TÜV RHEINLAND
ENERGIE UND UMWELT GMBH

Deutsche
Akkreditierungsstelle
D-PL-11120-02-00

Report on the performance test of the APDA-371 ambient dust monitor with PM_{10} pre-separator for suspended particulate matter PM_{10} manufactured by HORIBA Europe GmbH in Oberursel

TÜV-Report No.: 936/21221789/A
Cologne, 19 March 2013

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TÜV Rheinland Energie und Umwelt GmbH and its Ambient Air Quality department in particular
is accredited for the following activities:

- Determination of emissions and ambient air quality affected by air pollutants and odorous substances,
- Inspection of correct installation, functionality and calibration of continuous emission monitoring systems including systems for data evaluation and remote monitoring of emissions,
- Measurements in combustion chambers;
- Performance testing of measuring systems for continuous monitoring of emissions and air quality as well as electronic data evaluation and remote monitoring systems for emissions,
- Determination of the stack height and air quality forecasts for hazardous and odorous substances;
- Determination of emissions and ambient air quality affected by noise and vibration, determination of
- sound power levels and noise measurements at wind turbines;

according to EN ISO/IEC 17025.

The accreditation will expire on 22-01-2018. DAkkS registration number: D-PL-11120-02-00.

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Summary Overview

HORIBA Europe GmbH commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out performance test of the APDA-371 ambient dust monitor with PM_{10} pre-separator for suspended particulate matter PM_{10}. The performance test was carried out in respect of the following standards and requirements:

- VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated June 2002.
- VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated August 2004
- [3] EN 12341 "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“, German version EN 12341: 1998
- Guideline "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated January 2010

The APDA-371 ambient dust monitor with PM_{10} pre-separator uses a radiometric method to determine dust concentrations. A pump sucks in ambient air through the PM_{10} sampling head. The dust-loaded sample air is then pulled to a filter tape. The determination of the mass concentration precipitated on the filter tape is then performed relying on the principle of beta absorption.

The tested certification range was:

Component	Certification range
$PM_{2,5}$	0–1000 µg/m³

With the exception of a modified front design, the APDA-371 ambient dust monitor with PM_{10} pre-separator is absolutely identical to the BAM-1020 measuring system designed and completely manufactured by Met One Instruments, Inc. The latter is publically announce as performance-tested in the Federal Gazette as BAM-1020 with PM_{10} pre-separator. The announcement history of the BAM-1020 with PM_{10} pre-separator manufactured by Met One Instruments, Inc. is as follows:

1. BAM-1020 with PM_{10} pre-separator UBA announcement of 12 April 2007 (BAnz. S. 4139, Chapter III Number 1.2)

   The most recent notification regarding this measuring system was:

   BAM-1020 with PM_{10} pre-separator UBA announcement of 12 February 2013 (BAnz AT 05.03.2013 B10, Chapter V 2nd notification), statement issued on 4 October 2012.

   A further statement dated 18 March 2013 will be submitted to the relevant body regarding the software version of the measuring system.

Public announcement of the APDA-371 ambient dust monitor with PM_{10} pre-separator, identical design with the BAM-1020 measuring system with PM_{10} pre-separator was asserted.

APDA-371 ambient dust monitor with PM_{10} pre-separator, UBA announcement of 25 January 2010 (BAnz. S. 552, Chapter IV 11th notification).

Moreover, the following notification was published with respect to the APDA-371 ambient dust monitor with PM_{10} pre-separator manufactured by HORIBA Europe GmbH:

APDA-371 ambient dust monitor with PM_{10} pre-separator, UBA announcement of 6 July 2012 (BAnz AT 20.07.2012 B11, Chapter IV 3rd notification), statement issued on 22 March 2012.

The most recent notification regarding instrument BAM-1020 with PM_{10} pre-separator also applies to the APDA-371 ambient dust monitor with PM_{10} pre-separator (UBA announcement of 12 February 2013 (BAnz AT 05.03.2013 B10, Chapter V 2nd notification) as does the cited statement. It was taken into account for the relevant notification proposal and listed in the appendix.

No actual test were performed for the performance test of the APDA-371 ambient dust monitor with PM_{10} pre-separator. The publication is based on document inspections and on-site audits.

The measuring system is exclusively manufactured by Met One Instruments, Inc. in Grants Pass, USA. The instruments are manufactured at the same time as the manufacturer's own instruments under the exact same conditions by the same staff using the same material. Checks of the relevant drawings and audits of the production site in Grants Pass demonstrated that the instruments are absolutely identical in design.

The minimum requirements were satisfied during the performance test.

TÜV Rheinland Energie und Umwelt GmbH therefore propose public announcement of the tested measuring system as certified for continuous monitoring of the ambient air quality affected by suspended particulate matter, PM_{10} fraction.

The present report contains a certification proposal for the APDA-371 ambient dust monitor with PM_{10} pre-separator. Appendices include the report on performance testing as well ass an addendum to that report for the BAM-1020 measuring system with PM_{10} pre-separator, notifications regarding the APDA-371 ambient dust monitor with PM_{10} pre-separator and the manual for the APDA-371 ambient dust monitor with PM_{10} pre-separator.

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Report on the performance test of the APDA-371 ambient dust monitor with PM10 pre-separator for suspended particulate matter PM10 manufactured by HORIBA Europe GmbH in Oberursel

AMS designation:	APDA-371 ambient dust monitor with PM_{10} pre-separator for suspended particulate matter, PM_{10} fraction
Manufacturer:	HORIBA Europe GmbH Hans-Mess-Straße 6 61440 Oberursel
Test period:	from February 2006 to December 2006
Date of report:	19 March 2013
Report Number:	936/21221789/A
Editor:	Dipl.-Ing. Karsten Pletscher karsten.pletscher@de.tuv.com
Technical Supervisor:	Dr Peter Wilbring peter.wilbring.@de.tuv.com

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1. General

1.1 Certification proposal

Based on the positive results obtained, the following recommendation on the announcement of the AMS as a certified system is put forward:

AMS designation:

APDA-371 with PM_{10} pre-separator

Manufacturer:

HORIBA Europe GmbH, Oberursel

Field of application:

For continuous monitoring of suspended particulate matter, PM_{10} fraction, in ambient air from stationary sources

Measurement ranges during performance testing:

Component	Certification range	Unit
PM_{10}	0–1000	µg/m³

Software versions:

Version 3236-07 5.1.1

Restrictions:

None

Notes:

1. For monitoring PM_{10} the instrument must at least be equipped with the following: Sample heater (BX-830), sampling head (BX-802) and ambient temperature sensor (BX-592) or combined pressure and temperature sensor (BX-596).
2. The heater may only be used in the way of operation which was used during performance testing.
3. The operating flow has to be regulated in terms of ambient conditions (mode ACTUAL).
4. Cycle time during performance testing was 1s. Thus filters were automatically replaced once an hour. Every filter spot was sampled once only.
5. The measuring system must be operated in a lockable measurement cabinet.
6. The instrument must be calibrated on-site regularly using a gravimetric PM_{10} reference method in accordance with EN 12341.
7. Optionally, the measuring system may be operated with the BX-125 pump.
8. Since January 2012, the measuring system has been sold with a re-designed back plate, which provides space for additional interfaces such as the BX-965 report processor for example.
9. The measuring system complies with the requirements of standard EN 12341

and those of guideline “Demonstration of Equivalence of Ambient Air Monitoring Methods”, version dated January 2010. Moreover, the manufacturing process and the QMS used for the APDA-371 meet the requirements specified in standard EN 15267.

10. The APDA-371 with PM_{10} pre-separator was first certified as follows: UBA announcement of 25 January 2010 (BAnz. S. 552, Chapter IV 11th notification). The most recent notification was that announced by the Federal Environment Agency on 6 July 2012 (Fed Gaz. AT 20.07.2012 B11, chapter IV, 3rd notification).
11. This report on the performance test is available online at www.qal1.de.

Test Report:

TÜV Rheinland Energie und Umwelt GmbH, Cologne
Report No.: 936/21221789/A dated 19 March 2013

Cologne, 19 March 2013

Dipl.-Ing. Karsten Pletscher

Dr. Peter Wilbring

Appendices

- Report on the performance test of the BAM-1020 measuring system with PM_{10} pre-separator for suspended particulate matter PM_{10} manufactured by Met One Instruments, Inc., TÜV Report No. 936/21205333/A of 06/12/2006.
- Addendum to the report No. 936/21205333/A of 06/12/2006 on the performance test of the BAM-1020 measuring system with PM_{10} pre-separator for suspended particulate matter PM_{10} manufactured by Met One Instruments, Inc., TÜV Report No. 936/21220762/A of 12/12/2012.
- Notifications published with respect to the APDA-371 with PM_{10} pre-separator manufactured by HORIBA Europe GmbH
- Operation manual for the APDA-371 ambient dust monitor with PM_{10} pre-separator.

