1.1	7.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	24/02/2006			29.5	31.1	2.6	49.7	-6.8	1.9	2.1	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	25/02/2006	27.9	28.8	29.1	31.6	1.0	50.8	-8.1	1.3	9.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	26/02/2006			31.1	32.2	-1.9	72.8	-6.2	0.5	5.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	27/02/2006			32.1	34.1	1.2	89.1	-0.4	0.2	5.0	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	28/02/2006			11.8	14.0	1.2	88.9	-0.4	1.7	9.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	01/03/2006	15.5	15.7	15.6	14.9	-0.7	71.4	-5.3	1.2	15.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	02/03/2006	19.1	20.0	22.1	21.8	0.7	60.2	-6.1	0.3	19.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	03/03/2006	45.8	45.9	43.9	46.3	0.3	80.6	-2.6	0.5	12.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	04/03/2006			46.1	47.8	0.2	69.4	-4.8	0.0	15.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	05/03/2006			21.0	23.1	2.6	65.8	-3.2	1.6	10.0	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	06/03/2006	21.1	21.0	19.8	22.0	2.4	69.6	-2.5	2.4	3.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	07/03/2006	26.2	26.6	26.8	28.7	2.8	54.0	-5.6	0.5	8.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	08/03/2006	14.6	13.6	14.3	16.3	4.9	86.9	2.9	0.9	10.1	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	09/03/2006	14.8	14.6	16.8	16.2	7.9	81.5	5.0	1.1	11.3	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	10/03/2006	12.1	12.0	11.1	11.6	4.9	77.4	1.3	0.5	12.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	11/03/2006			25.8	27.5	-1.2	68.7	-6.2	2.3	11.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	12/03/2006			29.9	31.7	-3.2	51.9	-11.7	0.7	6.7	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	13/03/2006	24.7	24.5	25.7	28.0	-0.1	42.0	-11.5	0.5	7.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	14/03/2006	30.2	30.1	31.4	33.2	2.2	39.6	-10.2	0.8	8.0	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	15/03/2006	33.3	33.6	35.2	36.7	4.4	42.9	-7.1	0.9	8.3	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	16/03/2006	39.2	39.1	42.1	43.5	2.6	46.4	-7.8	1.0	13.1	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	17/03/2006			39.5	40.8	2.8	52.3	-6.0	1.9	18.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	18/03/2006	37.0	37.2	40.3	40.4	3.8	57.7	-3.8	1.2	12.7	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	19/03/2006			58.8	61.9	4.5	55.5	-3.6	0.7	6.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	20/03/2006	62.5	62.5	60.9	64.8	3.9	62.4	-2.7	0.5	4.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	21/03/2006			31.8	32.9	3.6	43.3	-7.7	1.0	8.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	22/03/2006	29.3	29.4	31.1	33.6	3.3	42.2	-8.3	2.0	12.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	23/03/2006	21.3	22.7	28.8	28.7	6.6	33.7	-8.3	1.8	8.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	24/03/2006			33.6	36.1	8.7	72.3	4.0	0.3	8.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	25/03/2006	8.1	9.8	11.5	12.2	13.4	66.4	7.3	1.7	6.1	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	26/03/2006			11.1	11.5	15.6	66.7	9.4	0.5	3.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	27/03/2006			13.4	14.7	13.4	60.2	5.8	1.4	4.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	28/03/2006	8.9	9.3	13.4	13.8	9.8	58.2	2.0	0.7	6.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	29/03/2006	10.3	11.2	16.1	17.3	9.1	70.2	3.9	0.9	8.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	30/03/2006			9.8	10.6	12.8	68.7	7.2	1.3	9.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	31/03/2006	9.6	10.9	15.3	16.3	12.2	61.9	5.1	2.6	5.3	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	01/04/2006			11.5	12.5	10.7	65.2	4.4	0.8	2.0	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	02/04/2006			10.0	10.5	11.5	46.8	0.5	3.0	3.1	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	03/04/2006			20.3	22.8	8.3	59.9	0.9	1.2	6.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Parking Lot	04/04/2006			24.7	26.7	5.5	54.0	-3.0	1.4	23.7	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	26/07/2006	49.1	48.6	52.8	54.2	26.5	55.8	17.0	0.0	3.6	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	27/07/2006	39.0	39.7	43.4	44.4	24.1	64.7	17.0	0.0	2.3	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	28/07/2006					20.6	80.1	17.0	0.0	2.3	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	29/07/2006					21.7	70.5	16.1	0.0	1.2	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	30/07/2006	17.8	19.2	20.0	21.6	21.0	70.5	15.4	0.0	0.9	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	31/07/2006	17.6	18.7	21.3	21.8	20.1	63.0	12.8	0.0	1.3	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	01/08/2006	15.9	16.0	16.8	19.6	17.5	71.6	12.3	1.0	1.1	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	02/08/2006	17.4	17.8	18.7	20.2	15.7	72.8	10.8	0.8	1.3	Nitrate is average of 2009 to 2011 ion data on this date

Site	Start Date	Reference 1 / µg m^{-3}	Reference 2 / µg m^{-3}	Candidate 1 / µg m^{-3}	Candidate 2 / µg m^{-3}	Average Ambient Temp / °C	Average RH/ %	Average Ambient Dew Point / °C	Average WS / ms^{-1}	Average Volatile / µg m^{-3}	Notes
Titz - Rödingen	03/08/2006	16.5	17.6	16.2	17.8	15.1	79.8	11.6	0.0	2.3	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	04/08/2006	22.5	23.0	24.8	25.0	17.9	77.2	13.8	0.2	1.4	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	05/08/2006	20.1	21.4	24.3	25.2	19.3	73.3	14.4	0.1	1.2	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	06/08/2006	18.7	18.7	21.0	22.4	18.7	71.0	13.3	0.1	1.3	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	07/08/2006	22.0	22.9	21.6	23.3	18.8	75.0	14.3	0.3	1.9	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	08/08/2006	14.6	14.8	13.7	14.8	15.9	71.7	10.8	0.2	7.1	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	09/08/2006	29.8	28.0	27.7	28.5	15.0	78.3	11.2	0.0	0.9	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	10/08/2006	22.6	22.9	23.0	23.7	13.7	78.1	10.0	0.0	1.3	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	11/08/2006	18.0	16.6	16.9	17.5	12.7	81.0	9.5	0.1	1.2	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	12/08/2006	20.4	19.5	20.5	21.8	14.1	74.4	9.6	0.1	2.1	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	13/08/2006	13.8	12.9	13.5	13.2	15.0	71.8	9.9	0.6	1.5	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	14/08/2006	13.8	12.9	20.4	20.9	15.2	80.4	11.9	0.4	1.3	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	15/08/2006	30.7	30.3	29.9	30.5	16.0	79.4	12.4	0.2	1.8	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	16/08/2006	22.0	23.6	24.8	25.3	17.4	75.3	13.0	0.2	0.9	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	17/08/2006	16.9	17.8	16.9	17.7	18.9	73.9	14.1	0.2	2.5	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	18/08/2006	12.1	11.6	13.1	12.7	18.8	68.8	13.0	1.6	1.6	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	19/08/2006	11.5	13.2	13.8	15.4	18.3	72.4	13.3	0.1	1.6	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	20/08/2006	10.3	11.6	13.5	14.4	16.5	75.0	12.1	1.7	1.1	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	21/08/2006	15.4	15.5	18.5	18.8	15.7	80.3	12.3	0.3	0.8	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	22/08/2006	19.5	20.4	21.0	21.7	14.8	79.5	11.3	0.0	3.9	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	23/08/2006	38.2	38.9	42.6	42.8	17.5	72.0	12.4	0.1	1.8	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	24/08/2006	15.0	16.1	17.1	18.4	16.0	75.1	11.6	1.2	0.8	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	25/08/2006	31.9	31.0	32.5	34.0	16.1	80.5	12.7	0.1	0.9	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	26/08/2006	31.1	30.6	32.3	31.5	15.5	79.9	12.0	0.0	0.8	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	27/08/2006	21.3	21.0	22.8	23.5	15.6	80.5	12.3	0.1	0.8	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	28/08/2006	12.8	13.2	14.4	14.6	12.7	81.7	9.6	0.4	1.1	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	29/08/2006	13.7	14.5	15.7	14.5	12.7	77.8	8.9	0.2	1.5	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	30/08/2006					13.1	79.6	9.7	0.0	2.0	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	31/08/2006	16.7	18.2	22.3	22.0	16.9	69.9	11.4	0.6	2.2	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	01/09/2006	23.3	23.1	26.1	26.1	20.0	66.1	13.4	0.6	1.7	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	02/09/2006	20.4	20.0	20.5	23.5	19.8	65.5	13.2	2.1	1.8	Nitrate is average of 2009 to 2011 ion data on this date
Titz - Rödingen	03/09/2006	9.3	8.9	10.3	12.6	20.2	75.9	15.8	2.7	1.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	29/09/2006	32.9	30.4	33.5	34.6	18.7	68.5	12.8	0.4	3.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	30/09/2006	18.8	19.7	16.5	17.8	18.2	67.3	12.1	0.1	2.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	01/10/2006	15.2	15.4	11.5	13.0	18.6	63.8	11.6	0.5	3.3	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	02/10/2006	17.9	17.0	12.0	13.1	16.6	64.2	9.8	0.3	4.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	03/10/2006	18.8	18.1	15.4	16.9	14.3	73.4	9.6	0.2	4.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	04/10/2006	23.5	23.7	21.5	23.3	12.7	75.6	8.5	0.4	2.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	05/10/2006	14.1	12.6	15.2	15.7	14.9	68.1	9.0	0.2	1.0	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	06/10/2006	14.1	12.8	13.1	13.0	15.9	72.1	10.8	1.2	0.7	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	07/10/2006	20.6	21.3	19.3	20.1	12.1	70.4	6.9	2.0	3.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	08/10/2006	23.7	23.0	21.8	22.0	12.7	69.6	7.3	0.0	1.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	09/10/2006	30.4	30.4	30.8	29.7	15.4	70.2	10.0	0.1	1.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	10/10/2006	36.2	35.9	34.8	35.0	15.1	74.7	10.6	0.1	2.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	11/10/2006	39.7	38.9	36.5	37.9	16.7	70.6	11.3	0.7	4.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	12/10/2006	51.1	50.4	49.5	51.3	17.4	75.3	13.0	0.1	8.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	13/10/2006	42.0	42.0	40.3	42.5	15.3	77.8	11.5	0.0	5.7	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	14/10/2006	52.1	50.0	47.8	49.3	11.7	73.8	7.1	0.6	6.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	15/10/2006	37.7	35.7	37.5	37.6	11.6	67.7	5.9	0.4	2.5	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	16/10/2006	31.0	29.2	32.0	32.8	11.7	67.3	5.8	2.0	1.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	17/10/2006	31.8	30.1	33.8	33.9	12.6	65.8	6.3	2.6	5.2	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	18/10/2006	31.8	30.1	34.8	35.4	15.1	65.3	8.6	1.3	7.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	19/10/2006	22.7	21.6	21.8	23.2	15.1	76.0	10.9	1.6	2.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	20/10/2006	14.2	13.1	13.3	14.5	14.9	76.7	10.8	0.1	2.9	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	21/10/2006	13.6	11.8	12.0	13.8	15.7	69.1	10.1	0.3	3.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	22/10/2006	13.2	12.9	11.6	15.2	16.6	69.3	10.9	1.6	6.0	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	23/10/2006	15.4	15.4	15.4	16.7	16.7	76.9	12.6	1.2	5.6	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	24/10/2006	19.4	19.2	18.1	18.6	13.2	74.5	8.8	2.2	1.4	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	25/10/2006	19.8	18.7	22.5	22.5	14.5	66.3	8.3	2.8	0.8	Nitrate is average of 2009 to 2011 ion data on this date
Cologne, Frankfurter Str.	26/10/2006	33.4	29.0	31.1	33.7	19.1	64.2	12.2	0.5	2.2	Nitrate is average of 2009 to 2011 ion data on this date
Steyregg	05/6/2008	20.2	20.4	26.1	26.4	18.1	73.1	13.2	2.2	2.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	06/6/2008	16.6	17.3	20.8	20.3	17.8	77.2	13.7	1.9	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	07/6/2008	13.9	14.9	16.7	17.6	17.9	76.6	13.8	1.0	3.0	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	08/6/2008	20.7	21.5	20.0	21.2	17.4	85.0	14.8	0.8	3.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	09/6/2008	14.7	15.4	17.1	17.2	19.9	71.1	14.5	1.3	3.4	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	10/6/2008					22.4	64.9	15.4	1.2	2.3	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	11/6/2008	24.1	24.7	21.8	23.5	18.5	74.5	13.8	1.8	3.2	Nitrate is average of volatile fraction of 2 FDMSs.

Site	Start Date	Reference 1 / µg m^{-3}	Reference 2 / µg m^{-3}	Candidate 1 / µg m^{-3}	Candidate 2 / µg m^{-3}	Average Ambient Temp / ºC	Average RH/ %	Average Ambient Dew Point / ºC	Average WS / ms^{-1}	Average Volatile / µg m^{-3}	Notes
Steyregg	12/6/2008	21.9	22.7	22.0	21.1	16.8	65.2	10.2	1.5	2.4	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	13/6/2008	19.6	20.1	17.6	19.7	10.9	80.0	7.6	1.3	3.0	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	14/6/2008	17.6	17.9	20.4	19.6	13.3	71.9	8.4	0.6	3.4	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	15/6/2008	16.2	16.6	15.5	15.5	16.9	58.7	8.8	0.8	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	16/6/2008	12.0	11.9	12.1	12.4	16.9	69.1	11.2	1.0	2.3	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	17/6/2008					16.6	83.1	13.7	1.0	2.6	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	18/6/2008		14.4	15.5	14.3	16.8	84.0	14.1	1.0	2.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	19/6/2008					20.0	70.9	14.6	0.8	3.0	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	20/6/2008		20.4	23.8	21.6	21.2	65.3	14.4	1.3	2.3	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	21/6/2008		19.5	18.9	18.6	22.5	63.9	15.3	1.0	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	22/6/2008		27.6	21.2	21.6	26.2	62.6	18.5	0.8	2.8	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	23/6/2008		23.1	22.3	22.1	24.8	64.4	17.6	1.1	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	24/6/2008					21.9	75.4	17.3	1.0	3.2	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	25/6/2008	28.6	29.4	28.2	28.3	25.1	70.1	19.3	1.3	2.4	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	26/6/2008	31.2	32.4	30.6	30.0	20.5	85.6	18.0	0.9	4.3	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	27/6/2008	25.4		28.0	27.8	20.5	71.3	15.1	0.8	3.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	28/6/2008	16.5	16.5	17.9	18.3	20.5	67.6	14.3	1.4	3.2	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	29/6/2008	16.7	17.7	15.9	16.2	23.7	65.1	16.7	1.0	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	30/6/2008	19.4	18.6	18.3	18.0	21.0	73.3	16.1	1.3	3.0	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	01/7/2008					22.8	65.0	15.9	1.6	3.8	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	02/7/2008					24.2	68.6	18.1	1.2		Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	03/7/2008	35.6	35.8	37.1	36.4	24.0	69.5	18.0	1.9	2.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	04/7/2008	19.5	19.1	20.4	20.4	18.1	70.5	12.6	1.9	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	05/7/2008	18.1	17.6	18.4	18.5	18.9	60.3	11.0	1.3	2.5	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	06/7/2008	14.4	14.6	12.2	13.7	21.6	76.4	17.3	1.2	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	07/7/2008	23.6	24.2	19.0	19.2	14.8	93.0	13.7	1.2	3.0	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	08/7/2008					17.6	70.3	12.1	1.2	2.6	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	09/7/2008	15.6	16.3	14.0	14.2	17.7	73.8	12.9	1.1	2.5	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	10/7/2008	19.7	18.3	17.2	18.0	20.7	72.0	15.4	0.7	2.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	11/7/2008	20.0	18.8	18.7	19.2	24.6	61.9	16.8	1.6	2.3	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	12/7/2008	19.0	19.2	16.8	16.6	19.8	80.8	16.4	1.4	2.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	13/7/2008	15.7	15.7	12.4	12.0	17.0	87.1	14.8	1.6	2.1	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	14/7/2008	20.5	21.5	20.2	20.0	15.8	82.8	12.9	1.5	2.6	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	15/7/2008					19.5	61.0	11.8	1.9	3.4	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	16/7/2008	22.9	23.4	23.8	24.3	21.2	66.8	14.7	1.4	3.2	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	17/7/2008	17.3	17.6	12.6	12.1	15.6	92.5	14.4	0.7	3.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	18/7/2008	20.9	20.8	18.8	18.0	15.9	86.4	13.7	0.9	4.1	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	19/7/2008	15.5	15.2	14.2	13.3	21.4	69.7	15.7	1.0	3.2	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	20/7/2008	17.3	17.6	14.0	13.3	17.8	82.5	14.8	1.4	2.8	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	21/7/2008	18.6	18.9	16.6	18.8	15.1	68.3	9.3	1.7	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	22/7/2008					13.9	81.5	10.8	2.5	2.8	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	23/7/2008	22.6	22.0	19.4	18.7	16.1	80.1	12.6	1.4	3.6	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	24/7/2008	30.5	31.1	26.8	25.7	15.6	93.9	14.6	1.3	4.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	25/7/2008	26.8	28.0	27.0	25.0	18.2	94.6	17.3	0.8	4.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	26/7/2008	20.4	20.5	21.9	19.9	20.9	87.5	18.7	0.3	3.8	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	27/7/2008	21.7	22.0	21.4	20.1	22.3	72.5	17.1	1.4	2.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	28/7/2008	22.5	23.7	23.9	24.5	23.6	64.4	16.5	1.8	2.7	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	29/7/2008					24.3	69.9	18.4	0.9	3.1	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	30/7/2008	19.5	20.4	19.4	18.5	23.2	74.6	18.5	1.2	3.3	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	31/7/2008	19.3	20.1	20.1	18.0	22.8	71.3	17.3	1.1	3.6	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	01/8/2008	25.6	25.9	21.5	21.3	24.3	68.3	18.1	1.5	3.4	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	02/8/2008	16.8	18.4	16.0	13.2	20.4	84.9	17.7	0.7	3.9	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	03/8/2008	10.7	11.7	10.0	8.7	22.1	72.7	16.9	0.9	3.6	Nitrate is average of volatile fraction of 2 FDMSs.
Steyregg	04/8/2008	20.5	22.1	21.2	19.7	22.2	69.2	16.3	2.1	3.0	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	05/12/2007	121.1	121.8	125.6	128.7	1.1	83.9	-1.3	0.1	3.0	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	06/12/2007	107.7	105.9	108.1	109.6					6.2	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	10/12/2007	71.4	69.5	71.4	71.6	1.1	98.4	0.8	0.2	5.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	13/12/2007	11.3	11.0	16.8	18.6	4.7	41.4	-7.3	1.8	3.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	16/12/2007		31.1	30.5	31.9	-1.3	84.7	-3.6	0.6	3.5	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	17/12/2007	53.8		52.1	53.4	-2.7	83.5	-5.1	0.3	5.4	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	19/12/2007		82.5	90.0	91.9	-4.8	84.8	-7.0	0.8	7.5	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	20/12/2007	78.6	79.5	84.3	85.5	-5.9	89.1	-7.4	0.7	9.0	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	07/01/2008		107.4	109.9	113.1	-1.2	93.9	-2.1	0.3	8.4	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	08/01/2008	95.5	94.6	96.8	101.4					8.8	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	09/01/2008		86.5	91.4	93.0	-1.6	88.0	-3.3	0.2	8.9	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	10/01/2008	65.0	64.9	67.4	70.6	-1.9	90.6	-3.2	0.3	8.9	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	13/01/2008	63.7	62.1	59.2	62.4	3.1	100.0	3.1	0.0	7.8	Nitrate is average of volatile fraction of 2 FDMSs.