TÜV RHEINLAND IMMISSIONSSCHUTZ
UND ENERGIESYSTEME GMBH

Report on the suitability test of the ambient air quality measuring system BAM-1020 with PM10 pre-separator of the company Met One Instruments, Inc. for the measured component suspended particulate matter PM10

TÜV-Report: 936/21205333/A
Cologne, December 06, 2006

TÜV Rheinland Immissionsschutz und Energiesysteme GmbH holds an accreditation under the terms of DIN EN ISO/IEC 17025 in the following field of work:

- Determination of emissions and ambient air quality of air pollutants and odorants;
- Verification of the correct installation and the function as well as the calibration of continuous operating emission measuring systems including systems for data evaluation and remote monitoring of emissions;
- Suitability testing of measuring systems for continuous monitoring of emissions and ambient air quality as well as for electronic systems for data evaluation and remote monitoring of emissions

The accreditation is valid up to 04-12-2010.
DAR-Registration number: DAP-PL-3856.99.

Akkreditiertes Prüfinstitut

Deutscher Akkreditierungs Rat

DAP-PL-3856.99

Report on the suitability test of the ambient air quality measuring system BAM-1020 with PM10 pre-separator of the company Met One Instruments, Inc. for the measured component suspended particulate matter PM10

Tested measuring system:	BAM-1020 with PM10 pre-separator
Manufacturer of the instrument:	Met One Instruments, Inc. 1600 NW Washington Blvd. Grants Pass, Oregon 97526 USA
Time period of testing:	from: February 2006 until: December 2006
Date of report:	December 06, 2006
Number of report:	936/21205333/A
Scope of report:	altogether 320 pages appendix from page 148 manual from page 169 with 151 pages

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1 Summary and proposal for declaration of suitability

1.1 Summary

According to the 1st Daughter Directive 1999/30/EC of 22 April 1999 „relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air“ of the Ambient Air Quality Framework Directive 96/62/EC of 27 September 1996 „on ambient air quality assessment and management“, the methods described in DIN EN 12341 „Determination of the PM10 fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods“ have to be used as reference method for the measurement of the PM10 concentration. Nevertheless, the Member States may also use a different method, if it is demonstrated, that „it displays a consistent relationship to the reference method. In that event the results achieved by that method must be corrected by a relevant factor to produce results equivalent to those that would have been achieved by using the reference method. “(1999/30/EC, Annex IX, Art. IV, Para.2).

The Guideline VDI 4202, Sheet 1 of June 2002 describes the „Minimum requirements for suitability tests of automated ambient air quality measuring systems“. The general framework for the related test work is described in Guideline VDI 4203, Sheet 1 „Testing of automated measuring systems – General concepts “of October 2001. VDI 4203, Sheet 3, „Testing of automated measuring systems – Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants“ of August 2004 specifies this framework.

Furthermore, the Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods” of the ad-hoc-EC-working group of November 2005 describes another method for the test of equivalency of non-reference methods. Though the mentioned Guidance is not normative, the application is recommended by the so-called CAFE-committee for the present.

On behalf of Met One Instruments, Inc., TÜV Rheinland Immissionsschutz und Energiesysteme GmbH has performed the suitability test of the measuring system BAM-1020 for the component PM10.

The suitability test was carried out in compliance with the following guidelines and requirements:

- VDI-Guideline 4202, Sheet 1, „Minimum requirements for suitability tests of automated ambient air quality measuring systems – Point-related measurement methods of gaseous and particulate pollutants ", June 2002 [1]
- VDI-Guideline 4203, Sheet 3, „Testing of automated measuring systems – Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants", August 2004 [2]
- European Standard EN 12341, „Air quality - Determination of the PM10 fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version DIN EN 12341: 1998 [3]
- Guidance "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version of November 2005 [9]

The investigations according to the Guidance "Demonstration of Equivalence of Ambient Air Monitoring Methods" have been carried out exemplarily on the basis of the measured data according to [1], [2] and [3], obtained during the field test. Hereby the investigations have been performed deviant to the requirement of the Guidance only at three instead of four field test sites and with less than respectively 40 valid paired measurements per field test site.

The measuring system BAM-1020 determines the particulate concentration by a radiometer measuring principle. With the aid of a pump, ambient air is sucked through a PM10 sampling head. The dust-loaded sampling air is afterwards sucked on a filter tape. The determination of the separated mass of dust on the filter tape is performed after the respective sampling by the radiometric measuring principle of beta-attenuation.

The investigations have been carried out in the laboratory and during a field test, lasting several months.

The field test, lasting several months, was performed at the test sites according to Table 1:

Table 1: Description of the test sites

	Cologne, parking lot	Titz-Roedingen	Cologne, Frankfurter Str.	additional Cologne, Frankfurter Str.
Time period	02/2006 – 04/2006	07/2006 – 09/2006	09/2006 – 10/2006	10/2006 – 11/2006
Used PM10-sampling inlet	BX-802 US	BX-802 US	BX-802 US	BX-809 EU
No. of pairs of measured values: Candidate	52	37	28	26
Characterization:	Urban background	Rural situation	Traffic	Traffic
Rank of pollution	average to high	low	average to high	average to high

The minimum requirements have been fulfilled in the suitability test.

Therefore the TÜV Rheinland Immissionsschutz und Energiesysteme GmbH proposes the publication as a suitability-tested measuring system for continuous monitoring of ambient air quality of suspended particulate matter PM10.

1.2 Proposal for declaration of suitability

Due to the positive achieved results, the following recommendation for declaration of suitability as suitability-tested measuring system is:

1.2.1	**Measurement task**	:	Continuous monitoring of ambient air quality of suspended particulate matter PM10
1.2.2	**Name of device**	:	BAM-1020 with PM10 pre-separator
1.2.3	**Measured components**	:	PM10
1.2.4	**Manufacturer**	:	Met One Instruments, Inc. 1600 NW Washington Blvd., Grants Pass, OR 97526, USA
1.2.5	**Suitability**	:	For continuous monitoring of ambient air quality of the PM10-fraction in suspended particulate matter in stationary applications.
1.2.6	**Measuring ranges in the suitability test**	:	0 to 1.000 mg/m³ = 0 to 1000 µg/m³
1.2.7	**Software version**	:	Version 3236-02 3.2.1b
1.2.8	**Restrictions**	:	None
1.2.9	**Remarks**	:	1. For recordation of PM10, the system has to be equipped with the following options: Sample heater (BX-830), sampling inlet (BX-802), ambient temperature sensor (BX-592) and air pressure sensor (BX-594). 2. The heater may only be used in the operational mode, which has been applied during the suitability test. 3. The volume flow regulation has to be carried out at actual volume with reference to the ambient conditions (operational mode ACTUAL). 4. The measuring system has been operated with the sample heater BX-830 during the complete suitability test. 5. The cycle time during the suitability test was 1 h, i.e. an automatic filter change has been performed every hour. Each filter spot has been used one time. 6. The measuring system has to be operated in a lockable measuring cabinet. 7. The measuring system has to be calibrated with the gravimetric PM10-reference method according to DIN EN 12341 on the site at regular intervals.

1.2.10	**Test house**	**:**	TÜV Rheinland Immissionsschutz und Energiesysteme GmbH, Cologne, Germany TÜV Rheinland Group Responsible investigator: Mr. Dipl.-Ing. Karsten Pletscher
1.2.11	**Test report**	**:**	936/21205333/A of December 06, 2006

1.3 Summary of test results

Minimum requirement	Requirement	Test results	ful-filled	Page
4 Requirements on the instruments design				
4.1 General requirements				
4.1.1 Measured value display	Shall be available	The measuring system has got a measured value display.	yes	49
4.1.2 Easy maintenance	Maintenance work should be possible without larger time and effort, if possible performed from outside.	Maintenance work can be done from outside with common tools and justifiable operating expense.	yes	51
4.1.3 Functional check	Particular instruments for this shall be considered as part of the device, be applied in the corresponding sub-tests and be assessed. Test gas units shall indicate their operational readiness to the measuring system by status signals and shall provide direct or remote control via the measuring system. Uncertainty of the test gas unit shall not exceed 1 % of B2 within three months.	All instrument functions, listed in the manual, are available, can be activated and are functioning. The current status of the system is monitored continuously and is indicated by a series of different status messages (operational, alarm and error status.	yes	53
4.1.4 Set-up times and warm-up times	The manual shall contain specifications for this.	The set-up times and the warm-up times have been determined.	yes	55
4.1.5 Instrument design	The manual shall contain specifications for this.	The specifications for the instrument design, mentioned in the manual, are complete and correct.	yes	56
4.1.6 Unintended adjustment	Shall have protection against it.	The measurement system is protected against unintended and unauthorized adjustment of instrument parameters. Moreover the measuring system has to be locked in a measurement cabinet.	yes	57
4.1.7 Data output	Shall be offered digital and/or analogue.	The measured signals are offered analogue (0-1 resp. 10 V resp. 0–16 mA / 4-20 mA) and digital (via RS 232).	yes	58
4.2 Requirements for measuring systems for mobile application	Permanent operational stand-by shall be secured; requirements for stationary application shall also be fulfilled for mobile application.	In the context of the field test, the measuring system was operated at several different sites. A mobile application of the measuring system was not tested within the scope of the test.	no	60