Site	Start Date	Reference 1 / µg m^{-3}	Reference 2 / µg m^{-3}	Candidate 1 / µg m^{-3}	Candidate 2 / µg m^{-3}	Average Ambient Temp / °C	Average RH / %	Average Ambient Dew Point / °C	Average WS / ms^{-1}	Average Volatile / µg m^{-3}	Notes
Graz	14/01/2008	50.4	48.8	50.4	52.9	2.2	97.9	1.9	0.2	6.9	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	15/01/2008	49.3	48.6	49.5	51.4	0.6	98.0	0.4	0.4	7.9	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	16/01/2008	52.9	51.3	46.5	48.3	3.4	91.6	2.1	0.3	5.7	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	17/01/2008	57.9	57.1	53.5	55.3	4.5	97.9	4.2	0.1	6.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	20/01/2008	63.9	64.2	61.0	62.8	5.9	90.5	4.5	0.1	6.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	21/01/2008	100.5	97.9	98.8	99.9	3.9	89.2	2.3	0.2	6.9	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	22/01/2008	44.6	44.6	42.6	44.4	4.4	58.3	-3.1	1.2	2.8	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	23/01/2008	52.4	50.3	52.3	53.7	0.4	61.6	-6.1	0.7	3.3	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	24/01/2008	90.6	92.0	89.5	90.1					5.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	28/01/2008	20.1	18.9	16.2	20.3	4.6	67.4	-0.9	0.9	2.4	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	30/01/2008	78.2	77.6	80.8	84.4	2.2	80.1	-0.9	0.3	5.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	31/01/2008	72.8	71.4	71.8	73.8	2.6	78.2	-0.8	0.6	10.4	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	03/02/2008	22.0	21.7	21.4	23.3	2.7	77.3	-0.9	0.8	5.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	04/02/2008	55.5	56.3	59.1	61.4	3.5	89.4	1.9	0.3	6.6	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	05/02/2008	44.7	44.3	45.2	47.1					6.2	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	06/02/2008	43.3	43.6	45.6	47.5	3.1	93.7	2.2	0.4	5.5	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	07/02/2008	43.2	42.2	38.9	41.5	2.8	58.1	-4.6	1.1	2.8	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	10/02/2008	64.6	64.1	59.0	61.3	1.4	69.0	-3.6	0.2	5.5	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	11/02/2008	83.6	82.3	85.1	85.5	0.2	73.7	-4.0	0.4	5.8	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	12/02/2008	87.9	87.0	85.2	90.2	-0.7	72.5	-5.0	0.3	6.6	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	13/02/2008	111.4	109.8	111.9	115.3					7.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	14/02/2008	97.9	96.8	99.3	103.3					10.3	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	17/02/2008	52.6	51.2	46.0	48.9	-3.5	46.3	-13.4	0.4	5.7	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	18/02/2008	47.1	47.2	49.5	53.1	4.4	33.9	-10.1	0.6	4.9	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	19/02/2008	69.7	69.2	76.8	81.0	4.5	53.3	-4.2	0.7	6.2	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	20/02/2008	102.8	104.5	102.5	105.9					9.3	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	21/02/2008	84.0	82.7	93.0	97.1					8.9	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	24/02/2008	60.9	62.4	53.4	57.7	8.1	61.0	1.0	0.3	5.7	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	25/02/2008	73.8	74.8	82.6	86.2					4.5	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	26/02/2008	79.6	77.7	92.0	94.5	8.4	65.5	2.4	0.4	6.9	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	27/02/2008	43.1	42.6	58.1	61.6	10.2	53.1	1.0	0.6	4.4	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	28/02/2008	52.7	51.6	56.9	60.1	7.1	68.1	1.6	0.6	5.4	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	02/03/2008	10.8	11.1	6.6	7.4	13.3	41.7	0.5	1.9	2.6	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	03/03/2008	24.3	24.9	37.5	40.9	12.2	51.9	2.6	1.2	2.8	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	04/03/2008	15.2	14.7	18.0	20.4	3.2	77.6	-0.4	0.8	3.1	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	05/03/2008	17.3	18.2	16.3	19.6	1.7	46.5	-8.6	1.3	2.4	Nitrate is average of volatile fraction of 2 FDMSs.
Graz	06/03/2008	26.0	25.3	28.8	31.3	2.0	42.8	-9.4	0.6	3.7	Nitrate is average of volatile fraction of 2 FDMSs.
Tusimice	07/01/2010	47.0		47.7	49.8	-7.0	85.0	-10.0	0.0	15.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	08/01/2010	50.4		51.6	53.3	-7.0	92.0	-8.0	0.6	10.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	09/01/2010			50.8	51.6	-6.0	93.0	-7.0	0.6	8.1	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	10/01/2010			17.6	16.7	-4.0	94.0	-5.0	1.2	2.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	11/01/2010	40.2		43.2	42.7	-7.0	92.0	-8.0	0.0	10.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	12/01/2010	53.7		62.5	62.5	-8.0	92.0	-9.0	0.0	15.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	13/01/2010	68.5		72.2	74.6	-7.0	94.0	-7.0	0.0	8.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	14/01/2010	31.6		33.3	34.9	-3.0	91.0	-5.0	0.0	5.0	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	15/01/2010	44.4		46.4	46.8	-3.0	92.0	-4.0	0.0	5.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	16/01/2010			41.0	40.8	-2.0	88.0	-4.0	0.6	7.2	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	17/01/2010			51.6	51.0	-3.0	93.0	-4.0	0.0	4.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	18/01/2010	21.9		23.6	23.3		94.0		0.0	5.9	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	19/01/2010	29.3		30.1	32.2	-13.0	24.0	-56.0		7.2	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	20/01/2010	51.7		53.2	53.6	-8.0	53.0	-33.0		8.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	21/01/2010	77.2		79.1	79.8	-5.0	91.0	-7.0	0.0	13.0	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	22/01/2010	91.8		92.1	93.2	-8.0	88.0	-10.0	0.0	15.9	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	23/01/2010			89.9	89.9	-9.0	91.0	-10.0	0.0	10.1	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	24/01/2010			69.4	71.3	-8.0	87.0	-9.0	0.0	12.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	25/01/2010			64.4	64.6	-9.0	87.0	-10.0	0.6	8.9	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	26/01/2010	53.8		66.8	66.7	-10.0	85.0	-12.0	0.6	11.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	27/01/2010	48.4		55.4	54.8	-13.0	79.0	-16.0	0.6	7.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	28/01/2010	5.8		9.6	7.9	-2.0	85.0	-5.0	2.5	4.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	29/01/2010	6.0		7.7		-1.0	88.0	-3.0	1.2	3.2	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	30/01/2010			10.4		-2.0	82.0	-5.0	1.2	5.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	31/01/2010					-7.0	85.0	-9.0	0.0	6.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	01/02/2010	12.7		14.0	13.0	-8.0	84.0	-10.0	0.0	6.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	02/02/2010	6.4		8.4	8.3	-2.0	80.0	-5.0	1.2	3.0	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	03/02/2010	9.2		12.1	11.7	-1.0	82.0	-3.0	1.2	3.0	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	04/02/2010	55.7		57.8	57.9	-5.0	92.0	-6.0	0.6	10.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	05/02/2010	55.1		55.1	55.9	-2.0	89.0	-3.0	0.0	11.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).

Site	Start Date	Reference 1 / µg m-3	Reference 2 / µg m-3	Candidate 1 / µg m-3	Candidate 2 / µg m-3	Average Ambient Temp / ºC	Average RH/ %	Average Ambient Dew Point / ºC	Average WS / ms-1	Average Volatile / µg m-3	Notes
Tusimice	06/02/2010	66.8		68.9	69.9	-2.0	96.0	-2.0	0.0	7.1	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	07/02/2010	46.5		50.7	51.3	-7.0	89.0	-9.0	0.6	7.0	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	08/02/2010	48.3		51.1	50.6	-9.0	84.0	-11.0	0.0	12.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	09/02/2010	62.7		64.4	64.0	-8.0	85.0	-10.0	0.0	9.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	10/02/2010	87.2		90.9	92.1	-6.0	91.0	-8.0	0.0	18.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	11/02/2010	50.9		54.9	55.7	-6.0	90.0	-7.0	1.2	13.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	12/02/2010	16.1		17.0	18.3	-5.0	90.0	-7.0	0.0	11.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	13/02/2010	11.0		13.0	13.0	-5.0	86.0	-7.0	0.0	7.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	14/02/2010	29.2		31.8	31.9	-6.0	85.0	-8.0	0.0	8.1	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	15/02/2010	47.5		52.8	53.8	-5.0	82.0	-8.0	0.0	12.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	16/02/2010	57.9		61.3	61.5	-7.0	84.0	-9.0	0.6	6.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	17/02/2010	75.3		76.6	76.6	-7.0	91.0	-8.0	0.0	8.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	18/02/2010	69.0		73.0	74.8	-1.0	93.0	-2.0	0.0	6.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	19/02/2010	55.2		58.6	60.3	0.0	96.0	-1.0	0.0	7.9	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	20/02/2010	20.4		21.4	22.3	1.0	82.0	-2.0	0.6	3.9	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	21/02/2010	19.9		20.2	20.8	-1.0	84.0	-3.0	0.6	4.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	22/02/2010	67.8		72.0	72.9	-2.0	92.0	-4.0	0.0	4.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	23/02/2010	112.5		113.0	115.6	0.0	89.0	-2.0	0.0	5.2	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	24/02/2010	70.6		78.1	79.2	3.0	92.0	2.0	0.0	6.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	25/02/2010	64.6				3.0	86.0	1.0	0.6	5.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	26/02/2010	37.1		39.4	37.8	2.0	90.0	1.0	0.6	2.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	27/02/2010	25.0		29.8	29.0	4.0	73.0	0.0	1.2	2.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	28/02/2010	13.5		19.7	19.7	0.0	88.0	-2.0	0.0	2.1	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	01/03/2010	6.5		9.5	9.1	3.0	71.0	-1.0	2.5	2.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	02/03/2010	13.8		18.2	17.4	0.0	78.0	-3.0	0.6	5.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	03/03/2010	12.6		16.4	15.3	-1.0	75.0	-5.0	1.2	5.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	04/03/2010	14.9		21.4	19.0	-3.0	82.0	-6.0	0.6	5.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	05/03/2010	14.3		24.1	22.3	-5.0	74.0	-9.0	1.9	3.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	06/03/2010	24.0		35.1	31.7	-6.0	82.0	-8.0	1.2	6.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	20/04/2010	41.0		45.1	42.8	9.0	72.0	4.0	0.6	13.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	21/04/2010	13.8		17.2	15.9	6.0	70.0	1.0	1.9	4.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	22/04/2010	19.6		26.2	25.4	4.0	63.0	-3.0	1.2	5.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	23/04/2010	32.9		38.6	37.8	5.0	67.0	-2.0	0.6	9.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	24/04/2010	48.0		51.9	50.2	10.0	60.0	2.0	0.6	13.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	25/04/2010	36.8		41.4	40.2	11.0	64.0	4.0	0.6	7.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	26/04/2010	20.4		25.1	23.1	11.0	73.0	6.0	1.2	4.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	27/04/2010	19.5		23.4	21.4	11.0	74.0	6.0	1.2	7.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	28/04/2010	26.2		33.1	30.5	11.0	70.0	4.0	0.6	11.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	29/04/2010	35.6		45.2	43.6	15.0	60.0	6.0	0.6	5.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	30/04/2010	27.2		34.4	34.0	17.0	60.0	9.0	1.2	5.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	01/05/2010	13.2		16.6	14.7	14.0	73.0	10.0	0.0	4.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	02/05/2010	29.0		33.0	28.9	11.0	93.0	10.0	0.6	4.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	03/05/2010	15.1		17.4	15.5	11.0	87.0	9.0	0.6	4.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	04/05/2010	21.1		27.0	25.7	8.0	89.0	6.0	0.6	3.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	05/05/2010	24.8		29.6	26.6	7.0	85.0	5.0	1.2	5.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	06/05/2010	12.0		13.2	11.2	8.0	96.0	8.0	0.0	2.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	07/05/2010	8.5		12.5	9.0	9.0	80.0	5.0	0.6	2.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	08/05/2010	18.1		20.8	18.5	9.0	74.0	4.0	0.6	7.2	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	09/05/2010	15.7		17.8	15.6	9.0	83.0	6.0	0.6	4.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	10/05/2010	39.4		41.5	39.9	10.0	92.0	9.0	0.0	7.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	11/05/2010	30.5		30.4	28.8	13.0	90.0	11.0	0.6	5.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	12/05/2010	14.4		16.3	14.9	13.0	79.0	9.0	1.2	4.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	13/05/2010	17.5		18.7	16.5	9.0	84.0	7.0	0.6	7.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	14/05/2010	4.7		6.4	4.9	7.0	91.0	6.0	0.6	2.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	15/05/2010	12.9		13.4	13.8	6.0	89.0	5.0	1.9	1.2	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	16/05/2010	16.0		18.6	19.8	9.0	74.0	4.0	2.5	4.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	17/05/2010	19.4		25.3	24.2	11.0	71.0	5.0	2.5	7.2	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	18/05/2010	11.6		15.9	15.5	9.0	73.0	5.0	3.1	2.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	19/05/2010	6.4		8.8	7.2	8.0	88.0	6.0	1.2	2.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	20/05/2010	11.0		16.5	14.2	11.0	92.0	9.0	0.6	4.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	21/05/2010	26.4		29.8	28.5	13.0	86.0	11.0	1.2	6.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	22/05/2010	27.0		30.3	28.5	16.0	76.0	11.0	0.6	6.6	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	23/05/2010	16.8		20.3	16.9	14.0	80.0	10.0	1.2	4.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	24/05/2010	17.0		21.4	20.2	15.0	84.0	12.0	1.2	2.8	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	25/05/2010	21.2		29.3	27.7	14.0	84.0	11.0	1.2	4.9	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	26/05/2010	30.2		30.7	31.7	11.0	90.0	9.0	0.0	5.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	27/05/2010	29.4		41.3	36.9	14.0	87.0	12.0	1.2	3.9	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).