Minimum requirement	Requirement	Test results	ful-filled	Page
5. Performance requirements				
5.1 General	Manufacturer's specifications in the manual shall not be contradictory to the results of the suitability test.	Differences between instrument layout and manuals have not been observed.	yes	61
5.2 General requirements				
5.2.1 Measuring range	Upper limit of measuring range larger than B_2.	A measuring range of 0 -1,000 µg/m³ is set by default. Other measuring ranges in the range between at minimum 0-100 µg/m³ and at maximum 0-10,000 µg/m³ are possible.	yes	62
5.2.2 Negative output signals	Shall not be suppressed (life zero).	Negative measuring signals are displayed directly and are output correctly via the respective measured value outputs by the measuring system.	yes	63
5.2.3 Analytical function	Relationship between output signal and measured quantity shall be represented by analytical function and determined by regression analysis.	A statistically secured relationship between the reference method and the instrument reading could be proved.	yes	65
5.2.4 Linearity	Deviation of group averages of measured values from the calibration function in the range from zero to B_1 maximum 5 % of B_1 and in the range from zero to B_2 maximum 1 % of B_2.	For particulate measuring systems, this test has to be performed according to the minimum requirement 5.3.1 „Equivalency of the sampling system".	yes	66
5.2.5 Detection limit	Maximum B_0.	The detection limit has been determined from the investigations to 1.7 µg/m³ for device 1 (SN 4924) and to 1.9 µg/m³ for device 2 (SN 4925).	yes	67
5.2.6 Response time	Maximum 5 % of averaging time (equal to 180 seconds).	Not applicable.	-	69
5.2.7 Dependence of the zero point on ambient temperature	Measured value at zero point shall not exceed B_0 at ΔT_u of 15 K between +5 °C and +20 °C respectively of 20 K between +20 °C and +40 °C.	Considering the values offered from the device, a maximum influence of the ambient temperature on the zero point of 0.7 µg/m³ could be detected.	yes	70

Minimum requirement	Requirement	Test results	ful-filled	Page
5.2.8 Dependence of the measured value on ambient temperature	The deviation of the measured value in the range of B1 shall not be exceed ± 5 % at ΔT_u of 15 K between +5 °C and +20 °C respectively of 20 K between +20 °C and +40 °C.	There have been no deviations > 0.1 % for device 1 (SN 4924), and no deviations > 0.2 % for device 2 (SN 4925), related to the start value at 20 °C.	yes	72
5.2.9 Drift of zero point	In 24 hours and in the maintenance interval maximum B_0.	The measuring system carries out a regular device-internal check of the zero point of the radiometric measurement during each measurement cycle. This test leads to no interruption of the ongoing measuring operation at all. The obtained values, determined within the scope of the drift investigations, are within the allowed limits in the maintenance interval.	yes	75
5.2.10 Drift of measured value	In 24 hours and in the maintenance interval maximum 5% of B_1.	The measuring system carries out a regular device-internal check of the sensitivity of the radiometric measurement during each measurement cycle. This test leads to no interruption of the ongoing measuring operation at all. The values for the drift of the sensitivity, determined within the scope of the test, were at maximum 0.44 % (SN 4924) respectively -0.02 % (SN 4925) in the maintenance interval.	yes	81
5.2.11 Cross-sensitivity	In the range of zero point maximum B_0 and in the range B_2 maximum 3 % of B_2.	Not applicable.	-	86
5.2.12 Reproducibility RD	$R_D \geq 10$, related to B_1.	The reproducibility RD was at minimum 16 during the field test.	yes	87
5.2.13 Hourly averages	Formation shall be possible.	The formation of hourly averages for the component SPM PM10 is not necessary for the monitoring of the relevant limit values, but possible.	yes	89
5.2.14 Mains voltage and frequency	Change in measured value at B_1 maximum B_0 in the mains voltage interval (230 +15/-20) V and change in measured value for mobile applications maximum B_0 in the power frequency interval (50 ± 2) Hz.	Through changes in the mains voltage, maximum deviations of -1.6 µg/m³ at the zero point and maximum 0.2 % at the tested reference points could be detected.	yes	92
5.2.15 Failure in mains voltage	Uncontrolled emission of operation or calibration gas shall be avoided; instrument parameters shall be secured by buffering against loss; operation mode shall be secured after return of mains voltage and measurement shall be resumed.	All instrument parameters are protected against loss by buffering. The measuring system is in normal operating condition after return of power supply and continues independently the measurements with reaching the next hour.	yes	93

Minimum requirement	Requirement	Test results	ful-filled	Page
5.2.16 Operating states	Shall be able to be controlled by telemetrically transmitted status signals.	The measuring systems can be controlled and monitored extensively from an external PC via a modem.	yes	94
5.2.17 Switch-over	Measurement/functional check and/or calibration shall be able to be activated telemetrically and manually.	Generally all necessary operations for functional check and calibration can be monitored directly at the device or via telemetric remote control.	yes	95
5.2.18 Availability	At least 90 %.	The availability was 99.7 % for both devices without outages, caused by testing, respectively 99.0 % incl. outages, caused by testing.	yes	96
5.2.19 Efficiency of the converter	At least 95 %.	Not applicable.	not applicable	98
5.2.20 Maintenance interval	Preferably 28 days, at least 14 days.	The maintenance interval is defined by the accruing maintenance work and it is 4 weeks.	yes	99
5.2.21 Overall uncertainty	Fulfillment of the requirements on the data quality [G10 to G12].	The overall uncertainties have been 7.23 % respectively 7.89 % for U(c) and 7.44 % respectively 8.28 % for $U(\bar{c})$.	yes	100
5.3.1 Equivalency of the sampling system	To the reference method according to EN 12 341 [T2] shall be demonstrated.	The reference-equivalence functions are bounded within the limits of the acceptance envelope. Furthermore the variance coefficient R^2 of the determined reference-equivalence functions is ≥ 0.95 for the respective concentration range.	yes	104

Minimum requirement		Requirement	Test results	ful-filled	Page
5.3.2	Reproducibility of the sampling systems	Shall be demonstrated in the field test according to DIN EN 12341 [T2] for two identical sampling systems.	The two-sided confidence interval CI95 is, with maximum 2.54 µg/m³, below the specified level of 5 µg/m³.	yes	112
5.3.3	Calibration	By comparison measurement in the field test with reference method according to DIN EN 12341 [T2]; relationship between measured signal and gravimetrically determined reference concentration to be determined as a steady function.	Refer to module 5.2.3.	-	116
5.3.4	Cross-sensitivity	Maximum 10 % of B_1.	No interfering influence > 1.46 µg/m³ deviation from the nominal value on the measured signal through the air humidity, which is contained in the medium being measured could be detected. During the field test, it could be observed no negative influence on the measured values during varying relative air humidity and activated heating system.	yes	118
5.3.5	Daily averages	24 h-mean values shall be possible; time needed for the filter change maximum 1 % of averaging time.	With the described system configuration and with a measurement cycle of 60 min, the formation of valid daily averages on the basis of 24 single measurements is possible.	yes	120
5.3.6	Constancy of sample volumetric flow	± 3 % of nominal value during sampling time; Instantaneous values ± 5 % of nominal value during sampling time.	All determined averages over the measurement cycle deviate less than ± 3 %, all instantaneous values deviate less than ± 5 % from the nominal value.	yes	122
5.3.7	Tightness of the sampling system	Leakage maximum 1 % of sample volume.	The maximum determined leakages have been 0.6 % for device 1 (SN 4924) as well as 0.6 % for device 2 (SN 4925).	yes	124
5.4	Requirements for multiple-component measuring systems	Shall be fulfilled for each single component in the simultaneous operation of all measuring channels; the formation of hourly averages shall be secured in case of sequential operation.	Not applicable.	-	125

Minimum requirement	Requirement	Test results	ful-filled	Page
Additional test criteria according to Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“				
Determination of the between-instrument uncertainty ubs [9.5.2.1]	Shall be determined in the field test according to point 9.5.2.1 of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“ for two identical systems.	The between-instrument uncertainty ubs is with at maximum 1.22 µg/m³ below the required value of 3 µg/m³.	yes	127
Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6]	Determination of expanded uncertainty of candidates according to the points 9.5.2.2et seq. of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“.	The determined uncertainties WCM are below the set expanded relative uncertainty Wdqo of 25 % for PM for all regarded datasets without the application of correction factors.	yes	134
Application of correction factors or terms [9.7]	If the highest calculated expanded uncertainty of candidates is larger then the expanded relative uncertainty, specified in the requirements on the data quality of ambient air quality measurements according to EU-Guideline [7], an application of correction factors is allowed. The corrected values shall meet the requirements according to the points 9.5.2.2et seq. of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“.	The candidate systems fulfill the requirements on the data quality of ambient air quality measurements during the test without the application of correction factors.	yes	143

2 Terms of reference

2.1 Kind of testing

On behalf of Met One Instruments, Inc., TÜV Rheinland Immissionsschutz und Energiesysteme GmbH has performed the suitability test of the measuring system BAM-1020 with PM10 pre-separator. The test was performed as a complete suitability test.