Site	Start Date	Reference 1 / µg m^{-3}	Reference 2 / µg m^{-3}	Candidate 1 / µg m^{-3}	Candidate 2 / µg m^{-3}	Average Ambient Temp / °C	Average RH/ %	Average Ambient Dew Point / °C	Average WS / ms^{-1}	Average Volatile / µg m^{3}	Notes
Tusimice	28/05/2010	22.3		27.1	29.0	14.0	85.0	11.0	0.6	4.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	29/05/2010	34.5		31.5	35.4	14.0	77.0	9.0	0.6	9.7	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	30/05/2010	6.6		7.2	6.1	13.0	87.0	11.0	0.6	1.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	31/05/2010	3.9		6.2	4.3	10.0	83.0	8.0	1.9	1.2	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	01/06/2010	4.7		7.1	4.1	10.0	87.0	8.0	2.5	1.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	02/06/2010	4.9		9.4	7.0	11.0	91.0	9.0	2.5	1.0	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	03/06/2010	9.2		19.1	19.9	12.0	95.0	11.0	1.2	1.5	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	04/06/2010	14.7		21.3	19.8	14.0	78.0	10.0	1.2	3.1	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	05/06/2010	21.0		29.8	26.6	16.0	73.0	10.0	0.6	3.4	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Tusimice	06/06/2010	22.0		23.3	22.9	19.0	74.0	13.0	0.6	2.3	Met data from Destnice (26 KM NW). Nitrate from Prague (62 km East).
Teddington	10/04/2012			12.4	10.5	8.1	69.5	2.9	0.2	2.3	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	11/04/2012			13.2	12.7	8.6	69.6	3.4	0.4	2.8	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	12/04/2012	13.8	13.7	19.5	14.7	7.3	81.6	4.4	0.2	4.8	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	13/04/2012	21.3	21.2	26.1	22.0	9.6	69.1	4.2	0.7	7.8	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	14/04/2012	11.4	11.7	18.4	12.7	8.1	60.1	0.8	2.2	1.8	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	15/04/2012	11.5	12.2	17.0	12.0	5.8	63.9	-0.5	1.5	1.5	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	16/04/2012	10.4	10.0	14.7	11.1	8.4	51.9	-0.9	1.0	4.5	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	17/04/2012	8.7	8.4	13.4	9.8	8.5	75.4	4.4	0.9	3.4	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	18/04/2012	8.3	8.2	11.5	9.6	8.4	85.8	6.2	0.9	3.0	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	19/04/2012	12.1	10.9	16.2	12.5	8.1	86.1	5.9	0.1	3.3	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	20/04/2012	6.9	6.9	11.2	7.9	7.8	79.4	4.5	0.2	3.7	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	21/04/2012	7.9	7.7	12.2	8.5	8.9	70.6	3.8	0.2	2.2	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	22/04/2012	9.1	8.5	12.4	9.4	9.7	75.8	5.6	0.5	3.1	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	23/04/2012	7.4	7.4	11.0	8.6	7.9	84.4	5.5	2.0	2.8	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	24/04/2012	12.1	12.0	16.0	13.3	9.4	70.5	4.3	1.5	4.8	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	25/04/2012	9.4	9.5	13.0	11.7	10.0	83.6	7.4	1.9	4.8	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	26/04/2012	12.4	12.3	18.5	14.6	11.4	71.7	6.5	1.2	0.4	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	27/04/2012	13.9	14.4	19.0	15.4	11.3	77.8	7.6	0.7	3.1	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	28/04/2012	4.4	4.5	10.6	6.3	7.5	91.8	6.3	3.5	4.6	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	29/04/2012	8.2	8.4	14.8	12.3	11.3	73.8	6.8	2.4	2.2	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	30/04/2012	15.1	15.2	21.0	16.7	14.6	69.7	9.2	2.4	4.1	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	01/05/2012	20.5	20.6	27.5	22.1	14.0	76.2	9.9	0.6	6.3	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	02/05/2012	22.8	23.1	28.6	24.3	10.8	80.9	7.7	1.2	4.2	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	03/05/2012	16.0	16.3	21.3	18.5	8.5	86.7	6.4	0.6	3.3	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	04/05/2012	12.8	13.1	18.7	16.2	8.4	77.4	4.7	1.7	2.2	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	05/05/2012	10.2	10.2	15.3	12.9	7.8	66.5	2.0	1.8	1.3	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	06/05/2012	16.4	15.9	21.3	17.4	7.2	72.9	2.7	0.7	2.5	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	07/05/2012	10.3	10.6	15.6	13.5	11.9	82.2	8.9	0.8	3.1	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	08/05/2012	12.6	13.0	17.5	14.7	13.9	78.5	10.2	0.4	3.3	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	09/05/2012	5.5	5.5	11.9	9.2	14.9	91.0	13.4	0.8	3.1	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	10/05/2012	6.1	6.2	9.4	5.3	14.8	82.0	11.7	0.7	1.9	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	11/05/2012	8.4	8.6	13.5	11.4	11.5	56.0	3.0	1.2	0.5	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	12/05/2012	12.9	13.2	17.5	15.8	10.8	58.0	2.8	0.8	2.2	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	13/05/2012	12.1	11.9	14.3	14.2	12.1	58.7	4.3	0.4	3.0	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	14/05/2012	8.0	8.0	11.7	10.4	8.7	83.0	6.0	0.3	2.4	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	15/05/2012	8.9	9.1	14.3	11.6	7.5	76.4	3.6	1.0	1.0	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	16/05/2012	13.0	13.1	16.8	15.9	11.1	62.7	4.2	0.4	2.0	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	17/05/2012	26.4	27.0	29.5	28.2	12.6	58.1	4.5	1.5	6.0	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	18/05/2012	22.9	23.4	29.7	26.7	13.6	79.0	10.0	0.6	3.9	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	19/05/2012	19.4	20.0	24.5	23.3	13.1	69.8	7.7	1.6	4.9	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	20/05/2012	15.9	16.0	20.3	19.0	12.2	76.2	8.2	1.9	3.1	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.
Teddington	21/05/2012	31.2	31.7	41.3	42.0	14.5	75.5	10.2	1.5	6.2	Dew point calculated. Nitrate is volatile fraction of the Teddington and Bloomsbury FDMSs.

F. Instrument Manual

BAM 1020
PARTICULATE MONITOR
OPERATION MANUAL

BAM-1020-9800 REV K

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Table of Contents

1 INTRODUCTION

1.1 About This Manual

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. Below is a brief description of the BAM-1020 manual revision history:

Rev	Released	Manual Description
A-E	1998-2006	Obsolete revisions of the manual. These are only suitable for older BAM-1020 units with firmware Rev 2.58 or earlier. Users of these units should acquire a newer manual revision.
F	March 2007	Complete re-write of the entire manual to accompany the EPA PM2.5 FEM candidate modifications for the BAM-1020. Extensively corrected, reorganized, and updated all sections. Applies to all BAM-1020 units of all vintages. All BAM-1020 units using revision 3.0 or later firmware must have a Rev F or later manual.
G	May 2008	Minor revisions for the official sales release of the EPA designated PM2.5 FEM version of the BAM-1020. Added final PM2.5 designation requirements and installation drawings. Other minor revisions throughout the manual. Applies to all BAM-1020 units. All BAM-1020 units using revision 3.2.5 or later firmware should have a Rev G or later manual.
H	June 2010	Revisions to incorporate information about the PM-Coarse designated version, and to add information about new firmware features up to firmware rev 3.6. Additional maintenance procedures added.
J	Sep 2011	Minor revisions to zero filter test instructions.
K	Oct 2012	Added electrical safety requirements and smart heater configurations in section 2. Added report processor and firmware compatibility details. Firmware features up to version 3.7.

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.

Phone: **(541) 471-7111** Fax: (541) 471-7116

E-Mail: service@metone.com Web: www.metone.com

Address: Technical Services Department
Met One Instruments, Inc.
1600 NW Washington Blvd.
Grants Pass, OR 97526

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
W	1998
X	1999
Y	2000
A	2001
B	2002
C	2003
D	2004
E	2005
F	2006
G	2007

Letter	Year
H	2008
J	2009
K	2010
M	2011
N	2012
P	2013
R	2014
T	2015
U	2016
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 $PM_{10\text{-}2.5}$ 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.

1.8 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/m^3 (0 - 1000 $\mu g/m^3$)
Optional Ranges:	0 - 0.100, 0.200, 0.250, 0.500, 2.000, 5.000, 10.000 mg/m^3 (special applications)
Accuracy:	Exceeds US-EPA Class III $PM_{2.5}$ FEM standards for additive and multiplicative bias.
Measurement Resolution:	0.24 $\mu g/m^3$ (1.000 mg range). 2.4 $\mu g/m^3$ (10 mg range).
Data Resolution:	1 $\mu g/m^3$ (Concentration data stored and displayed in whole micrograms).
Sensitivity Std. Deviation: (σ) (1 hour)	Less than 2.4 $\mu g/m^3$ (less than 2.0 $\mu g/m^3$ typical). Auditable with zero filter test.
Lower Detection Limit: (2σ) (1 hour)	Less than 4.8 $\mu g/m^3$ from 0.000 to 0.100 mg/m^3 (less than 4.0 $\mu g/m^3$ typical). Auditable with zero filter test.
Lower Detection Limit: (2σ) (24 hour)	Less than 1.0 $\mu g/m^3$. 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 10^6 Beq), Half-Life 5730 years.
Beta Detector Type:	Photomultiplier tube with organic plastic scintillator.
Operating Temp. Range:	0° to +50℃. Shelter temperature should be stable t o within ±2℃ per hour.
Ambient Temp. Range:	-40° to +55℃ standard. Optional -50 degree tempera ture 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 0^{o} C and $+50^{o}$ 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 Inlet 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 items 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.

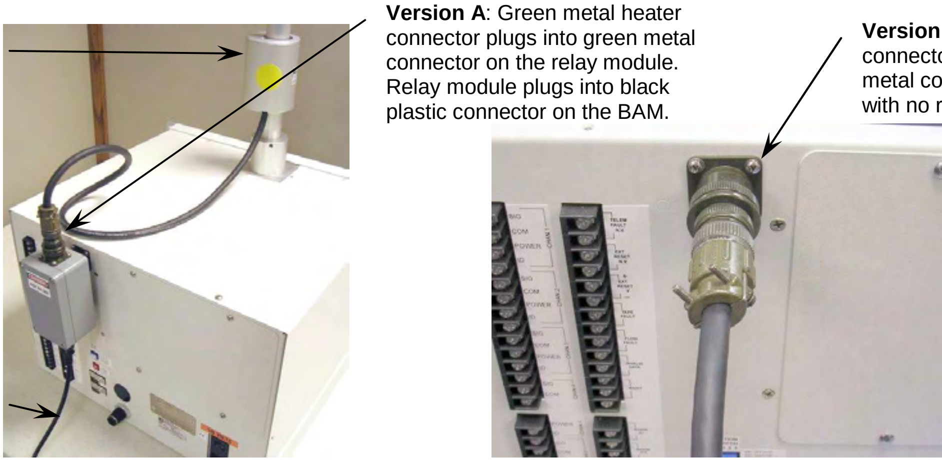
   Most units built between 2008 and 2012 were supplied with an external gray relay module which plugs into a mating **black plastic connector on the back of the BAM-1020**. The Smart Heater connector plugs into the green connector on the top of this relay module, as shown in the left photo below. These 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.



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 typically 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.

BX-596 AT/BP Sensor	
Wire Color	**Terminal Name**
Yellow	Channel 6 SIG
Black/Shield	Channel 6 COM
Red	Channel 6 POWER
Green	Channel 6 ID
White	Channel **7** SIG

BX-592 AT Sensor	
Wire Color	**Terminal Name**
Yellow or White	Channel 6 SIG
Black/Shield	Channel 6 COM
Red	Channel 6 POWER
Green	Channel 6 ID

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

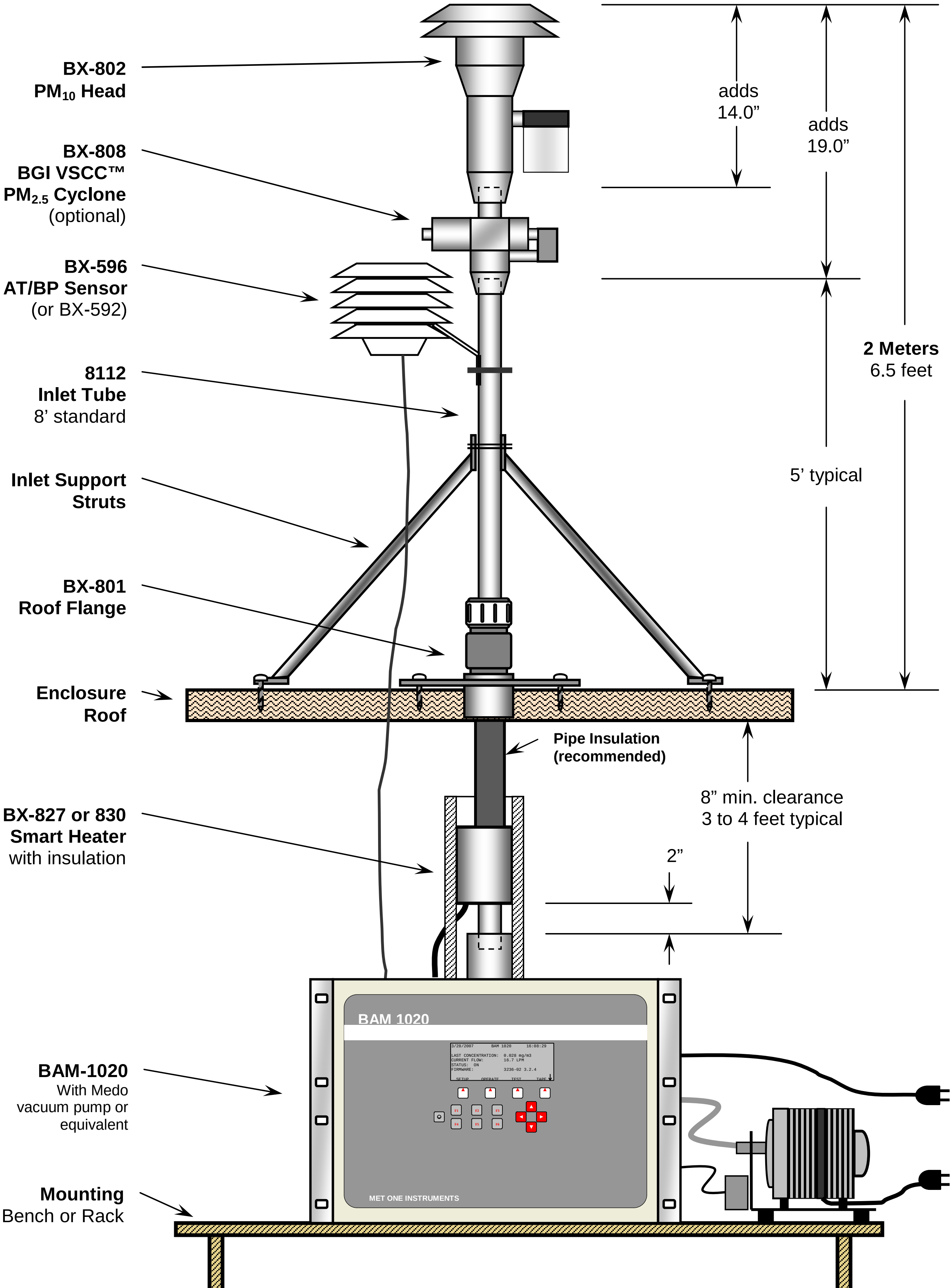
BAM. The cable has no polarity, so either the red or black wire can go to either terminal. Connect the other end of the cable to the two terminals on the pump.

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.

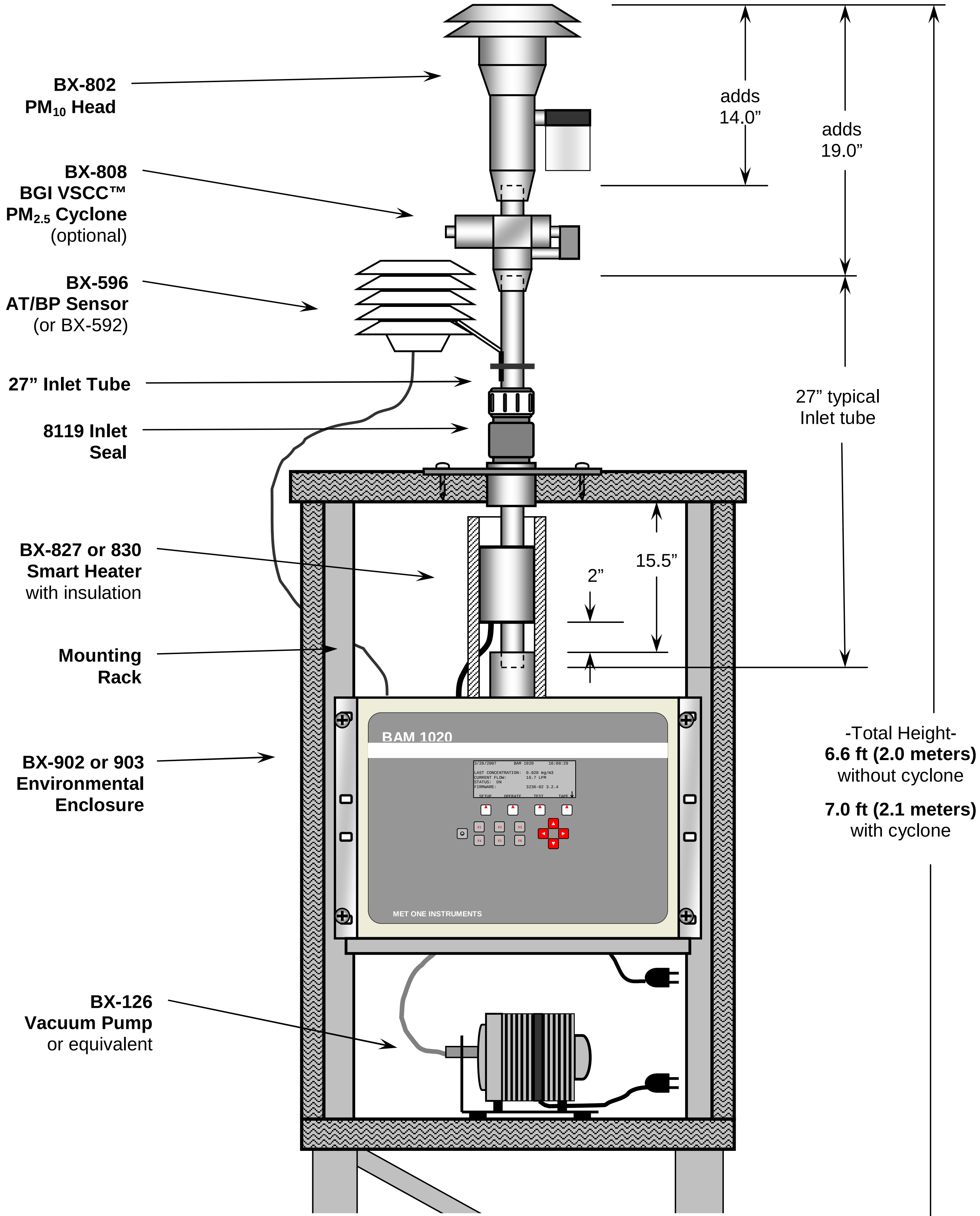
12. **Optional External Data Logger Connections:** The BAM-1020 has an analog output which may be recorded by a separate data logger if required. Connect the terminals on the back of the BAM marked "VOLT OUT +, -" to the data logger with 2-conductor shielded cable (not supplied). Polarity must be observed. 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.