2.2 Objective

The measuring systems shall determine the content of PM10 suspended particulate matter in ambient air in the concentration range 0 to 1.000 mg/m³ = 0 to 1000 µg/m³.

The suitability test was performed on the basis of the current guidelines for suitability tests.

The test was carried out considering the following guidelines:

- Guideline VDI 4202, Sheet 1, „Minimum requirements for suitability tests of automated ambient air quality measuring systems – Point-related measurement methods of gaseous and particulate pollutants “, June 2002, [1]
- Guideline VDI 4203, Sheet 3, „Testing of automated measuring systems – Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants “, August 2004, [2]
- European Standard DIN EN 12341, „Air quality – Determination of the PM10 fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods“, German version DIN EN 12341: 1998, [3]

Furthermore an additional evaluation of the field test data according to the criteria of the Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods” from the EU working group was performed within the scope of the suitability test at hand.

- Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version from November 2005, [9]

The investigations according to the Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods” have been carried out exemplarily on the basis of the measured data according to [1], [2] and [3], obtained during the field test. Hereby the investigations have been performed deviant to the requirement of the Guidance only at three instead of four field test sites and with less than respectively 40 valid paired measurements per field test site.

3 Description of the tested system

3.1 Measuring principle

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:

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

with:

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 and is checked within the scope of internal quality assurance hourly at the zero point (clean filter spot) and at the reference point (built-in reference foil) during operation. With the help of the generated data, measured values at zero and reference point can be easily affiliated. They can be compared with any stability requirements (drift effects) respectively with the nominal value for the reference foil (factory setting, please refer to appendix B in the manual).

3.2 Functionality of the measuring system

The particle sample passes the PM10-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. The heater can be controlled with the help of two control process variables respectively with their combination:

1. The 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 reached respectively is exceeded, the heater is switched off. Thereby the criterion for Delta-T is the striking one, which means, that in case the relative humidity RH is above the nominal value, but 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 measuring cabinet. For this configuration, the controlling of the heater with the help of the Delta-T criterion is not reasonable. For this reason, the heater was only controlled with the help of the parameter relative humidity RH during the complete test work.

The particles arrive at the measuring instrument and will be separated at the glass fiber filter tape for the radiometric measurement.

One measurement cycle (incl. 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. The sample time should be chosen greater than or equal to 13 minutes, so as to allow for the overlapping auto calibration time.
   If there is enough time left, another count I_{1x} occurs four minutes before the end of sampling time 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

Figure 1 shows schematically the course of a measurement cycle.

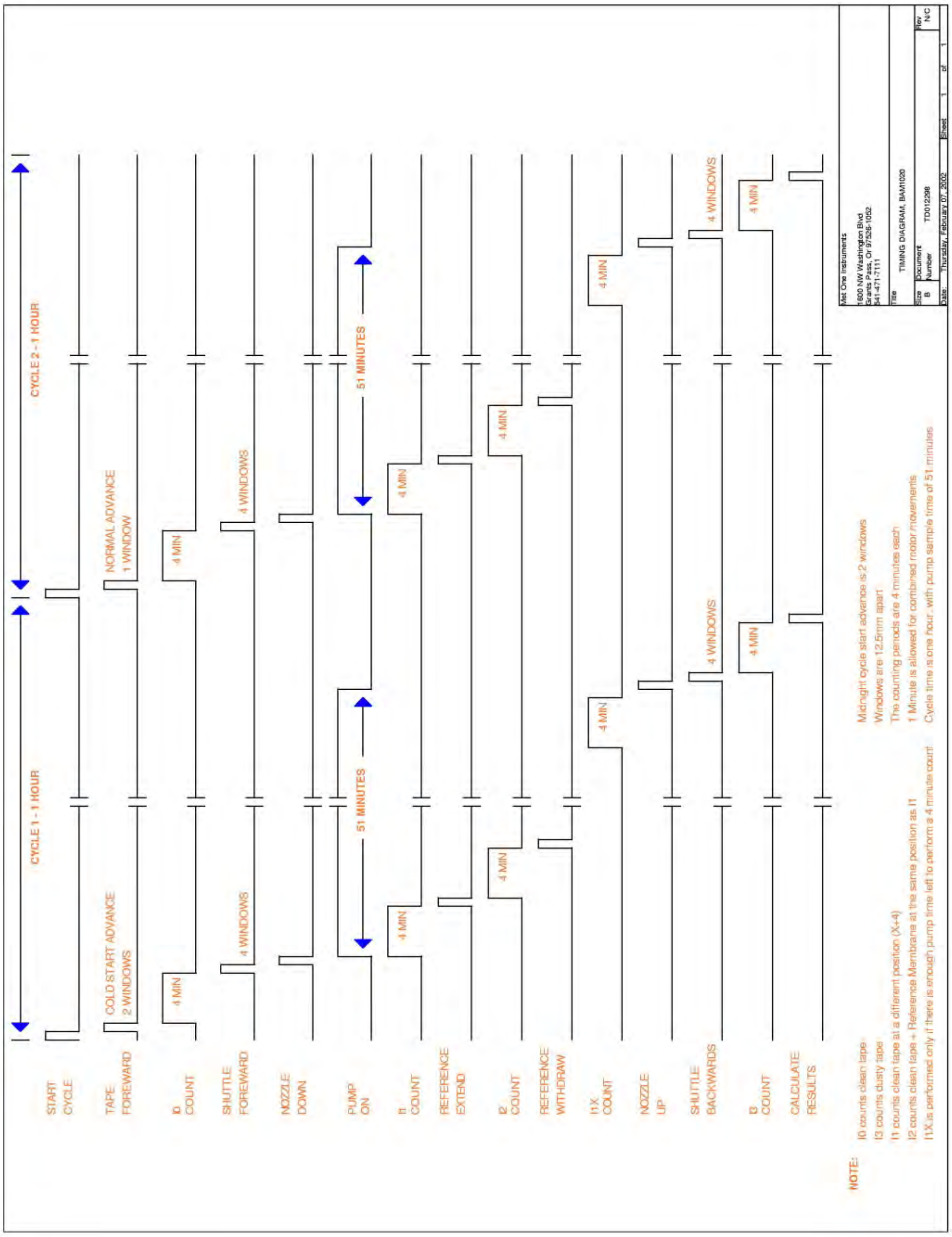

Figure 1: Timing diagram of the measurement cycle BAM-1020

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.

Furthermore, the measuring system allows an extension of the measuring time to 6 or 8 min in order to increase the precision of the radiometric measurement. The effective sampling time is then decreased to 46 respectively 42 min.

3.3 Extent and set-up of the measuring system

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

The tested measuring system consists of the PM10-sampling inlet (US (BX-802), EU (BX-809)), the sampling tube, the sample heater BX-830, the ambient temperature sensor BX-592 (incl. radiation protection shield), the air pressure sensor BX-594, the vacuum pump BX-127, the measuring instrument BAM-1020 (incl. glass fiber filter tape), the respective connecting tubes and lines as well as adapters, the roof flange as well as the manual in English language.