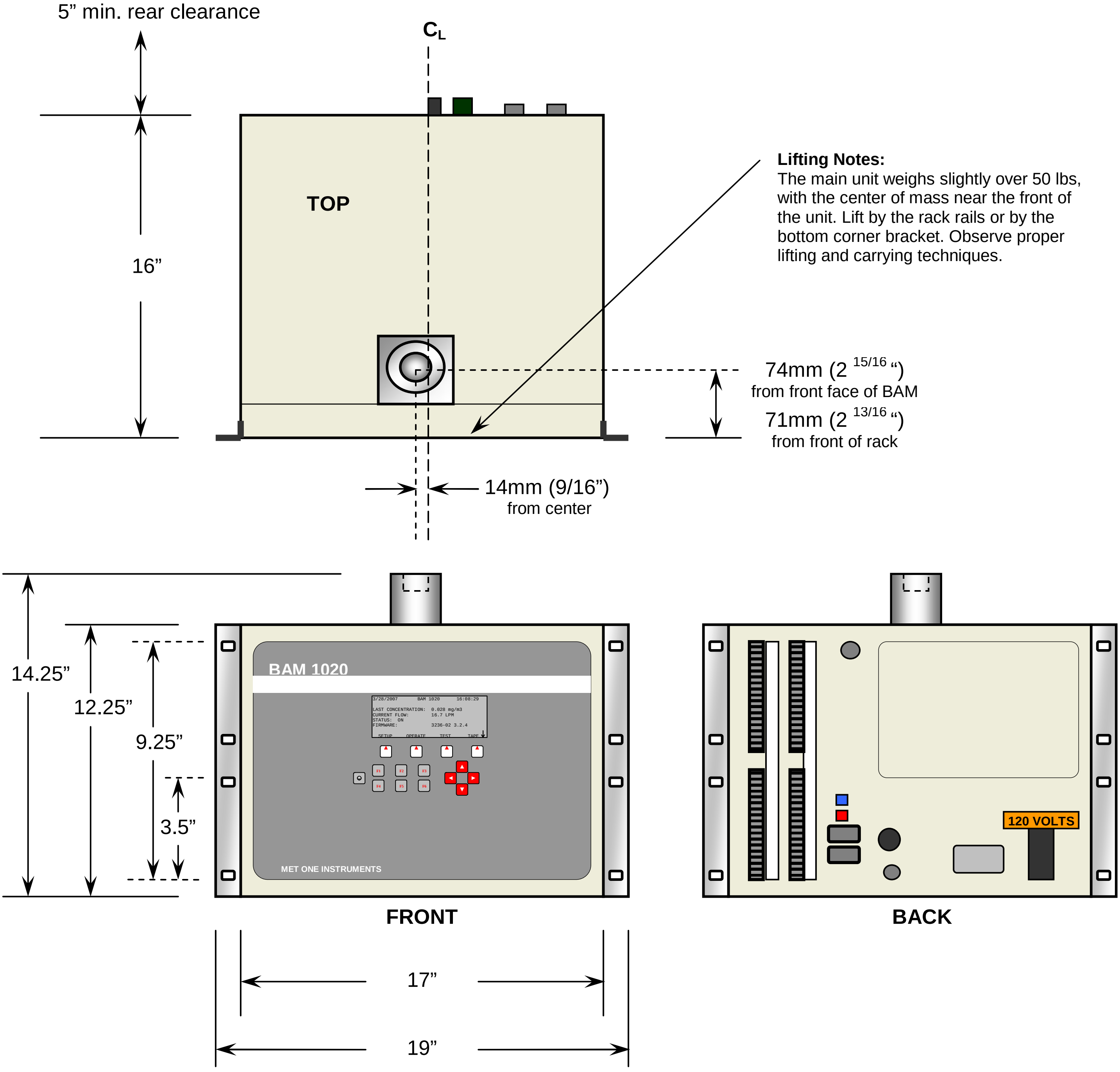
    The BAM-1020 has a variety of other telemetry I/O relays, error relays, and serial data connections located on the back of the unit as shown below. These items are described in Section 8 and Section 9 of this manual.



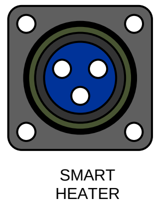
Typical BAM-1020 Installation in a walk-in shelter



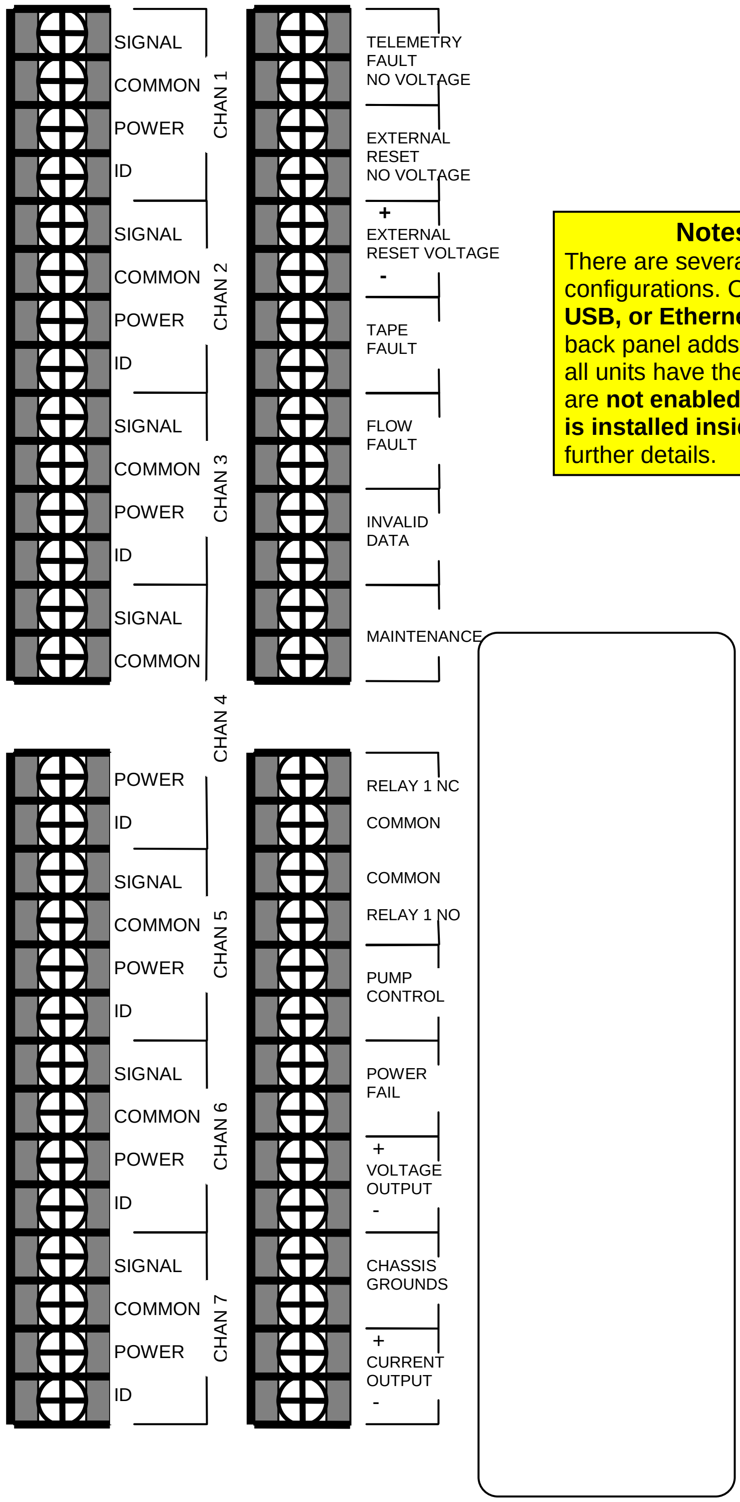
Typical BAM-1020 Installation in a BX-902 mini enclosure

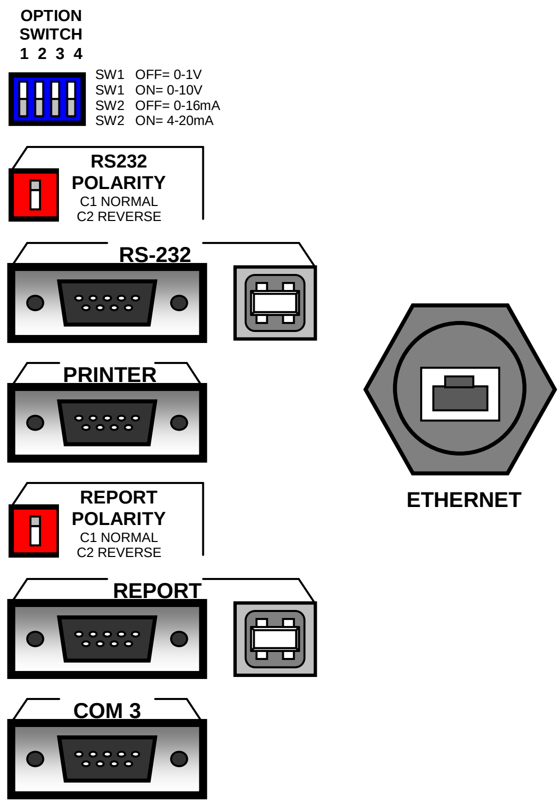


BAM-1020 mounting dimensions



Notes About Expanded Digital Ports:
There are several generations of the BAM-1020 digital port configurations. Older units do not have the **REPORT, COM 3, USB, or Ethernet** ports. The optional BX-965 *Report Processor* back panel adds and enabled these data ports. Starting in 2012, all units have these physical back panel connections, but they are **not enabled unless the optional BX-965 daughter board is installed inside the BAM**. Contact technical service for further details.





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

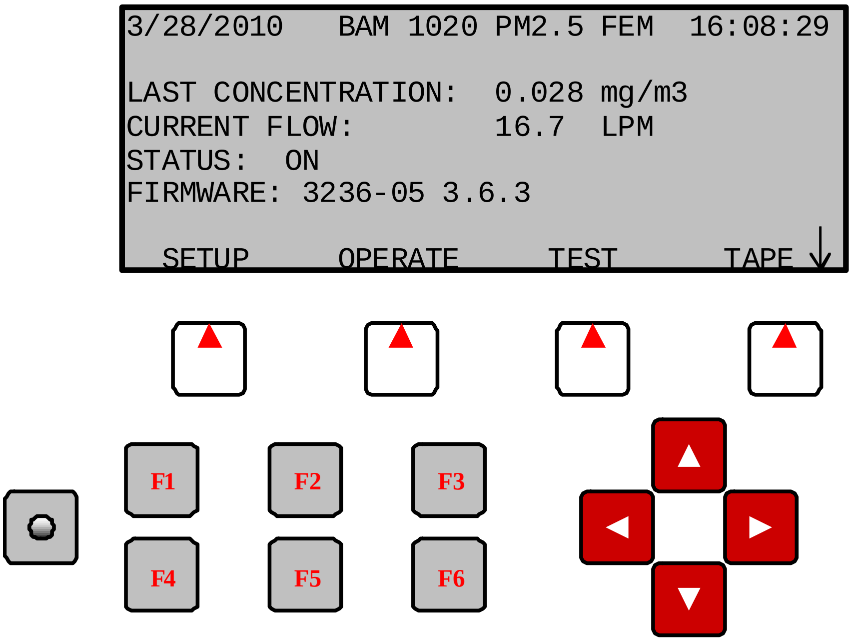
The BAM-1020 power switch is located on the back of the unit above the power cord. Verify that the unit is plugged in to the correct AC voltage, and that any electrical accessories are correctly wired before turn the unit on. (Section 2.6) When power is switched on, the main menu screen should appear after a few seconds as shown below. The unit will probably flash an error indicating that there is no filter tape installed. Note: Units running revision 3.1 or earlier firmware will display a slightly different main menu screen.

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 The Main Menu and Using the Keypad and Display

When the BAM-1020 is powered up it will display the main menu (top level menu) on the LCD display. This menu is the starting point for all functions of the BAM-1020 user interface. Note: The main menu will have a slightly different layout on BAM-1020 units configured in the dual-unit PM-coarse configuration.



The BAM-1020 Standard User Interface and Keypad

Soft Keys:
Directly beneath the display are four white buttons called "soft-keys" or "hot-keys". These are dynamic keys where the function changes in response to a menu option displayed directly above each key on the bottom row of the display. Whatever menu option is displayed above one of these keys is the function which that key will perform in that particular menu. These are used throughout the entire menu system for a variety of functions. For example, modifications made within a menu are usually not saved unless a SAVE soft-key is pressed. EXIT is also another common soft-key function.

Arrow (Cursor) Keys:
The four red arrow keys are used to scroll up, down, left, and right to navigate in the menu system, and to select items or change fields on the screen. The arrow keys are also often used to change parameters or increment/decrement values in the menu system.

Contrast Key:
The key with a circular symbol on it is for adjusting the light/dark contrast on the LCD display. Press and hold the key until the desired contrast is achieved. It is possible to over-adjust the contrast and make the entire display completely blank or completely dark, so be careful to set it to a visible level or it may appear that the unit is not operating.

Function Keys F1 to F6:
The function keys serve as shortcuts to commonly used menu screens. The **F** keys are only functional from the main menu screen, or for entering passwords. The factory default password is F1, F2, F3, F4.

> **F1 "Current":** This key is a shortcut to the OPERATE > INST screen, used to display instantaneous data values being measured by the BAM-1020. See section 3.12.
>
> **F2 "Average":** This key is a shortcut to the OPERATE > AVERAGE screen, used to display the latest average of the data recorded by the BAM-1020. See Section 3.13.

F3 “Error Recall”: This key allows the user to view the errors logged by the BAM-1020. The errors are sorted by date. The last 12 days which contain error records are available, and the last 100 errors can be viewed.

F4 “Data Recall": This key allows the user to view the data stored in the BAM-1020, including concentrations, flow, and all six external channels. The data is sorted by date, and the user can scroll through the data hour-by-hour using the soft-keys. Only the last 12 days which contain data records are available for viewing in this menu.

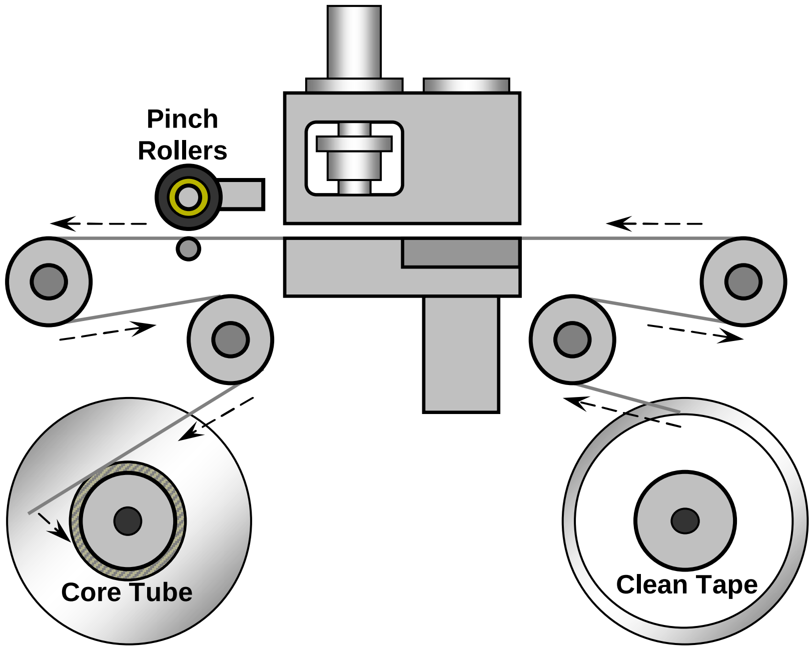
F5 “Transfer Module”: This key is used to copy the memory contents to an optional data transfer module. The transfer module option is obsolete and no longer used.

F6: This key is not assigned a data function.

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. The unit should automatically raise the sample nozzle.
2. Lift the rubber pinch roller assembly and latch it in the UP position.
3. Unscrew and remove the two clear plastic reel covers.
4. 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.
5. 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.
6. 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.
7. Align the filter tape so that it is centered on all of the rollers. Newer units have score marks on the rollers to aide in visually centering the tape.
8. **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!**
9. Press the TENSION soft-key in the TAPE menu. The BAM-1020 will set the tape to the correct tension and alert you if there was an error with the process. Exit the menu.



BAM-1020 Filter Tape Loading Diagram

3.5 Self-Test

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 right 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 TAPE menu. Press the SELF TEST soft-key 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 an **OK** or a **FAIL** tag. If all of the test items are OK, the status will show SELF TEST PASSED as shown in the drawing below. If any item fails, the status will show ERROR OCCURRED.

```
02/08/1999          15:29:30
LATCH: OFF          TAPE BREAK: OK
CAPSTAN: OK         TAPE TENSION: OK
NOZZLE DN: OK       SHUTTLE: OK
NOZZLE UP: OK       REF EXTEND: OK
FLOW: OK            REF WITHDRAW: OK
Status:   SELF TEST PASSED
TENSION   SELF TEST              EXIT
```

Self-Test Status Screen

LATCH: This will show OFF if the photo interrupter senses that the pinch rollers are unlatched (down) as in normal operation. It will show ON if the roller assembly is latched in the up position. The tape cannot advance if the rollers are up!

CAPSTAN: The unit will rotate the capstan shaft forward and backwards and will check if the photo interrupter sees the shaft rotating. The Capstan shaft is what moves the filter tape back and forth.

NOZZLE DN: 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.

NOZZLE UP: 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.