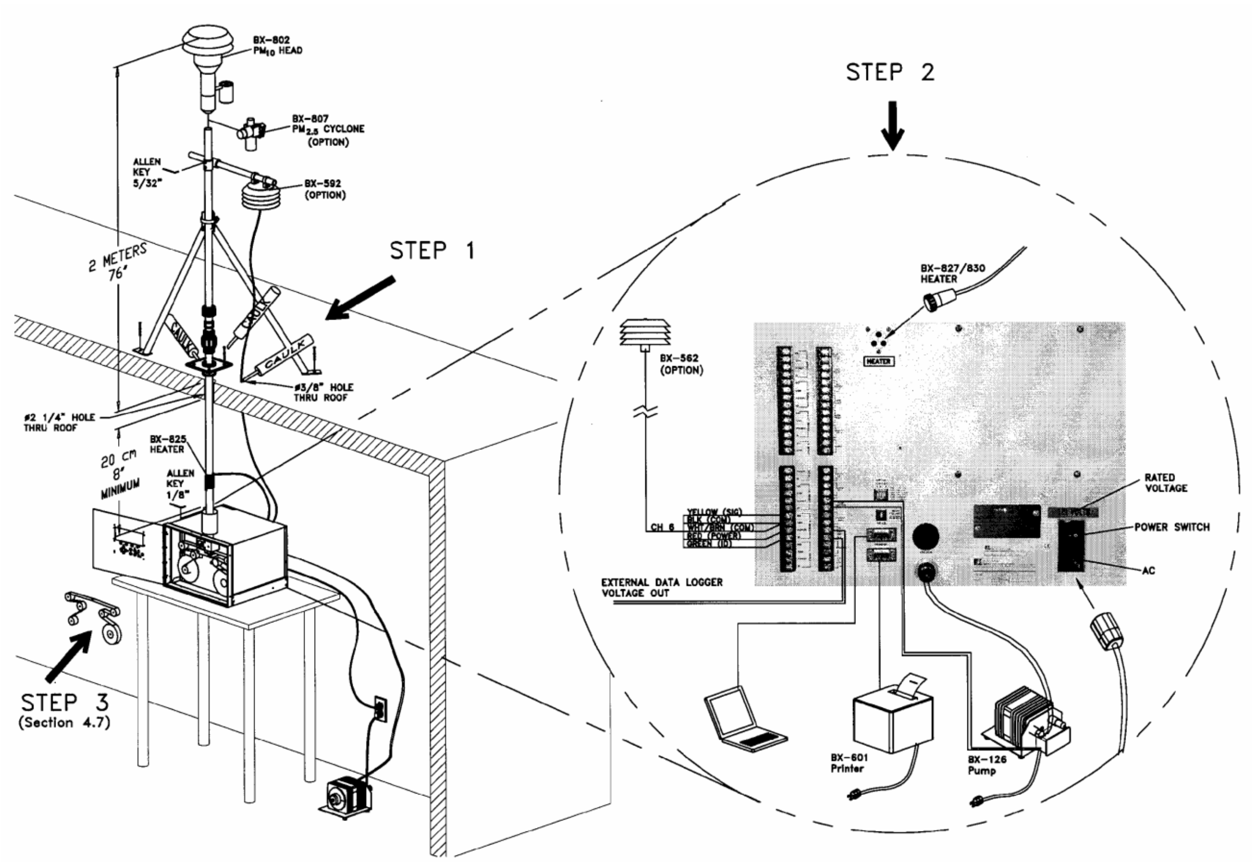

Figure 2: Overview measuring system BAM-1020

The measuring instrument BAM-1020 offers the possibility to connect up to 6 different sensors at the available analogue inputs. For example, besides the ambient temperature sensor BX-592 and the air pressure sensor BX-594, the connection of sensors for 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 imaginable.

Concerning the sampling inlets, either an US-PM10 sampling inlet (type: BX-802, manufacture and design according to Guideline EPA 40 CFR Part 50) or an EU-PM10 sampling inlet (type: BX-809) is available. The sampling inlet serves as a pre-separator for the suspended particulate matter, which is drawn from the ambient air. The instruments are operated with a constant, regulated volume flow of 16.67 l/min = 1.0 m³/h. As an alternative option, it is possible to use TSP-sampling inlets as well as PM2.5-cyclones, installed behind the PM10-sampling inlet.

Figure 3: US- PM10-sampling inlet BX-802 for BAM-1020

Figure 4: European PM10-sampling inlet BX-809 for BAM-1020

The sampling tube connects the sampling inlet and the measuring instrument. The length of the sampling tube was 2.4 m during the test, differing lengths can be manufactured with respect to the local conditions.

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 Functionality of the measuring system.

Figure 5: Sample heater BX-830

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. The measuring system BAM-1020 contains, besides the radiometric measurement part, the glass fiber filter tape incl. 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 the communication with the system.

Figure 6: Measuring instrument BAM-1020

Figure 7: Measuring systems BAM-1020, installed in measurement cabinet

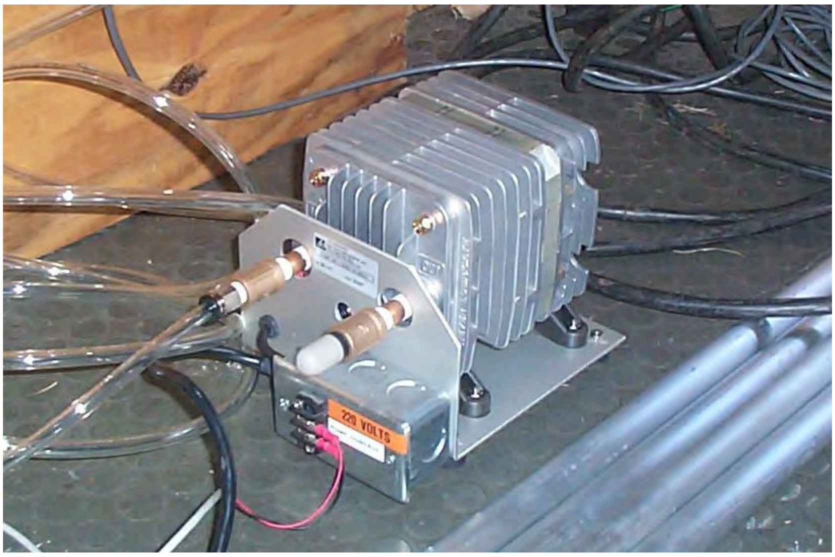

Figure 8: Vacuum pump

Figure 9: Front view BAM-1020, front cover opened

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.

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

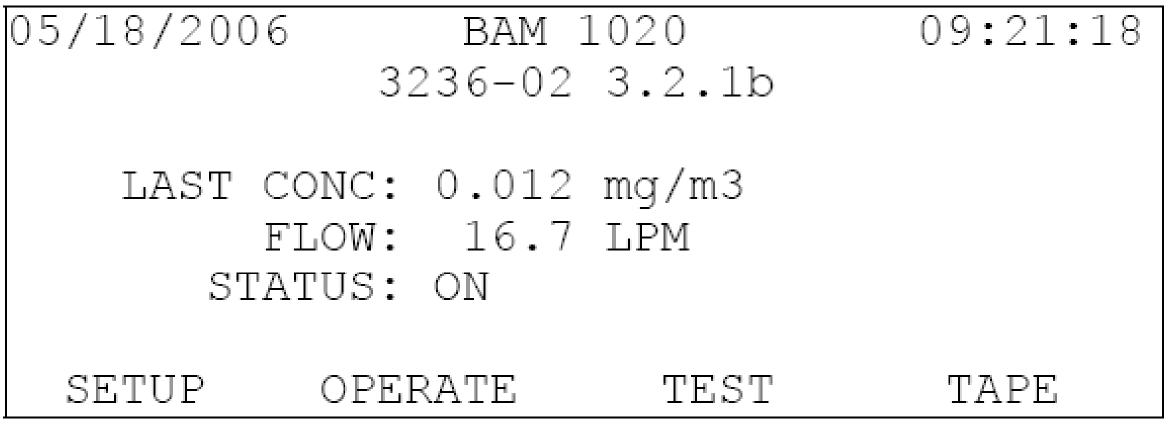

Figure 10: Main screen of the user display

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 (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 pass word, interfaces, external sensors and sample heater.

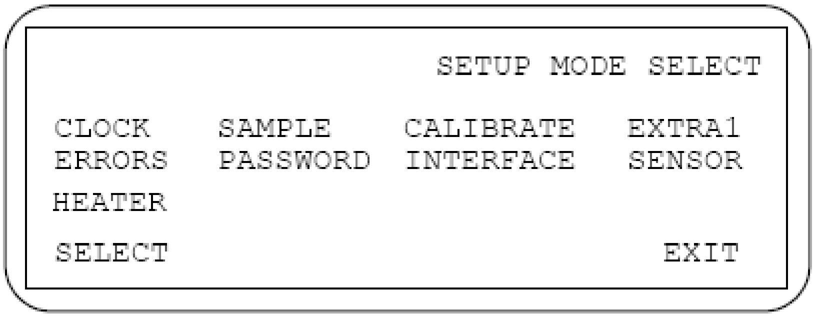

Figure 11: Menu „SETUP“

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 on „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. crack of filter tape).

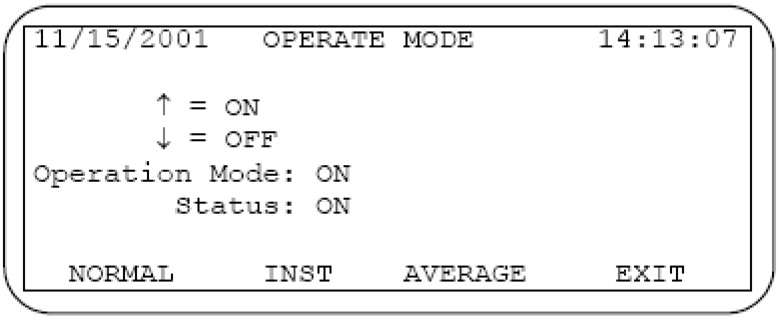

Figure 12: Menu „OPERATION“

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.

```
TEST  MENU

COUNT      PUMP       TAPE       DAC
CALIBRATE  INTERFACE  FLOW       ALIGN
HEATER     FILTER-T   RH


 SELECT                             EXIT
```

Figure 13: Menu „TEST“

4. Menu „TAPE“ (Press soft key „TAPE“):
   In the menu „TAPE“, it is possible to start at any time (= aborting the ongoing measurement) an extensive self test of the measuring system. In this self test, which takes around 4 min, several mechanic 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 after abort, in each case after a change of the filter tape.

```
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
```

Figure 14: Menu „TAPE/SELF TEST“

Besides the 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 the connection of printer, PC and modem. The communication with the instrument can be done for instance with the software HyperTerminal.

The serial interface #1 serves form 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:

```
---------------------------------------
|  > BAM-1020 <    System Menu      |
---------------------------------------

Select One of the Following:

0 - None
1 - Display Current Day Data
2 - Display All Data
3 - Display New Data
4 - Display System Configuration
5 - Display Date / Time
6 - CSV Type Report
7 - Display last 100 errors
8 - Display > BAM-1020 < Utility Commands
9 - Display Pointers

Press <Enter> to Exit a Selection
```

Figure 15: Communication via serial interface #1 – system menu

During the test work, the measured data have been readout and recorded once a week. They are suitable for further data integration to daily mean values in an external spreadsheet. The following picture shows an example for data, which have been recorded that way.

Station	1							
Time	Conc(mg)	Qtot(m3)	BP(mm)	WS(MPS)	no(V)	RH(%)	Delta(C)	AT(C)
9/28/2006 14:00	0.029	0.834	755.1	2.3	0.015	35	58.3	20.7
9/28/2006 15:00	0.031	0.834	754.9	2.1	0.012	33	58.4	21.7
9/28/2006 16:00	0.024	0.834	754.7	2.1	0.012	32	58.5	22
9/28/2006 17:00	0.03	0.834	754.5	2	0.011	32	58.5	22.3
9/28/2006 18:00	0.025	0.834	754.4	2	0.01	32	58.5	22.3
9/28/2006 19:00	0.029	0.834	754.3	2	0.01	33	58.5	21.5
9/28/2006 20:00	0.034	0.834	754.4	2	0.01	35	58.5	20.4
9/28/2006 21:00	0.048	0.834	754.5	2	0.01	36	58.5	19.1
9/28/2006 22:00	0.047	0.834	754.6	2	0.01	37	58.5	18.1
9/28/2006 23:00	0.051	0.834	754.8	2	0.01	37	58.5	17.1
9/29/2006 0:00	0.036	0.834	754.8	2	0.01	37	58.5	16.6
9/29/2006 1:00	0.035	0.834	754.7	2	0.01	37	58.5	16
9/29/2006 2:00	0.029	0.834	754.6	2	0.01	38	58.5	15.8
9/29/2006 3:00	0.03	0.834	754.6	2	0.01	38	58.5	15.3

Conc(mg):	concentration value in mg/m³, ambient conditions
Qtot(m³):	total sample volume in m³ (here at 50 min sampling time)
BP(mm-Hg):	ambient pressure in mm-Hg
WS:	wind velocity, not active in this case
no(V):	not active in this case
RH(%):	relative humidity below the filter tape in % - used for control of the sample heater
Delta(C):	difference ambient temperature – temperature at filter tape – used for control of the sample heater, not active in this case
AT(C):	ambient temperature in °C

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.

Table 2 contains an overview of important technical specifications of the ambient air measuring system BAM-1020.

Table 2: Technical data BAM-1020 (specifications of manufacturer)

Dimensions / Weight		BAM-1020
	Measuring instrument	365 x 483 x 457 mm / 21 kg (without pump)
	Sampling tube	2.4 m
	Sampling inlet	BX-802 (US) BX-809 (EU)
Power supply		100/115/230 V, 50/60 Hz
Power consumption		75 W, Detector Control Unit
Ambient conditions		
	Temperature	-30 - +60 °C (specification of manufacturer) +5 - +40 °C in suitability test
	Humidity	not condensing
Sample flow rate		16,67 l/min = 1 m³/h
Radiometry	**Source**	^{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 Default: 4 min
	Sampling time	depending on measuring time radiometry 50, 46 or 42 min Default: 50 min
Parameter sample heater BX-830 (optional)		
	maximum temperature difference filter tape – ambient temperature	Default: 5°C
	Nominal value for relative humidity at filter tape	Default: 45 %
Buffer capacity (internal)		30 – 200 days, depending on cycle time
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

4 Test program

4.1 General

The suitability test was carried out with two identical devices with the serial numbers SN 4924 and SN 4925.

At the beginning of the suitability test (February 2006), the software version 3236-02 2.65 was installed at the candidates. During the test work, the software was continuously enhanced and optimized up to the version 3236-02 3.2.1b. The changes have been checked and parts of the test work have been repeated, if necessary. There is no influence to expect on the instruments performance due to the performed alterations up to the version 3236-02 3.2.1b.

A field test at different field test sites over several months followed the laboratory test, during which the performance characteristics were assessed.

All determined concentrations are expressed in µg/m³, referred to standard conditions (273 K, 101.3 kPa). The additional evaluations according to Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods” were done with concentrations, converted to ambient conditions.

During the test work, there have been no changes on the instruments in manufacture and shape.

In the following report, the minimum requirements according to the considered guidelines [1,2,3] for each test point are stated with number and wording in the respective headlines.

4.2 Laboratory test

The laboratory test was performed with two identical devices of the type BAM-1020 with the serial numbers SN 4924 and SN 4925. According to the guidelines [1,2,3], the following test program in the laboratory was carried out:

- Description of the instrument functions
- Determination of the detection limit
- Determination of the dependence of zero point / sensitivity on the ambient temperature
- Determination of the dependence of zero point / sensitivity on the mains voltage

The following instruments have been used for the laboratory test for the determination of the performance characteristics:

- Climate chamber (temperature range from –20 °C to +50 °C, accuracy better than 1 °C)
- Adjustable isolating transformer
- Reference foil (built-in firmly in the devices)

The recording of the measured values was carried out via HyperTerminal with the aid of a desktop PC.

The results of the laboratory tests are compiled in point 6.

4.3 Field test

The field test was performed with two identical measuring systems.

Device 1:	No. SN 4924
Device 2:	No. SN 4925

The field investigations at the three different test sites were performed with an US-PM10-sampling inlet (BX-802). After having finished these investigations on Oct. 26, 2006, the candidates have been additionally equipped with the EU-PM10-sampling inlet (BX-809) at the field test site Cologne, Frankfurter Str. Target of these additional investigations has been the proof that the results, obtained with both different types of sampling inlets, do not differ significantly from each other and thus the operation of the system is basically possible with both types of sampling inlets.

For the field test, the following test program was established:

- Investigation of the comparability of the candidate systems according to DIN EN 12341 and (additionally) according to Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods”)
- Investigation of the comparability of the candidate system with the reference method (according to DIN EN 12341 and (additionally) according to Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods”)
- Additional investigations of the comparability of the two candidate systems according to DIN EN 12341 and (additionally) according to Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods” at field test site Cologne, Frankfurter Str. with EU-PM10-sampling inlet,
- Additionally investigation of the comparability of the candidate systems with the reference method (according to DIN EN 12341 and (additionally) according to Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods”) at field test site Cologne, Frankfurter Str. with EU-PM10-sampling inlet.
- Investigation of the constancy of the sampling flow rate
- Determination of the ability for calibration, erection of the analytical function
- Determination of the reproducibility R

- Determination of the drift behavior at zero and reference point
- Investigation of the tightness of the sampling system
- Examination of the dependence of the measured values on the air humidity, which is contained in the medium being measured
- Determination of the maintenance interval
- Determination of the availability
- Determination of the overall uncertainty of the candidate systems.

The following instruments have been used for the field test:

- Measurement cabinet of the TÜV Rheinland Immissionsschutz und Energiesysteme GmbH, climate-controlled on approximately 20 °C
- Weather station (WS 500 of the company ELV Elektronik AG) for the recording of meteorological data, e.g. ambient temperature, ambient pressure, relative humidity, wind velocity, wind direction and amount of precipitation
- 2 reference samplers according to point 5
- 1 classifying sampler according to point 5
- Flow meter DK 37 E (manufacturer: Krohne)
- Dry gas meter (manufacturer: Elster-Instromet)
- Measuring device for the registration of the power consumption Metratester 5 (manufacturer: Gossen Metrawatt)
- Reference foil (built-in firmly in the devices)

Two BAM-1020 – systems, two reference samplers and one classifying sampler have been used simultaneously for in each case 24 h during the field test. The classifying sampler as well as the reference samplers at the first field test site (LVS3) is working discontinuously, i.e. after sampling has occurred, the filters must be changed manually.