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

TAPE BREAK: 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: The unit will tension the filter tape, and then check the condition of the tensioner photo interrupters.

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

REF EXTEND: The unit will attempt to extend the reference membrane, and will check the motion with a photo interrupter.

REF WITHDRAW: The unit will attempt to withdraw the reference membrane, and will check the motion with a photo interrupter.

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. Most of these setup values will not be changed, since the default values are correct for most applications. 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 SETUP > 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 BAM SAMPLE, COUNT TIME, MET SAMPLE, RANGE, and OFFSET values in the SETUP > SAMPLE menu.
3. Review the FLOW RATE, FLOW TYPE, CONC TYPE, and HEATER CONTROL settings in the SETUP > CALIBRATE menu.
4. Review the scaling of any external sensors in the SETUP > SENSORS menu.
5. Review the Smart Heater control settings in the SETUP > HEATER menu.

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 "Status" line should display "ON" (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 SETUP or TEST menus. The BAM-1020 will also stop itself if a non-correctable error is encountered, such as broken filter tape or failed air flow.

3.9 Accessing the Flow Statistics Screen

While the BAM-1020 is displaying the main menu screen, the ▼ button can be pressed and the BAM will display a FLOW STATISTICS screen as shown below. This screen displays the flow, temperature and pressure statistics for the current measurement cycle. Pressing the ▼ key again will further scroll down to the remaining parameters below the viewable area of the display. This screen will not interrupt the sample cycle. This function is only available with revision 3.2 firmware or later.

```
03/28/2007   FLOW STATISTICS    16:26:30
 SAMPLE START: 2007/03/28 16:08:30
      ELAPSED: 00:18:00
    FLOW RATE: 16.7 LPM
 AVERAGE FLOW: 16.7 LPM
      FLOW CV: 0.2%
       VOLUME: 0.834m3
                                  EXIT
    FLOW FLAG: OFF
           AT: 23.0
       MAX AT: 23.5
   AVERAGE AT: 23.0
       MIN AT: 22.5
           BP: 760
       MAX BP: 765
   AVERAGE BP: 760
       MIN BP: 755
```

The FLOW STATISTICS Screen

3.10 The OPERATE Menus

Press OPERATE soft-key at the main menu to enter operate menu as shown below. This will not interrupt the sample if already running.

```
11/15/2006   OPERATE MODE       14:13:07

       ↑ = ON
       ↓ = OFF
Operation Mode: ON
        Status: ON

  NORMAL     INST    AVERAGE     EXIT
```

The OPERATE Menu

The DOWN arrow can be used to set the Operation Mode from ON to OFF. This will simply stop the measurement cycle, but will not power-down the BAM-1020. **NOTE: Even if the operator sets the Operation Mode to OFF, or the unit stops itself due to an error, it will still automatically set the mode back to ON at the top of the hour, and try to run a new cycle!** The only ways to prevent the unit from automatically starting an hourly cycle are to power off the unit, leave the unit in a TEST or SETUP menu, or leave the pinch rollers latched in the UP position.

The OPERATE menu has three soft-key options for viewing the operating status and sensor measurements while the unit is operating: NORMAL, INST, and AVERAGE.

3.11 The NORMAL Operation Screen

Normal Mode is the primary operation screen which displays most of the important parameters of the sample progress in one place, as shown below. Many operators leave their BAM-1020 in the NORMAL screen whenever the unit is operating, instead of the Main menu.

```
11/15/2009         Normal Mode       11:27:54
                                Flow: 16.7 LPM
                               AMB P: 764 mmHg
LAST C: 0.061 mg/m3           TAPE P: 584 mmHg
LAST m: 0.806 mg/cm2              RH: 27 %
                              Heater: OFF
                             Delta-T: 4.2 C
STATUS: SAMPLING                        EXIT
```

The NORMAL Operation Menu

The **LAST C** value indicates the last concentration record, updated at the end of the cycle. The **LAST m** value indicates the last measured value of the reference span membrane. The value should be very close or equal to the expected span value (**ABS**). The other values are instantaneous measurements.

3.12 The INSTANTANEOUS and AVERAGE Operation Screens

The INST (Instantaneous) screen displays the instantaneous data values that are being measured by the BAM-1020. This screen is useful for monitoring the current reading of any optional sensors that may be connected to the BAM-1020. All values except **Conc** (concentration) and **Qtot** (total flow volume) are current. The Conc represents the concentration of the last period. Qtot represents total flow volume during the last period.

```
11/15/2009                              11:27:54
          Eng Units                 Eng Units
1 Conc    0.010 mg  2 Qtot    .834 m3
3 WS      0.000     4 WD      0.000
5 BP      0.000     6 RH      0.000
7 SR      0.000     8 AT      0.000

                     VOLT/ENG    EXIT
```

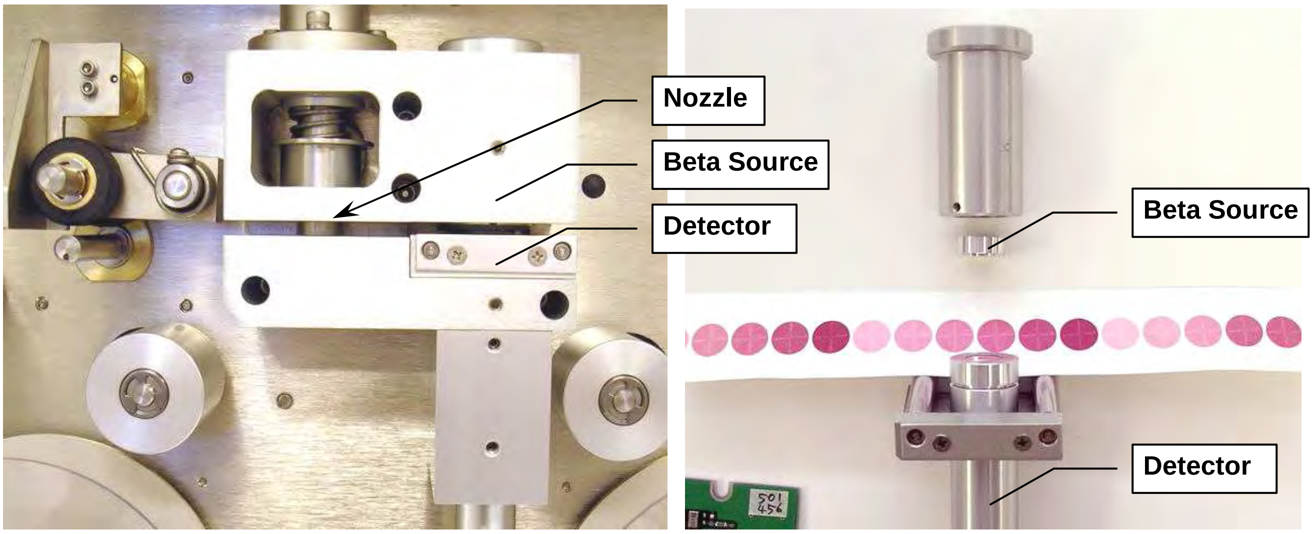
The Instantaneous Menu

The VOLT / ENG soft-key toggles the displayed values between units and voltages, useful for diagnostic checks on external sensors.

The AVERAGE screen is the same as the INST screen shown above, except that the concentration and flow are presented as the previous hour's average values, and the six external datalogger channels are average values over the average period of the data logger (set by the MET SAMPLE value in the SETUP > SAMPLE menu - usually also 60 minutes).

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.

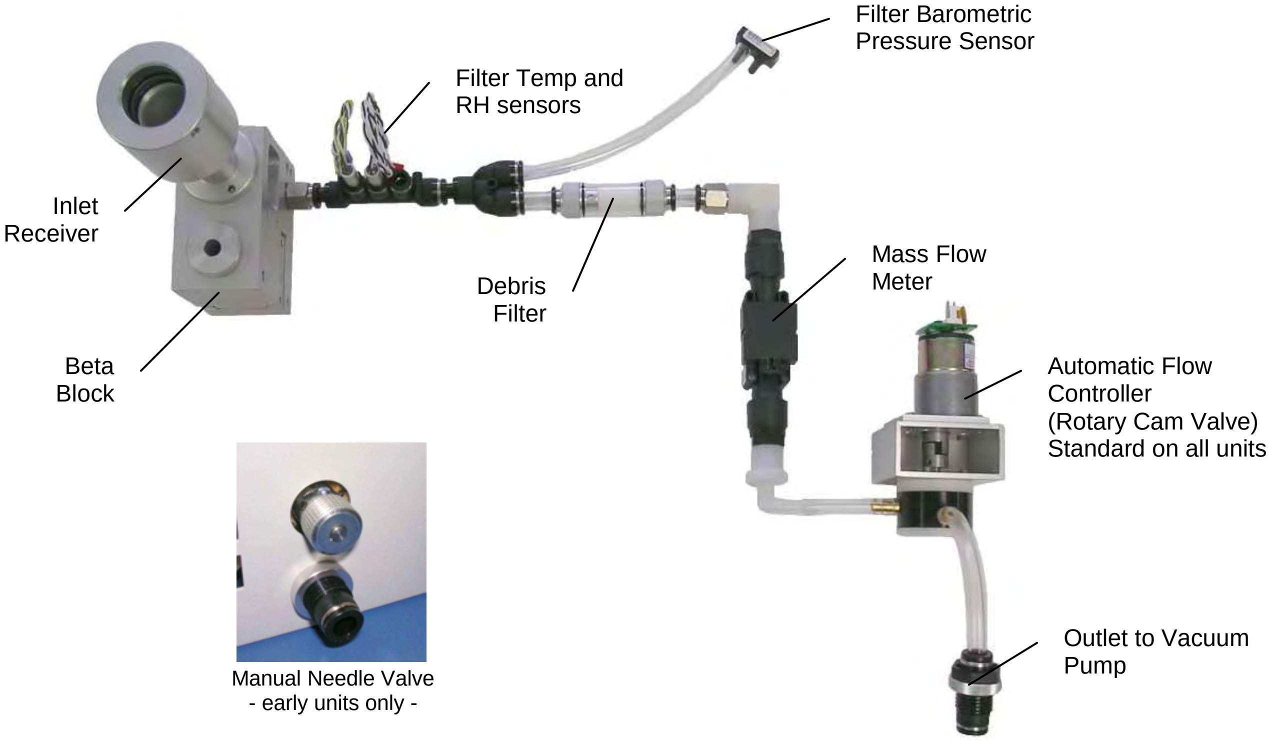
The air then goes down the inlet and through the filter tape, where the remaining particles are deposited. After the sample period is completed and the particulate spot is measured, there is almost always a clearly visible spot of dirt on the filter tape where the particulate was deposited. The BAM-1020 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. Some early units had a manual needle valve located on the back instead.

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 CONC TYPE setting. Both can be set to either STD or ACTUAL (see Section 6.3). 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. BAM-1020 units with firmware revision 2.58 and earlier (pre 2007) had a single FLOW TYPE setting which set both the flow control and the concentration reporting conditions.

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 CONC TYPE is set to ACTUAL so that the BAM will report the concentration based on the actual sample volume. On BAM-1020 units with firmware revision 2.58 and earlier, the FLOW TYPE is set to ACTUAL. The unit will control and report actual values if a temperature sensor is connected.

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 standard conditions. However, the cut-point of PM_{10} inlets are rated at an actual 16.7 L/min flow rate. For this reason, PM_{10} BAMs should be set with a FLOW TYPE of ACTUAL and a CONC TYPE of STD. 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.

On units with firmware revision 2.58 and earlier, the FLOW TYPE is set to STD for PM_{10}. However, if the BAM is equipped with a temperature sensor, it will automatically identify the sensor and perform actual flow control anyway.

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 > TAPE menu on the BAM. This will stop the operation cycle of the unit. Press the FWD soft key to advance the tape 1 “window” to a clean, unused spot.
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 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. Enter the TEST > PUMP menu and turn the pump on. The standard flow rate shown on the BAM display should stabilize at less than **1.0 L/min** in about 20 seconds.

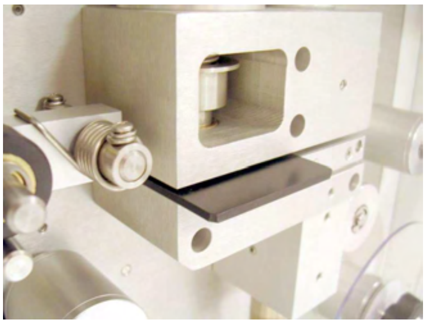
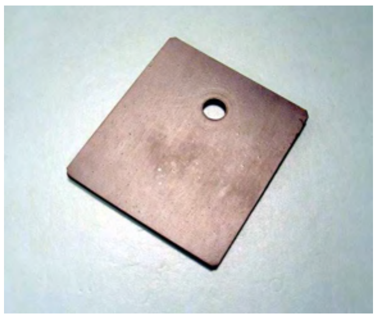
Record the as-found results. If the leak flow value is greater than 1.0 L/min, then there may be a vary small amount of leakage in the system. If the leak value is greater than 1.5 L/min, then there may be a more significant leak.

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.

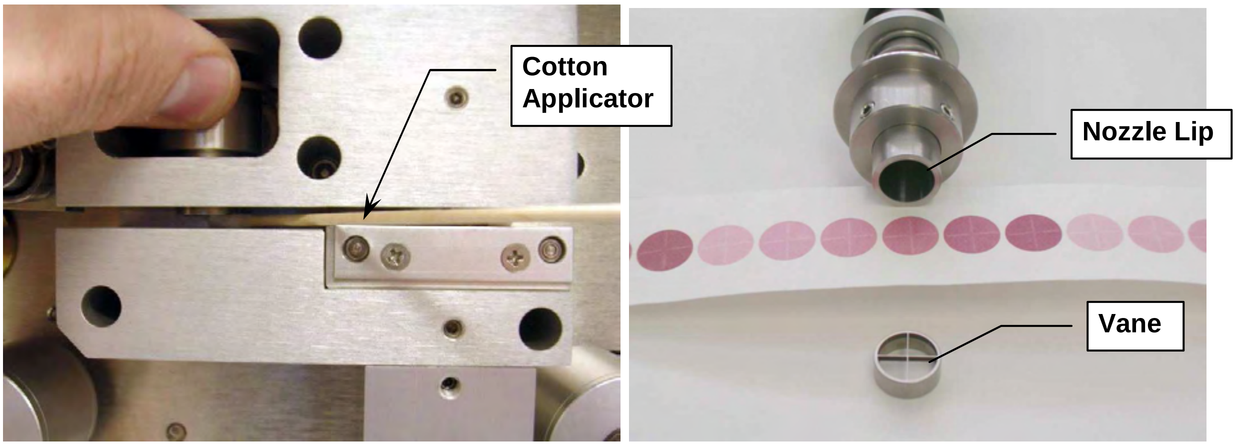



7440 Leak Isolation Shim

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:

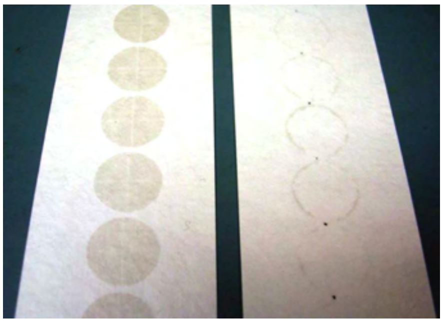
1. Latch up the tape pinch rollers, and raise the nozzle in the TEST > PUMP menu. Slide the filter tape out of the slot in the beta block nozzle area. It is not necessary to completely remove the filter tape from the unit.
2. With the nozzle up, use a small flashlight to inspect the vane. Any debris 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 > PUMP 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. The FLOW TYPE setting must be set to ACTUAL in the SETUP > CALIBRATE menu, or the flow calibration screen will not even appear as an option in the TEST menu. Perform a leak check and nozzle cleaning before doing any flow calibrations.

The TEST > FLOW calibration screen is shown below. The “BAM” column displays what the BAM-1020 measures for each parameter. The “STD” column is where you can enter the correct values from your traceable reference standard device. The <CAL> symbol appears to the left of row of the active selected parameter. The selected parameter can be changed by pressing the NEXT key. No calibration changes are made to the selected parameter unless the CAL 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.

```
MULTIPOINT FLOW CALIBRATION
            TARGET    BAM      STD
          AT:         23.8    23.8 C
          BP:          760     760 mmHg
<CAL> FLOW 1: 15.0    15.0    15.0 LPM
      FLOW 2: 18.4    18.4    18.4 LPM
      FLOW 3: 16.7    16.7    16.7 LPM
  CAL      NEXT      DEFAULT    EXIT
```

Actual Flow Calibration Screen

1. Enter the TEST > FLOW 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 use the NEXT soft key to select the AT (temperature), BP (pressure), and FLOW 3 (16.7) parameters one at a time. Compare the BAM column reading to your standard device for each parameter, and record the results. No calibrations are altered if the CAL or DEFAULT keys are not pressed. If calibration is required, go on to step 3.
3. Select the AT parameter if not already selected. Measure the ambient temperature with your reference standard device positioned near the BAM-1020 ambient temperature probe. Enter the value from your reference standard into the STD field using the arrow keys. Press the CAL soft key to calibrate the BAM reading. The BAM and STD temperature values should now be the same.
4. Press the NEXT key to select the BP field. Enter the barometric pressure value from your reference standard into the STD field, and press the CAL soft key to calibrate the BAM reading. The BAM and STD pressure values should now be the same.
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. Press the NEXT key to select the first flow point of 15.0 L/min. The pump will turn on automatically. *Allow the unit to regulate the flow until the BAM reading stabilizes at the target flow rate*. Enter the flow value from your standard device into the STD field

using the arrow keys, then press the CAL soft key. Note: *The BAM flow reading will not change to match the STD until after you have entered all three flow calibration points, since it is done on a slope.*

6. Press the NEXT key to select the second flow point of 18.4 L/min. Allow the flow to stabilize again, then enter the value from your standard device and press the CAL key. 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 vacuum pump needs to be serviced.
7. Press the NEXT key to select the third flow point of 16.7 L/min. Allow the flow to stabilize again, then enter the value from your standard device and press the CAL key.
8. After this third flow point is calibrated, the BAM flow reading 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 soft key 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.