The impaction plates of the PM10 sampling inlets have been cleaned approximately every 4 weeks and have been prepared with silicon paste, which ensures a secure separation of the coarse particles on the impaction plate.

The flow rate of the candidate systems as well as of the reference samplers have been checked with a dry gas meter, connected with a hose to the air inlet of the instrument, before and after the field test, as well as before and after every change of test site.

Test sites and arrangement of the measuring systems

The measuring systems have been installed in the field test in that way, that only the sampling inlets are arranged outside of the measurement cabinet above its roof. The central units of both candidate systems and those of the reference samplers have been installed inside the climate-controlled measurement cabinet. The connection of the central units with the sampling inlets was realized for the BAM-1020 -systems and for the reference samplers with the sampling tube. Only at field test site Cologne, parking lot, the complete reference samplers (LVS3) have been installed outside on the roof due to lack of space (old measurement cabinet). The classifying sampler was generally installed outside on the cabinet roof.

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

Table 3: Field test sites

No.	Test site	Time period	Characterization
1	Cologne, parking lot	02/2006 –04/2006	Urban background
2	Titz-Roedingen	07/2006 – 09/2006	Rural situation
3	Cologne, Frankf. Str.	09/2006 – 11/2006	Traffic

Figure 16 to Figure 18 show the course of the PM-concentrations at the field test sites, which have been obtained with the reference systems.

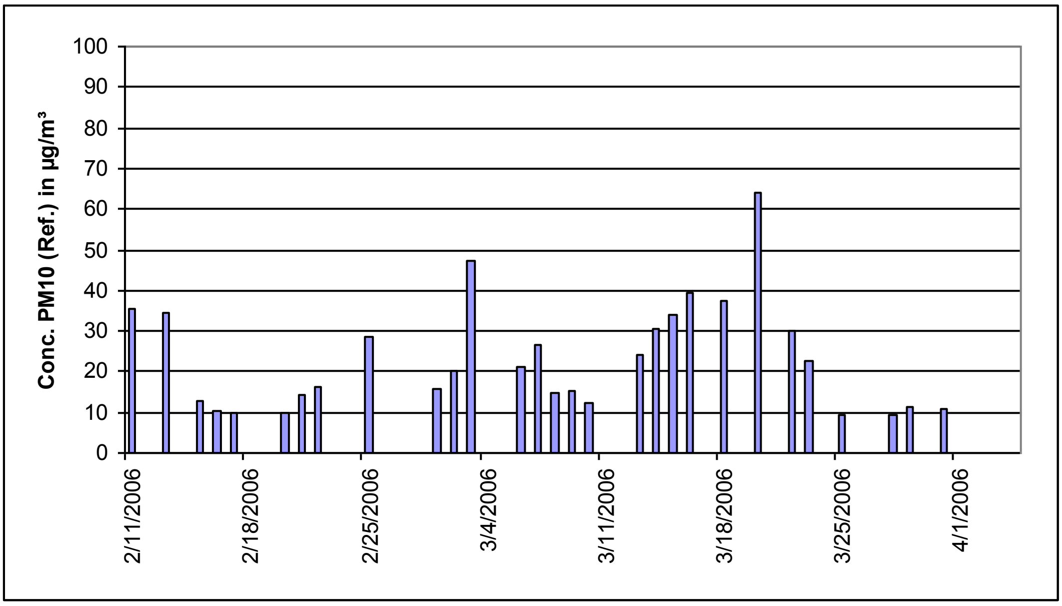

Figure 16: Course of PM10-concentrations (reference) at test site „Cologne, parking lot“

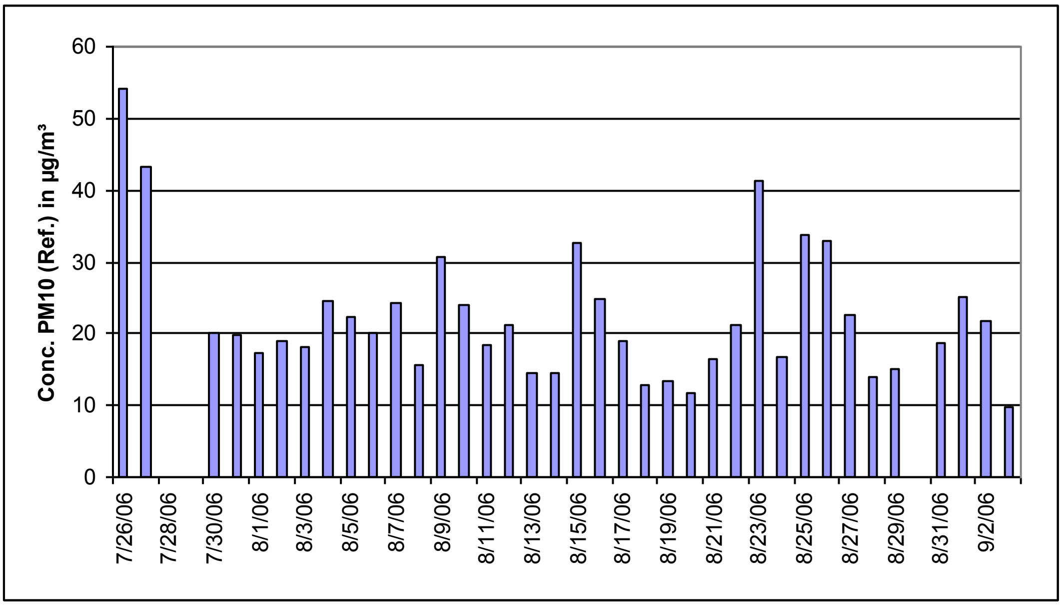

Figure 17: Course of PM10-concentrations (reference) at test site „Titz-Roedingen“

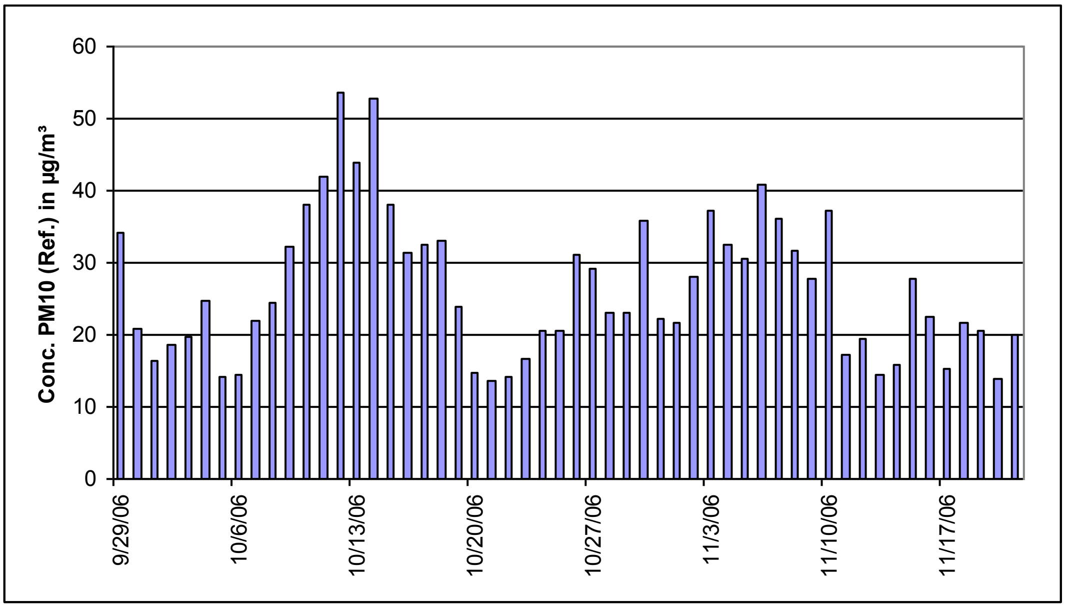

Figure 18: Course of PM10-concentrations (reference) at test site „Cologne, Frankfurter Str.“

The following pictures show the measurement cabinet at the field test sites Cologne (parking lot), Titz-Roedingen and Cologne (Frankfurter Str.).

Figure 19: Field test site „Cologne, parking lot“

Figure 20: Field test site „Titz-Roedingen“

Figure 21: Field test site Cologne, Frankfurter Str.

Together with the measuring systems for suspended particulate matter, a weather station for the determination of meteorological data has been installed at the measurement cabinet. There has been a continuous recording of ambient temperature, ambient pressure, relative air humidity, wind velocity, wind direction and precipitation. The data have been saved as 10min average values.