Actual flow calibrations in units with older firmware:
BAM-1020 units with firmware revisions 2.58 and earlier had a different TEST > FLOW screen, as shown below. These units are calibrated as described above, except that the flow calibration is performed at only a single point of 16.7 L/min. The NEXT key selects the AT or BP parameter to be calibrated, and the PUMP ON key selects the flow point for calibration. The ADJUST/SAVE key calibrates the selected parameter to the reference value.

```
      ACTUAL FLOW CALIBRATION MODE
F1= RESTORE DEFAULT
                      BAM      REFERENCE
AMBIENT TEMPERATURE:  23.8 C   23.4 C
BAROMETRIC PRESSURE:  741 mmHg 742 mmHg
VOLUMETRIC FLOWRATE:  16.7 lpm 16.9 lpm

ADJUST/SAVE   NEXT     PUMP ON    EXIT
```

Old Format of the Actual Flow Calibration Screen

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 be calibrated as described above in Section 5.6. If the unit must be operated in standard flow mode, see below.

STANDARD Flow BAMs with a Temperature Sensor:
If the BAM-1020 is an older PM_{10} unit without a separate CONC TYPE setting, or 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 STD to ACTUAL in the SETUP > CALIBRATE 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 STD flow type when finished. This works as long as the BAM is equipped with an ambient temperature sensor on input channel six.

STANDARD Flow BAMs without a Temperature Sensor:
If the BAM-1020 is an old type and does not even have a temperature sensor, then you will not have any access to actual flow mode or the TEST > FLOW calibration screen. In this rare case, you will only be able to audit the BAM standard flow rate from the TEST > PUMP screen, and compare it to the standard flow reading from your audit device. If the BAM flow is found to be out of the ±4% spec, then it can only be adjusted by altering the factory-set $\mathbf{C_v}$ and $\mathbf{Q_0}$ flow constant values in the SETUP > CALIBRATE menu. Contact technical service for instructions. BAM-1020 units have not been supplied in this configuration without a temperature sensor for some years.

5.8 Field Calibration of the Flow System – Manual Flow Valve

Metered flow type is only used on some early PM_{10} BAM-1020s have a hand-operated manual flow valve on the back. Because these units do not have an automatic flow controller or a temperature sensor, the flow system has limited accuracy, and the calibration procedure is complicated and time-consuming. For this reason, manual flow configurations have not been supplied by Met One for some years. Current production units all have a flow controller and temperature sensor.

The audit process for these old units involved comparing the standard BAM flow reading from the TEST > PUMP screen to the standard flow reading from your audit device. The calibration procedure involves altering the factory-set $\mathbf{C_v}$ and $\mathbf{Q_0}$ flow constant values in the SETUP > CALIBRATE menu so that the BAM matched your standard, then calculating and adjusting the manual valve to an inconsistent higher flow point to account for filter loading and the volumetric cut-point of the inlet head. Met One has a separate, detailed technical bulletin which describes the flow calibration of these old units without an automatic flow controller.

6 SETUP 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 SETUP 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 SETUP 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 SETUP menus are unit-specific calibration constants which must not be changed, or the accuracy and proper operation of the unit may be affected.

WARNING: Entering the SETUP menu system requires stopping the sample cycle. Older versions of firmware will not warn you before stopping the sample!

Press the SETUP soft-key to enter the menu as shown below. The Setup Menu provides a choice of operations. Use the arrow keys to navigate to the desired field, then press the SELECT soft-key to enter.

```
                    SETUP MODE SELECT
CLOCK     SAMPLE    CALIBRATE EXTRA1
ERRORS    PASSWORD  INTERFACE SENSOR
HEATER    QUERY     REPORTS

SELECT                          EXIT
```

The SETUP Menu

A brief description of each sub-menu in shown in the table below. Detailed information is provided in the following sub-sections.

Menu	Settings
CLOCK	BAM-1020 real-time clock date and time settings.
SAMPLE	Range, Offset, Sample Time, Count Time, Conc Units, Avg Period, Unit ID, and RS-232 settings.
CALIBRATE	Factory Calibration Values, (C_v, Q_0, ABS, µsw, K, BKGD) Flow rate, Flow type, Conc Type.
EXTRA1	Low concentration clamp, e1 – e4, Rarely used.
ERRORS	Analog error selections, Flow limits, Pressure drop limit.
PASSWORD	Password change screen.
INTERFACE	Cycle Mode early/standard, alarm relay polarity.
SENSOR	Meteorological sensor scaling and configuration screens, Channels 1 – 6.
HEATER	RH and Delta-T set-points for Smart Heater. Only visible if Heater Control is set to AUTO.
QUERY	Configuration for the custom Query data output file, and the European Bayern-Hessen protocol.
REPORTS	Daily data report hours.

6.1 CLOCK Setup Screen

The SETUP > CLOCK screen allows for the setting of the time and date. Time is a 24-hour clock only. Use the arrow keys to select and increment/decrement the desired field, then press the SAVE soft-key. 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.

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

The SETUP > SAMPLE screen is used to set the BAM-1020 sampling and averaging periods, and some other important settings. Review each of these settings carefully. The SAMPLE screen is shown below. The fields can be edited with the arrow keys, then saved with the SAVE soft-key.

```
                           SETUP SAMPLE
RS232 9600 8N1     BAM SAMPLE 042 MIN

STATION # 001      MET SAMPLE  60 MIN
RANGE   1.000 mg   OFFSET  -0.015 mg
CONC UNITS mg/m3   COUNT TIME   8 MIN
  SAVE                        EXIT
```

The SETUP > SAMPLE Screen

RS-232: 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 handshaking settings "8N1" means 8 data bits, no parity, 1 stop bit. These cannot be edited.

BAM SAMPLE: 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.

Count Time	BAM Sample	Used for
4 min	**50 min**	PM_{10} monitoring, units without a count time setting
6 min	46 min	not used
8 min	**42 min**	All $PM_{2.5}$ FEM, PM-coarse, EU $PM_{2.5}$ monitoring

The BAM SAMPLE 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.

STATION #: 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. Previous firmware revisions allowed a max value of 99.

MET SAMPLE: 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

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 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 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.

OFFSET: The OFFSET value is used to set the lower end of the BAM-1020 measurement range, and could more accurately be called a "range offset". The factory default value for 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 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 OFFSET value to 0.000 to avoid confusion, but this is never 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. Do not set the OFFSET to any value other than -0.015, or -0.005 mg.

Note: The OFFSET value is often misunderstood, and should not be confused with the BKGD (zero correction factor) or the "e1" (lower concentration limit clamp) values. 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.

CONC 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.

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.

6.3 CALIBRATE Setup Screen – Critical Flow and Calibration Settings

The SETUP > CALIBRATE screen is where most of 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. The CALIBRATE screen is shown below.

```
CALIBRATE SETUP
SPAN CHECK: 24HR     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
```

The SETUP > CALIBRATE Screen

SPAN CHECK: 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 V3.7.0, where the setting is invisible and fixed at hourly.

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.

CONC TYPE: This sets the way that the concentration values are reported. *The CONC TYPE must be set to ACTUAL for all $PM_{2.5}$ monitoring, and is almost always set to STD 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 STD, 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. Note: units with firmware prior to rev 3.0 do not have this setting available, and the concentration reporting is determined by the FLOW TYPE setting.

FLOW TYPE: This setting selects the flow control scheme used by the BAM-1020. The options are ACTUAL or STD. 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 CONC TYPE setting can be set to STD 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 STD 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 CONC TYPE setting) had the FLOW TYPE set to STD, which controlled both flow type and concentration reporting. However, if a temperature sensor was available, these older units automatically performed actual flow control.

Note: METERED flow type is obsolete, and was used for old BAM units with a manual flow valve. The flow was reported in EPA standard conditions only.

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 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. Older units built before 2007 had a µsw value near 0.285. **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 OFFSET (range offset) value in the SETUP > SAMPLE menu. See section 6.2.

STD TEMP: 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. This setting is not available on units using firmware revision 2.58 and earlier, where the standard temperature was always fixed at 25C.

HEATER: This setting selects which operation mode the Smart Inlet Heater is used in. 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 setup parameters for the Smart Heater logic are located in the separate SETUP > HEATER menu, which will not appear as an option in the SETUP menu unless this HEATER mode is set to AUTO.

If set to MANUAL, the unit will simply turn the heater on to full power regardless of filter conditions. This mode is not used.

6.4 EXTRA1 Setup Screen

The settings in the EXTRA1 screen are special settings that have been installed for special applications and generally will never be changed.

e1 Low Concentration Limit. This is the lowest concentration value the BAM-1020 is allowed to store or display, despite what is measured. Any measurements below this value are clamped. **This value must always be set to match the OFFSET value in the SETUP > SAMPLE menu.** The default value is -0.015 mg.

e2 Not Used. Always set to 0.500.

e3 Membrane OFF Delay. Not used. Always set to 0.000.

e4 Membrane Time Out. The time the unit allows for the membrane assembly to move before generating an error. Always set to 15.00 seconds.

6.5 ERRORS Setup Screen for the Analog Output

The SETUP > ERRORS screen allows the option of encoding BAM-1020 errors onto the analog output signal when used with an external analog data logger. Using this method, the BAM sets the analog output voltage to full scale (1.000 volts) whenever any of the enabled error types occur, otherwise the voltage represents the last valid concentration level. See Section 8 for external data logger setup information.

The operator can select which errors will cause this full-scale response by enabling (1) or disabling (0) each of the 12 error types as shown in the screen below. Most users simply enable all 12 error types if the BAM-1020 analog output is used.

```
                        SETUP MODE ERROR
EUMILRNFPDCT AP  FRI FRh
111111111111 150 10  20
1=ON,  0=OFF
 SAVE                              EXIT
```

The ERRORS Screen

Note: Some minor alarms such as E, U, R, P, or D can occur when there may be nothing wrong with the hourly concentration value, yet these alarms are still typically enabled to set the analog output to full-scale in order to alert the data system of their presence. In this case, the concentration value can still be downloaded from the BAM digitally. Regardless which error types are enabled for the analog output, *all alarms and errors are always stored in the BAM-1020 digital alarm log and data log*, and may be viewed by downloading the data.

The following table briefly describes which type of alarm each letter represents. Complete error and alarm descriptions are found in Section 7.2.

Code	Error/Alarm Type	Basic Description
E	**External Reset**	Failed BAM clock reset.
U	**Telemetry Fault**	External datalogger fault.
M	**Maintenance Alarm**	Sample cycle stopped due to SETUP or TEST menu use.
I	**Internal CPU Error**	Internal processor error, or failed data link between coarse units.
L	**Power Failure**	Power failure prevented sample completion.
R	**Reference Membrane**	Reference span membrane not extending or retracting properly.
N	**Nozzle Error**	Nozzle motor malfunction.
F	**Flow Error**	Flow system failure, or temperature/pressure sensor failure.
P	**Pressure Drop Alarm**	Tape blocked by excessive dust loading.

D	**Deviant Span Density**	Span check did not match the expected ABS value.
C	**Count Error**	Beta particle detector error.
T	**Tape System Error**	Broken filter tape, or an error in the tape control system.

The following settings related to the alarms are located in the SETUP > ERRORS screen:

AP 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.

FRl Flow Rate Lower Limit. The default setting is 10 L/min. Do not change the setting, since this parameter is superseded by the current flow alarm criteria. See the flow alarm description in Section 7.2.

FRh Flow Rate Higher Limit. The default setting is 20 L/min. Do not change the setting, since this parameter is superseded by the current flow alarm criteria. See the flow alarm description in Section 7.2.

6.6 PASSWORD Setup Screen

The SETUP > PASSWORD screen allows the program administrator to change the password required to enter many of the TEST or SETUP menus. The password prevents untrained users from accidentally changing critical settings or calibrations on the unit. The password can be any 4-key combination of the six function keys, F1 to F6. The default password is **F1, F2, F3, F4**. 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.

6.7 INTERFACE Setup Screen

The SETUP > INTERFACE screen is shown below. These settings are used to configure the BAM-1020 for operation with an external data logger recording the analog output. Most of these settings are rarely used.

```
                           Interface Setup

Cycle Mode: STANDARD Force Maint: OFF
Fault Polarity: NORM Split DELTAP: 00300
Reset Polarity: NORM


   SAVE                            EXIT
```

The INTERFACE screen

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.

Force Maint: This can be used to manually toggle the “M” digital maintenance flag and the maintenance relay on the back of the unit ON or OFF. Almost never used.

Fault Polarity: This sets the polarity of the Telemetry Fault Relay input. NORM is normally open, INV is normally closed. Almost never used.

Split DELTAP: Not used.

Reset 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. NORM is normally open, INV is normally closed. Almost all data loggers use normal open polarity for the signal.

6.8 SENSOR Setup Screen for External Met Sensors

The SETUP > SENSOR 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 SETUP > SENSOR 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.

```
                     SETUP CHAN PARAMS

CH    TYPE  UNITS  PREC  MULT   OFFSET
06    AT    C         1  0100.0  -050.0
       SENSOR FS VOLT:  1.000
INV SLOPE:N VECT/SCALAR:S MODE:AUTO ID

  SAVE             ID MODE      EXIT
```

The SENSOR Menu

CH: Selects the channel to be viewed. The up/down arrow keys select the channel.

TYPE: This is the parameter name. You can enter a name here by using the arrow keys to scroll through the alphabet and other ASCII characters.

UNITS: This is the measurement units label for the channel. You can enter a value here by using the arrow keys to scroll through the alphabet and other characters.

PREC: This is the precision field, which sets the number of available decimal places for the Multiplier and Offset parameters.

MULT: 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 (%).

OFFSET: This is the range offset value, or the measurement value that the sensor represents at 0.000V output. In the screen shown above, the 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.

FS VOLT: 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.

INV SLOPE: This setting allows the channel to recognize a sensor with an inverse slope. This is always set to **N** (no) except for use with thermistor temperature sensors with resistance-only outputs.

VECT/SCALAR: This value sets the averaging method. **S** (scalar) is used for all measurements except wind direction, which uses **V** (vector).

MODE: This field is toggled by pressing the ID MODE soft-key. The value can be set to either MANUAL or AUTO ID. In MANUAL mode, the user can enter their own setup parameters for the channel. AUTO ID mode is used with 500 series sensors, and must be selected in order for the unit to recognize the sensor automatically. **NOTE:** Any manually set parameters for that channel will be lost when changing to AUTO ID mode. **Channel 6 must be set to AUTO ID for all units equipped with an ambient temperature sensor.**

6.9 HEATER Setup Screen – RH Control Settings

The SETUP > HEATER screen is only visible if the HEATER CONTROL mode in the SETUP > CALIBRATE menu is set to AUTO. This menu 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.

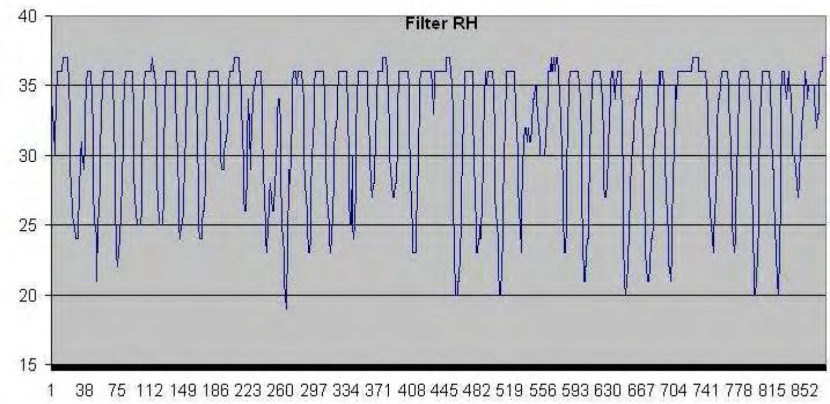
```
Heater Setup
          RH Control:  YES
         RH Setpoint:  35%
          Datalog RH:  YES (Chan 4)
     Delta-T Control:  NO
    Delta-T Setpoint:  99 C
     Datalog Delta-T:  NO (Chan 5)
  SAVE                          EXIT
```

The SETUP > HEATER Screen

RH Control: This must be set to YES for most applications. If YES is selected, 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 this is set to NO, The Smart Heater will stay in low power mode and no additional RH control will be performed.

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.

Datalog RH: If YES is selected, the filter RH values will be logged on channel 4 of the BAM-1020. Select YES if you do not have any external sensors attached to channel 4.



Properly Regulated Channel 4 Hourly Filter RH Graph

Delta-T Control: Delta-T Control is not used except in special study applications, and must be set to NO for all $PM_{2.5}$ FEM monitoring. The filter temperature on the BAM is always higher than ambient temperature due to the inlet heater. The BAM can calculate the Delta-T (temperature difference) if an ambient temperature sensor is connected. If Delta-T Control is set to YES, the Smart Heater will turn down to low power mode whenever the Delta-T Setpoint is exceeded, regardless of the filter RH.

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.

Delta-T Setpoint: Only used if Delta-T Control is enabled. This can be set from 1 to 99 degrees C. If the Delta-T exceeds this setpoint, the Smart Heater will turn down to low power mode, regardless of the RH level. An “N” alarm is logged any time this happens. Note: There is often a few degrees of Delta-T measured even if the heater is OFF, due to mild heating effect of the unit itself. Frequent errors will be logged if the setpoint is too low. Set this value to at least 8 or 10 degrees C if used. Set the value to 99 if Delta-T control is not used.

Datalog Delta-T: If YES is selected, the Delta-T values will be logged on met channel 5 of the BAM-1020, as long as no other external sensors are attached to channel 5. Note: *The measured Delta-T values may still be logged even if Delta-T control is set to NO*. Many BAM-1020 users log the Delta-T for informational purposes.

6.10 QUERY Setup Screen – Custom Data Array Setup

The SETUP > QUERY screen allows the user to configure a custom digital data array for the new 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. The query output is available in firmware revisions 3.6.3 and later and requires the Report Processor. The BH protocol is available in revision 5 series European firmware. 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.

```
N:08                       DATA QUERY FIELDS
 01 TIME       02 CONC       03 FLOW
 04 AT         05 BP         06 RH
 07 REF        08 ERRORS     09
 10            11            12
 13            14            15
 16            17
   SAVE                            EXIT
```

The SETUP > QUERY Screen

The **N:** field sets how many values to include in the array. Up to 17 parameters can be included. Increment the N value with the up/down arrow keys. For each increment of the N value, another position in the array will be activated, starting with position 01.

Each position in the array can be changed to any desired parameter using the left/right keys to select the position, and the up/down keys to scroll through the whole list of parameters. In the example above, eight parameters are included and the shown parameters were selected for each of the eight positions in the array. The available parameters are listed in the table below:

Parameter	Description
CONC	Concentration value for the last sample period.
Q_STD	Sample flow volume in cubic meters at standard conditions.
Q_ACT	Sample flow volume in cubic meters at actual AT/BP conditions.
STAB	Stability measurement. Diagnostics use only. EU firmware only.
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).
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. 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.
TIME	Date and Time stamp for the sample period. Ignored for BH protocol.
ERRORS	Decimal error codes of the 12 major error categories.

6.11 REPORTS Setup Screen – Daily Data Range

The SETUP > Reports screen is used to select which hours are included in the daily BAM-1020 data file 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 end 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 couple of agencies who have a data collection system built around the old setting.

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 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 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.

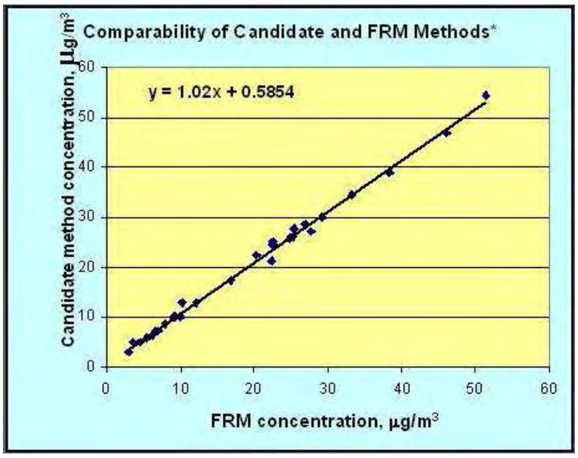
L	**Power Failure or Processor Reset**	This error occurs if AC input power is lost even momentarily, or if the power switch is turned off. Frequent “L” errors usually indicate poor quality AC power. If frequent power errors occur even when the unit is connected to a UPS backup system, contact Met One 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 > ALIGN 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. See Section 6.9. Download the error log file to tell if the alarm is from a nozzle failure or simply a Delta-T event.
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 "AP" 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 > ALIGN menu to manually operate the motors and photosensors. See Section 7.16. Tape errors can be caused by grit in the shuttle beam ball slide. Contact tech service if the left/right shuttle slide 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.



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

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 7.19) 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 6.2, 7.12, 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 > CALIBRATE 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.

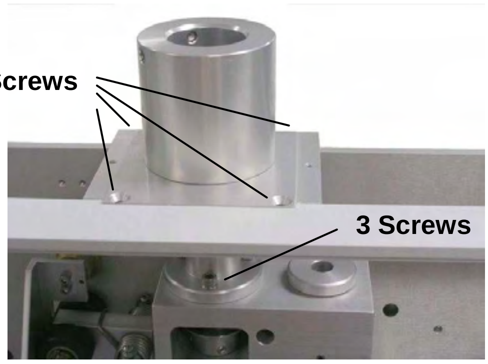
Problem:	The filter tape keeps breaking during normal operation.
Cause/Solution:	• The photo sensors which watch the tape transport motion may be out of alignment. Check the photo sensors as described by section 7.16. • This is sometimes caused by misalignment of the "SHUTTLE" photo sensor or the interrupter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

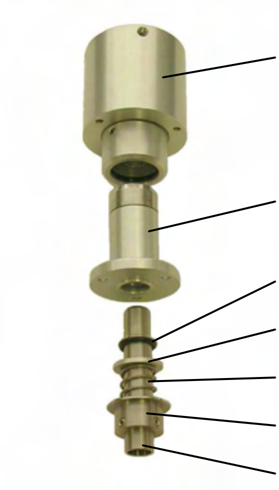
Problem:	The display shows "MISSING TEMP PROBE" message.
Cause/Solution:	• The unit requires a BX-596 or BX-592 ambient temperature sensor if either the CONC TYPE or FLOW TYPE are set to ACTUAL. If no sensor is attached to channel 6 of the BAM, this message will appear. • If the Auto ID line from the 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.

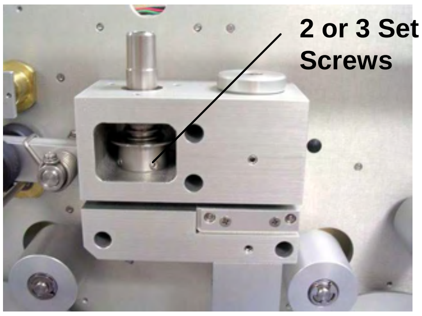
The sample nozzle may also be easily removed from the unit for further cleaning or rebuild. This requires a set of brass adjustment shims to set the spring tension during reassembly. The standard BX-308 BAM tool kit contains all of the required tools and instructions. The BX-310 kit includes the two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



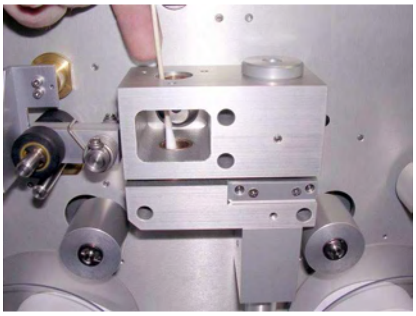


1. Remove the filter tape and the main BAM-1020 case cover. The sample nozzle must be in the down position. Lower it using the TEST > PUMP menu if needed. Lift the nozzle up and down against its spring with your thumb and note the action feel.
2. Remove the four screws (two flat head Philips, two 9/64” 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 $PM_{2.5}$ 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 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 6.3). 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.

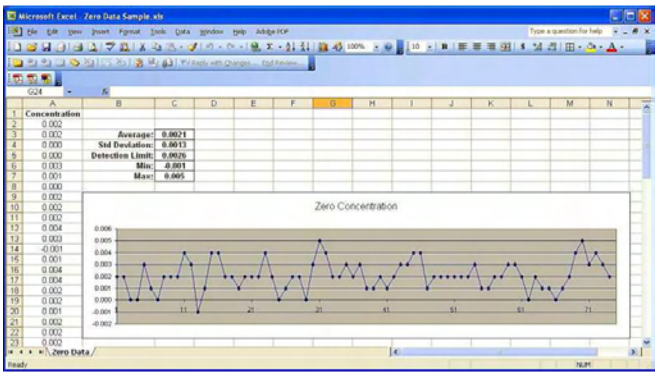
Note: For best results, the zero test should not be performed during a period of rapidly changing barometric pressure. The shelter room temperature must be within the specified range, and as stable as possible. See Section 2.2. This will prevent any rapid changes in air density between the beta source 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 SETUP > CALIBRATE 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 SETUP > CALIBRATE menu on the BAM. For example, the average of the data sample below is 0.0021 mg (2.1 µg), so the correct 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 soft-key from the main menu and is shown below. These screens are used to perform calibrations and audits of various sensors, as well as some advanced diagnostics to resolve failures and errors.

```
TEST MENU

COUNT      PUMP       TAPE      DAC
CALIBRATE  INTERFACE  FLOW      ALIGN
HEATER     FILTER-T   RH


 SELECT                          EXIT
```

The TEST Menu

7.9 COUNT Test Menu – Beta Detector Count Tests

The TEST > COUNT 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 six 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 GO soft key 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.

The M value on the screen indicates if the membrane was extended (Y) or withdrawn (N) during the count period. The MEMBRN and NO MEMBRN soft keys can be used to manually extend or withdraw the span membrane foil before a count test if desired.

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.

7.10 PUMP Test Menu – Manual Pump and Nozzle Tests

The TEST > PUMP screen is used to perform leak checks. 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 or checks should be performed using this screen! Obsolete BAM-1020 units with a manual flow valve were calibrated using this screen.

```
           NOZZLE/PUMP TEST MODE

NOZZLE: ▼

FLOW:        16.7 SLPM    PUMP:  ON


MOVE NOZZLE    PUMP ON    PUMP OFF    EXIT
```

The PUMP 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 TAPE Test Menu – Manual Filter Forward/Backward Tests

The TEST > TAPE menu allows the user to manually move the filter tape forwards or backwards in increments of 12.5mm "windows". This is useful for spooling up the first few turns of a fresh roll of tape, to test the tape transport mechanism, or to change spots of tape for flow or count tests. The nozzle will be automatically raised if necessary, and the tape will take a couple of seconds to move each window.

The "X:" value is the number of windows moved in the last motion. This number will be negative if the last move was backwards.

The FEED value is the number of tape windows you want to move. Use the arrow up/down keys to select up to 10 windows at a time.

The FWD and BKWD soft key move the tape forward or backward by the current amount of the FEED value.

7.12 DAC Test Menu – Analog Output Test

The TEST > DAC screen is used to test the function of the analog output voltage and the DAC (digital/analog converter) electronics. Use the up/down arrow keys 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 TEST > DAC screen, contact the service department.

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! Make sure the logger is scaling the voltage correctly. In most cases 0.000V should scale as -0.015mg, and 1.000V should scale as 0.985mg. See Section 6.2.

7.13 CALIBRATE Test Menu – Span Membrane Mass Tests

The TEST > CALIBRATE 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 **(m)** 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.

```
          CALIBRATION MODE

REF MBRN: <
COUNT  (Io):        634000
COUNT  (I):         556234
CAL MASS M:         0.801 mg/cm2

START    STOP                   EXIT
```

The CALIBRATE Test Screen

The REF MBRN value indicates if the reference membrane is currently extended **(>)** or withdrawn **(<)** from the beta particle path.

The COUNT (I_0) value is the total 4-minute beta count through the filter tape only.

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

The CAL MASS M value is the measured mass of the foil derived from the two count values.

The START soft key starts the test cycle. Counting will immediately begin. After 4-minutes the I_0 count will stop, the membrane will extend, and the I 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.

7.14 INTERFACE Test Menu – Relay I/O Channel Tests

The TEST > INTERFACE screen is used to test the relay inputs and outputs on the back of the BAM-1020. The two inputs TELEM FAULT and EXT RESET are tested by applying the appropriate signal to the terminals on the BAM, then verifying that the value on this screen changes 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 arrow keys, then verifying that the contact closure outputs on the back panel terminals respond accordingly with an Ohm-meter. The old RANGE relay output is no longer supported.

7.15 FLOW Test Menu

The TEST > FLOW screen is where the important flow audits, checks, and calibrations are performed on the BAM-1020. See section 5.6. This screen is also useful for checking the ambient temperature and barometric pressure sensors, and for pump capacity and flow controller tests.

7.16 ALIGN Test Menu – Tape Transport Motor and Photosensor Tests

The TEST > ALIGN 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 six ALIGN 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.

```
TEST MENU

NOZZLE    SHUTTLE    IDLER     CAPSTAN
LATCH     REF


SELECT                          EXIT
```

The TEST > ALIGN Menu

NOZZLE: This screen tests the two nozzle photosensors and the nozzle motor. Use the UP and DOWN soft-keys to move the nozzle, and monitor the status of the S4 and S5 photo sensors on the screen.

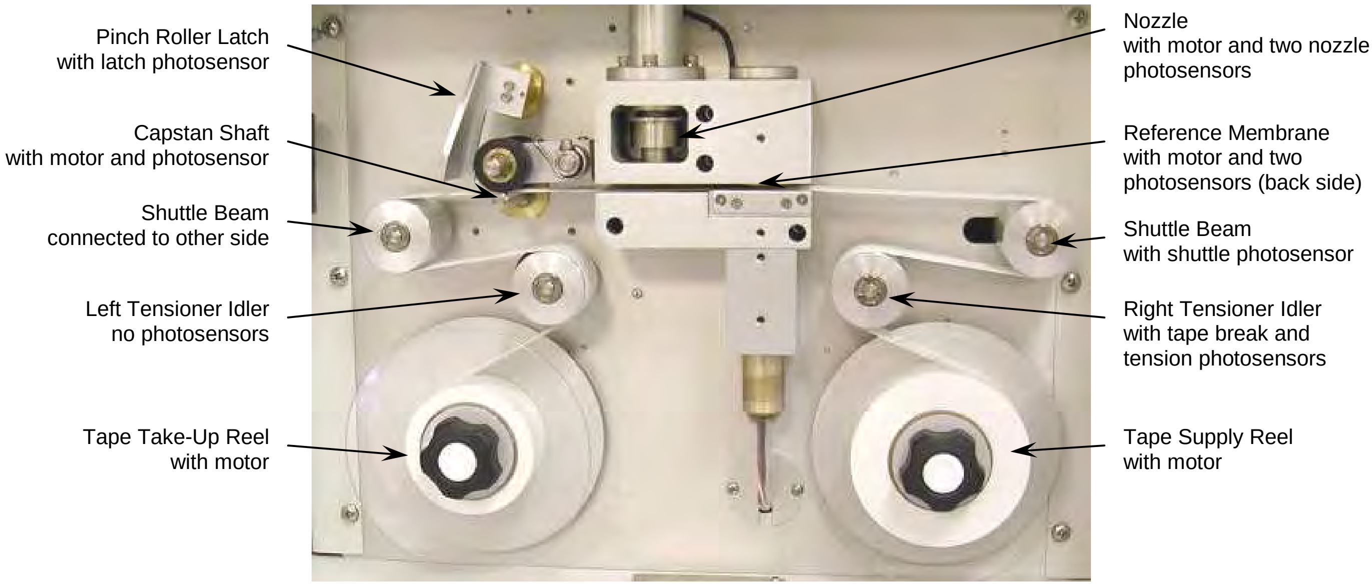
SHUTTLE: This screen tests the photosensor which monitors the position of the shuttle beam (the two outer tape rollers that move together). The status of photo sensor S7 should only change to ON when the beam is moved all the way to the right side. The shuttle must be moved by hand for this test. It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

IDLER: This screen 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.

CAPSTAN: 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 ADVANCE soft-key to rotate the Capstan counter-clockwise, and the BACKUP soft-key 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.

LATCH: This screen 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.

REF: This screen tests the two photo sensors which monitor the position of the reference membrane assembly. When the EXTEND soft-key is pressed the membrane should extend and the S2 photo sensor should be ON, and S3 OFF. When the WITHDRAW soft-key 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.



Tape Transport Assembly

7.17 HEATER Test Menu

The TEST > HEATER screen is used to force the Smart Heater ON or OFF for testing purposes. The heater takes several minutes to heat up or cool down noticeably. The heater automatically turns back off upon exit from the screen.

7.18 FILTER-T Test Menu – Filter Temperature Sensor Tests

The TEST > FILTER-T screen is used to check or calibrate the filter temperature sensor located in the air stream beneath the filter tape. When this screen is entered, the BAM will automatically raise the nozzle and turn the pump on. This allows ambient room air to equilibrate the filter temperature sensor. Allow the pump to run for at least 5 minutes to allow the sensor to equilibrate. When fully equilibrated, the filter temperature should match ambient within **+/- 1 deg C**. To calibrate it, enter the ambient room temperature from your reference standard into the REFERENCE field and press the CALIBRATE soft key. The RESET soft key can be used to revert to default calibrations and start over if difficulty is encountered.

Note: Never calibrate this sensor if the BAM inlet heater has been operating recently. The heater causes this sensor to measures higher than ambient. See the notes about equilibrating or removing the filter RH sensor for calibrations below.

7.19 RH Test Menu – Filter Humidity Sensor Test and Calibration

The TEST > RH screen is used to check or calibrate the filter relative humidity sensor located in the air stream beneath the filter tape. The sensor measures the RH of the sample air to control the Smart Inlet Heater system, which turns up or down as needed to maintain the sample near or below the RH setpoint value. See Section 6.9. The filter RH sensor (part 9278) should match ambient RH within +/- 4% when properly equilibrated. If the sensor fails, it usually reads something impossible like -25% or 135% RH.

```
FILTER RH CALIBRATION


      BAM:   32.5 %
REFERENCE:   33.1 %


CALIBRATE    RESET                Exit
```

The FILTER RH Test Screen

Important 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 sensor to measure significantly lower than ambient RH. For this reason it is usually best to leave the factory default calibration 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 sensor without removing it from the sample stream: Enter the TEST > FILTER RH screen. The BAM will raise the nozzle and 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 sensor 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 an accurate ambient RH value can be obtained. Enter the TEST > RH menu and allow the sensor to equilibrate for at least five minutes, then compare the BAM RH reading on the display to your reference RH device. To calibrate the sensor, enter the reference value into the BAM display and press CAL to change the BAM value to match.

The RESET key can be used to remove all previous field calibrations from the sensor and restore the default factory calibration. Do not press the CAL key after RESET, or whatever value happens to be in the REFERENCE field will be calibrated.

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.