The set-up of the (old) cabinet itself (only at test site Cologne, parking lot), as well as the arrangement of the sampling probes has been characterized by the following dimensions:

- Height of roof of cabinet: 2.7 m
- Height of sampling point for candidate / reference / 1.2 / 1.3 / 1.0 m above roof
- classifying sampler(s) 3.9 / 4.0 / 3.7 m above ground
- Height of weather vane: 4.5 m above ground

The height of the sampling point of both candidate systems has been restricted due to the length of the sampling probe – the heights of the reference and classifying sampler(s) have been adapted accordingly.

- Distance between candidates: 0.7 m
- Distance candidate 1 – reference 1: 1.0 m
- Distance candidate 1 – reference 2: 1.6 m
- Distance candidate 2 – reference 1: 1.6 m
- Distance candidate 2 – reference 2: 1.0 m
- Distance candidate 1 – classifier 1: 2.1 m
- Distance candidate 2 – classifier 1: 2.8 m

The set-up of the (new) cabinet itself (since test site Titz), as well as the arrangement of the sampling probes has been characterized by the following dimensions:

- Height of roof of cabinet: 2.7 m
- Height of sampling point for candidate / reference / 1.2 / 1.2 / 1.0 m above roof
- classifying sampler(s) 3.9 / 3.9 / 3.7 m above ground
- Height of weather vane: 4.5 m above ground

The height of the sampling point of both candidate systems has been restricted due to the length of the sampling probe – the heights of the reference and classifying sampler(s) have been adapted accordingly.

- Distance between candidates: 1.4 m
- Distance candidate 1 – reference 1: 1.1 m
- Distance candidate 1 – reference 2: 1.8 m
- Distance candidate 2 – reference 1: 1.8 m
- Distance candidate 2 – reference 2: 1.1 m
- Distance candidate 1 – classifier 1: 1.0 m
- Distance candidate 2 – classifier 1: 1.0 m

The following Table 4 contains, besides an overview on the most important meteorological characteristics, which have been obtained at the 3 field test sites, also an overview on the suspended particulate matter conditions during the test period. Occasionally appearing ratios of suspended particulate matter >100 % have been rejected as implausible ones. All single values can be found in the annexes 4 and 5.

Table 4: Ambient conditions at the field test sites, daily mean values

	Cologne, parking lot	Titz-Roedingen	Cologne, Frankfurter Str. (US+EU-inlet)
No. of paired values (reference)	29	37	54
PM 10-ratio under ambient conditions [%]			
Range	26.1 – 91.3	42.3 – 96.3	55.5 – 99.7
Average	62.1	78.3	79.7
Ambient temperature [°C]			
Range	-3.2 – 15.6	12.7 – 26.5	5.5 – 19.1
Average	4.7	17.3	12.7
Ambient pressure [kPa]			
Range	98.2 – 102.4	99.2 – 101.0	98.9 – 102.4
Average	100.3	100.0	100.8
Rel. humidity [%]			
Range	33.7 – 89.1	55.8 – 81.7	63.8 – 82.7
Average	64.0	74.2	71.8
Wind velocity [m/s]			
Range	0.0 – 3.0	0.0 – 2.7	0.0 – 3.8
Average	1.1	0.4	1.1
Precipitation [mm]			
Range	0.0 – 15.2	0.0 – 35.7	0.0 – 19.8
Average	2.6	5.6	2.2

Sampling time

DIN EN 12341 requires a sampling time of 24 h. In case of low concentrations. A longer sampling time is allowed, likewise in case of higher concentrations, a shorter sampling time is allowed.

Whilst during the field test, the sampling time has always been 24 h (from 8 am until 8 am), the sampling time was decreased for some tests in the laboratory in order to get a higher number of measured values.

Handling of data

The determined pairs of measured values from the field investigations for the candidate as well as for the reference samplers have been undergone a statistical outlier test according to Grubbs (99 %) before the respective evaluations for each test site. This procedure has been done to avoid any effects from obviously implausible data on the results. Pairs of measured values that have been identified as significant outliers may be removed as long from the pool of values as the critical value for the test parameter has been fallen below target. However, for each test site, at maximum 5 % of the pairs of measured values may be removed in total.

Table 5 gives an overview on the results of the performed outlier tests (candidate and reference) for each test site. There have been no significant outliers identified.

Table 5: Overview on outliers – candidates and reference

	Reference PM10				BAM 1020, PM10			
Test site	n	Date	G1	G2	n	Date	SN 4924	SN 4925
Cologne, parking lot	29		no outliers		52		no outliers	
Titz-Rödingen	37		no outliers		37		no outliers	
Cologne, Frankfurter Str.	28		no outliers		28		no outliers	
Cologne, Frankfurter Str. EU-Head	26		no outliers		26		no outliers	

Filter handling – mass determination

The following filters have been used during the suitability test:

Table 6: 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. The filters for the classifying sampler have been inserted into the TSP-sampling heads in the weighing room, so only a changing of the entire sampling head on the field test sites has been necessary. 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.

Thus the filter treatment has been according to the requirements of EN 12341, annex C.

5 Reference method

According to DIN EN 12341, 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
PM10-sampling inlet

as well as

Filter Changer SEQ47/50, indoor version, (since test site Titz)
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2005
PM10-sampling inlet

2. as classifying sampler: Small Filter Device GS 050
Manufacturer: Derenda, Xantener Str. 22, Berlin, Germany
Date of manufacture: 1992
TSP-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-Roedingen”, 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 entire sampling system is conditioned by an ambient air layer – for this sake, the sampling tube itself 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 EN 12341. 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 PM10 – concentration has been determined by dividing the gravimetrically determined dust amount on the filter by the associated sampled air volume in standard m³ (DIN EN 12341) respectively in ambient m³ (according to Guidance „Demonstration of equivalence of ambient air monitoring methods“).

As there have been two reference samplers in parallel available throughout the entire test work, the final PM10 – concentrations for the evaluations have been determined by averaging the two results of the respective parallel measurements.

The classifying sampler samples the suspended particulate matter in the ambient air according to German guideline VDI 2463, sheet 7. It includes the entire range of particle sizes (TSP = **T**otal **S**uspended **P**articulate Matter).

On principle, the performance of the classifying sampler is the same than the performance of the reference sampler in unregulated operating mode. The flow rate is measured with an impeller anemometer and is indicated in m³ through a coupled electro-mechanical counter, which has an precision of reading of 0,01 m³. The nominal flow should be 2.7 to 2.8 m³/h. During the sampling, the hourly flow should not fall below 2.6 m³/h. The sampled volume is determined with the difference of counts at the beginning and at the end of sampling.

The conversion of the sampled volume to standard conditions (273 K, 101.3 kPa) was made with the determined quantities ambient temperature, ambient pressure and under pressure at the gas meter.

The TSP – concentration has been determined by dividing the gravimetrically determined dust amount on the filter by the belonging sampled air volume in standard m³. The PM10-TSP ratio was calculated by division of the PM10 reference concentration by the associated content of TSP.

The sampling time was set with the aid of an electrical timer.

6 Test results

6.1 4.1.1 Measured value display

The measuring system shall be fitted with a measured value display.

6.2 Equipment

No additional equipment required.

6.3 Performance of test

It was checked, if the measuring system has got a measured value display.

6.4 Evaluation

The measuring system has got a measured value display. The respective measured concentration value from the last measurement cycle can be indicated on different screens of the users display.

6.5 Findings

The measuring system has got a measured value display.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Figure 22 shows the users display with the measured concentration value from the last measurement cycle.

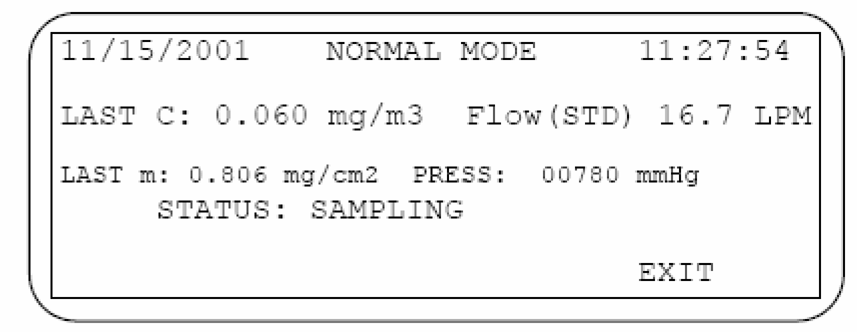

Figure 22: Display of measured concentration value from last measurement cycle

6.1 4.1.2 Easy maintenance

Necessary maintenance of the measuring systems should be possible without larger effort, if possible from outside.

6.2 Equipment

No additional equipment required.

6.3 Performance of test

The necessary periodical maintenance work was carried out according to the instructions of the manual.