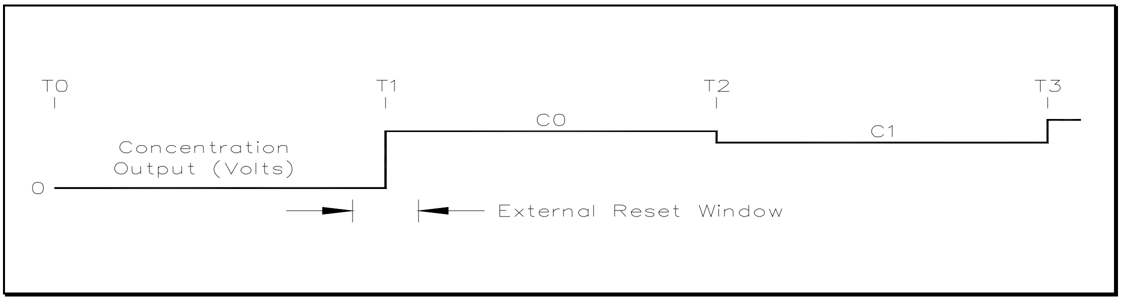
SWITCH	ON	OFF
SW1	0-10 vdc	0-1 vdc
SW2	4-20mA	0-16mA
SW3	Not used	Not used
SW4	Not used	Not used

Important Note: The scale of the output voltage of the BAM-1020 is determined by the RANGE and OFFSET setting. See Section 6.2. 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 DAC should be tested as described in Section 7.12 to ensure that the actual voltage output of the BAM matches the expected voltage.

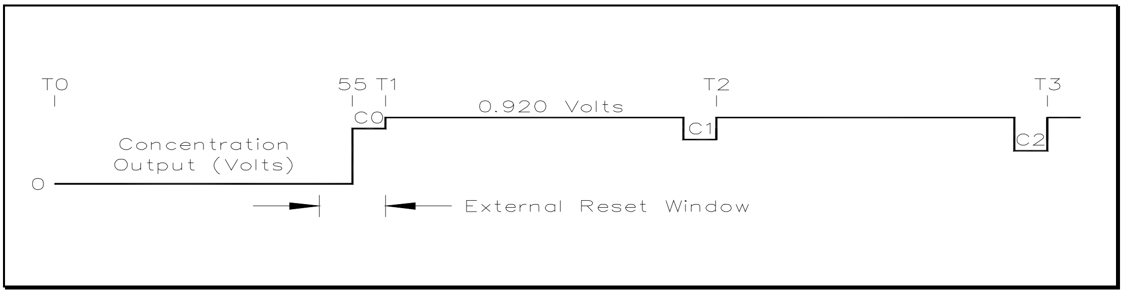
Analog Error Encoding: The analog output is the only voltage channel available between the BAM-1020 and the datalogger, so any errors generated by the BAM are reported using the same voltage signal. The BAM-1020 will set the analog output to its full-scale reading whenever a critical error prevents a valid concentration from being measured. It can optionally set the voltage to full-scale in response to other non-critical alarms as described in section 6.5. 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 SETUP > INTERFACE 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

$\mathbf{C_0}$ represents the concentration output level measured from time $\mathbf{T_0}$ to $\mathbf{T_1}$, where the T labels represent the top (beginning) of an hour (such as 12:00:00). As you can see, the concentration voltage $\mathbf{C_0}$ for the standard cycle is present for the whole next hour following the measurement. In early mode, the $\mathbf{C_0}$ voltage for the current hour is present for only the last 5 minutes of the hour just-sampled (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.

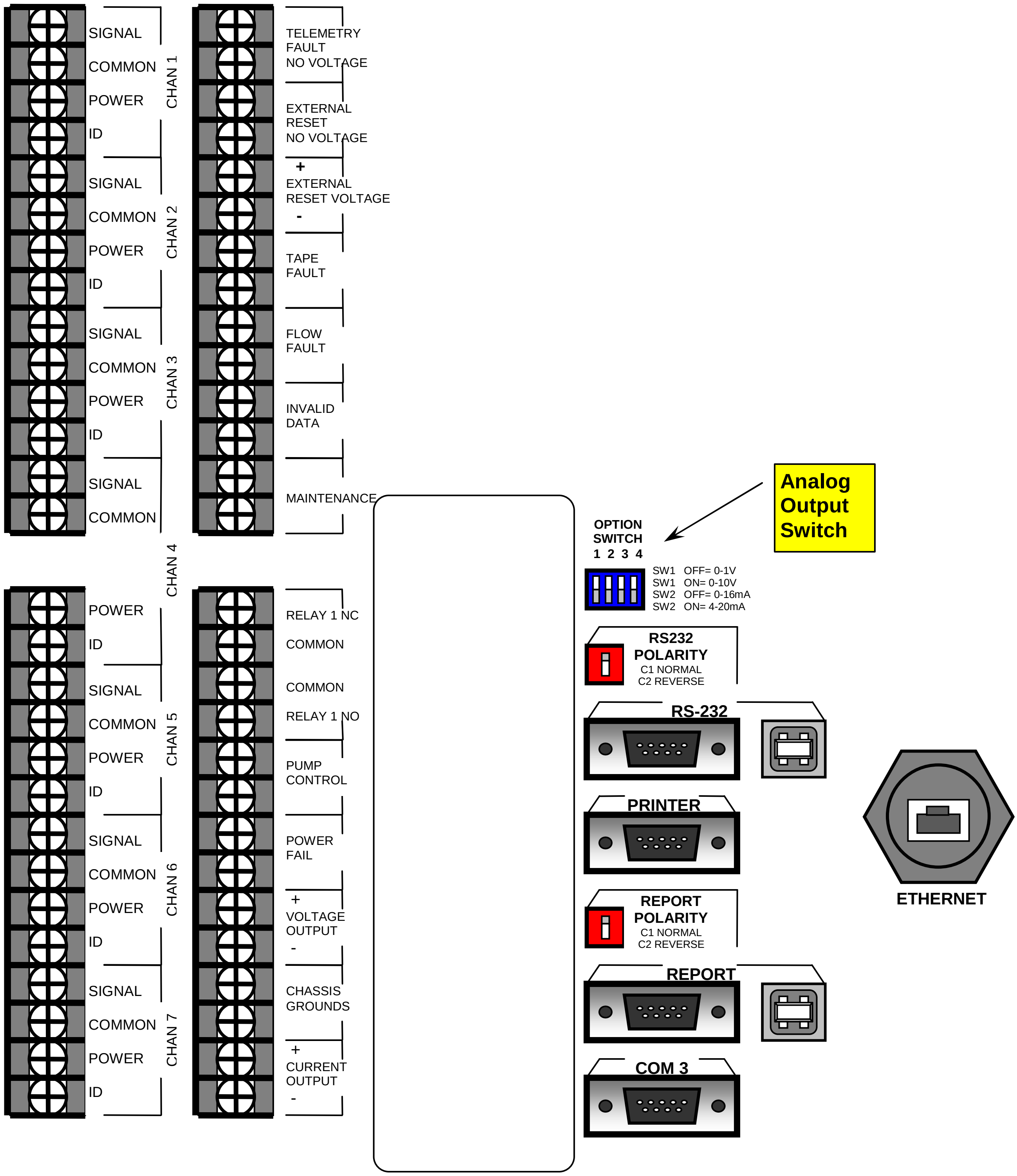
EARLY Mode Clock Resets:

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.



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 SETUP > INTERFACE 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.

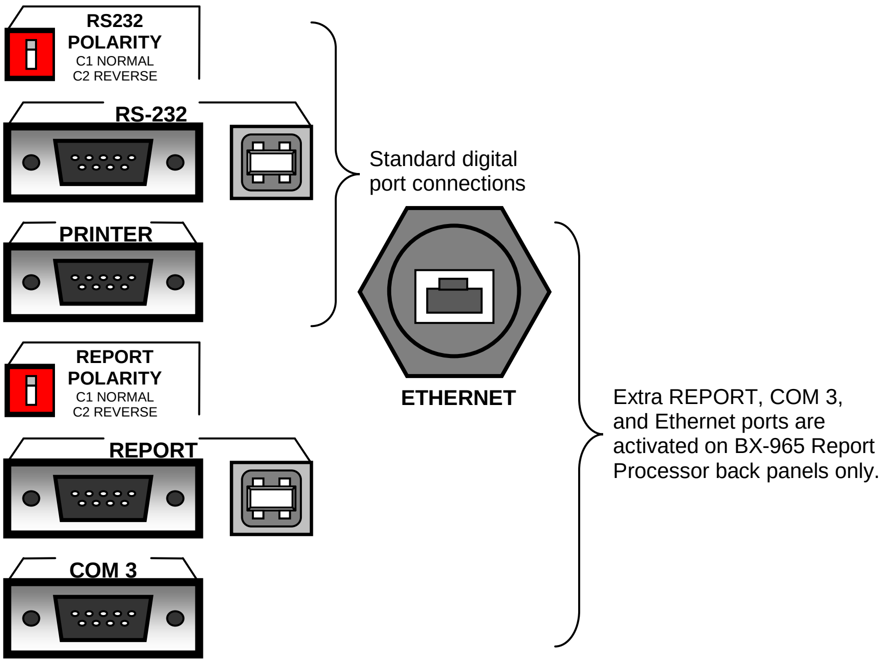
The BX-965 Report Processor back panel option was designed to allow easier digital data connectivity with the BAM-1020. The REPORT serial port works exactly like the classic RS-232 port and accesses the same files, except that it has its own CPU and memory and cannot be interrupted or ignored. The REPORT 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 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.

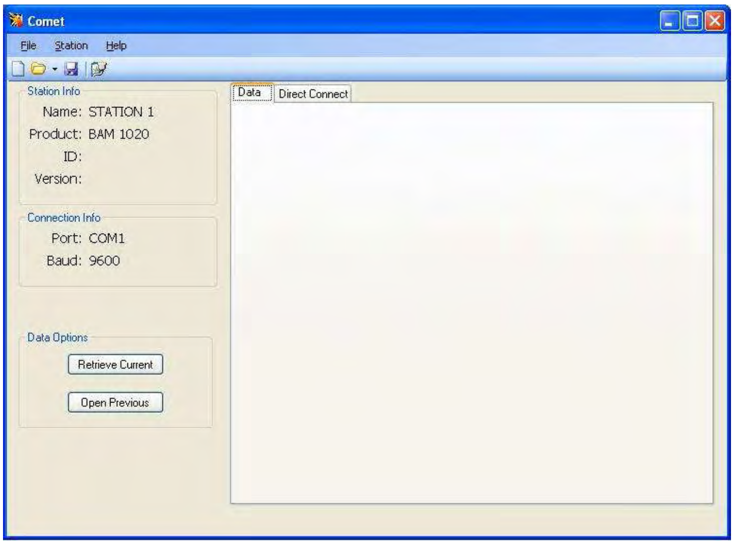
Communication Settings:

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

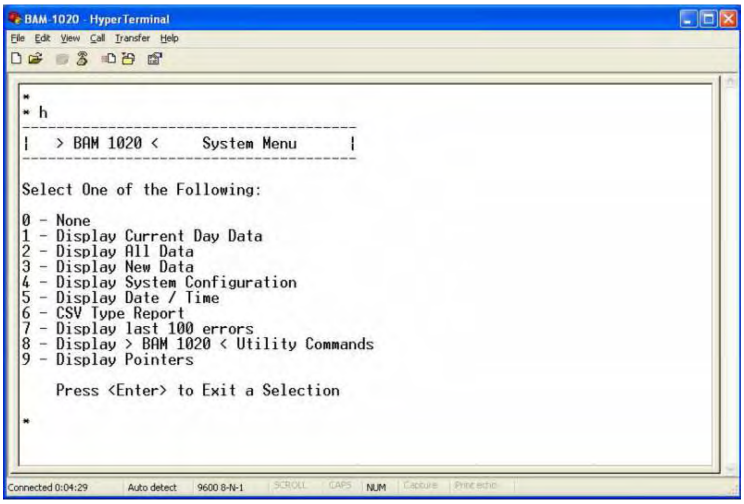
The BAM-1020 data can be easily downloaded through the serial ports using HyperTerminal® or other simple terminal programs. Nearly all PCs have the HyperTerminal program already included. The following describes how to set up the program with the BAM-1020:

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, 0.127,0,0,38,1.1,24.6,0,0,0,0,0,0,0,1,0,0,0,0,
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

Note: *The user can delete the menu characters from the beginning of the text file, leaving only the data header row and the data records, 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 SETUP > SAMPLE and SETUP > CALIBRATE 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:

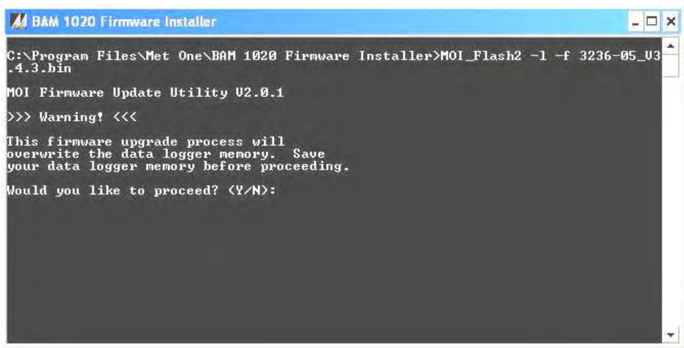
1. A Met One technician will probably e-mail you a link to the FTP file server site where the current Firmware Update Utility program is located. It will look something like the following:

   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 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 SETUP > SAMPLE and SETUP > CALIBRATE 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 units equipped with revision 3.6.3 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 6.10. **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.

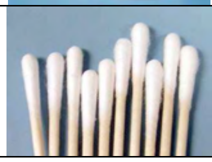
Note: Digital dataloggers may be programmed to use the <STX> (hex 02) character instead of the <ESC>, to prevent the echoing of the command back to the logger.

10 ACCESSORIES and PARTS

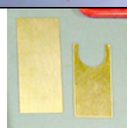
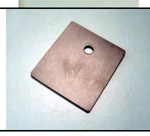
10.1 Consumables, Replacement Parts, and Accessories

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	**460130**	
Cotton-Tipped Applicators, nozzle cleaning, 100 pack Solon #362	**995217**	
Silicone O-Ring Grease, mini packets	**995712**	

Calibration & Service Tools

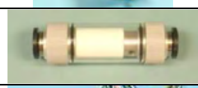
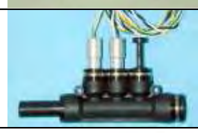
Description	Part Number	Graphic
BAM-1020 Basic Service Tool Kit: Includes nozzle shims, reel spacer, filter sensor removal tool, dark test shim, rubber leak check tool, hex wrenches.	**BX-308**	
BAM-1020 Distributor Service Tool Kit: Includes all of the above plus two spring scales.	**BX-308-1**	
BAM 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**	

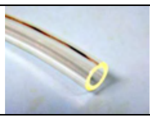
Zero Filter Calibration Kit, with leak check valve. Required for PM2.5 FEM monitoring. Same as BX-305 but with 0.2 micron filter.	**BX-302**	
Volumetric Flow Calibration Kit (BGI deltaCal™) Flow, Temp, and Pressure Reference Standards Met One recommended flow meter	**BX-307**	

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**	

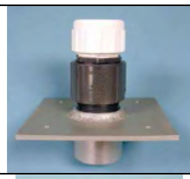
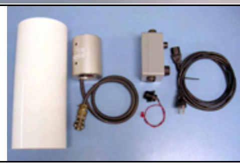
O-Ring Kit, Inlet Tube Receiver and Nozzle.	**9122**	
Pump Tubing, Clear, 10mm O.D., 6.5mm I.D. Polyurethane, 25 foot roll standard	**960025**	

Electrical & Electronic Parts

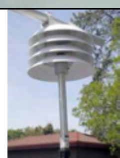
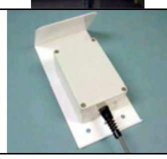
Description	Part Number	Graphic
LCD Display, 8x40 Character, Backlit	**2823**	**Contact Technical Service for Circuit Board Replacement Information.**
Circuit Board, Keypad Interface	**2960-2**	
Circuit Board, CPU	**3230-8**	
Circuit Board, Board Stack Interface	**3250-1**	
Circuit Board, Rear Panel 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 Sharp Cut Cyclone	**BX-807**	
PM2.5 Very Sharp Cut Cyclone, BGI Inc. VSCC™ Required for PM2.5 FEM monitoring	**BX-808**	
PM2.5 WINS Impactor	**BX-804**	

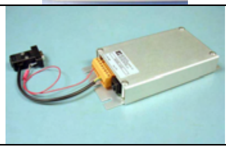
Inlet Roof Mounting Kit, with waterproof roof flange, inlet tube and braces. 8 foot inlet tube standard.	**BX-801**	
Inlet Tube Coupler Assembly, with o-rings Connects two inlet tubes together Inlet tube sold separately	**BX-821**	
Inlet Tube Extension Kit, 4 foot, with coupler and tube	**BX-822**	
Inlet 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. 596+ AT/BP/RH Combo Sensor, -50 +70C.	**BX-596** **BX-596-1** **BX-596+**	
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

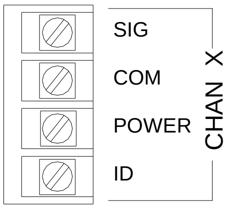
The BAM-1020 has six channels of inputs available on the back of the unit for data logging external sensors. The BX-500 Series sensors are a set of meteorological sensors designed for direct compatibility with these channels. The sensors each have an auto-identification (ID) signal wire with a voltage 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 AUTO in the SETUP > SENSORS 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 scaling and 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-596+ 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**	^{0}C	-40 to +55	95	-40	2.5	S	N	3.50v
	BP	mmHg	525 to 825	300	525	2.5	S		
BX-596-1	**AT**	^{0}C	-50 to +50	100	-50	2.5	S	N	4.10v
	BP	mmHg	400 to 825	425	400	2.5	S		
BX-596+	**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-596+ 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-596+ 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-596+ 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 loose 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

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

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 ± 3%. For BAM-1020 units equipped with the mass flow controller device, (σ_Q/Q) decreases to ± 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 ± 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

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:

Manual Notes: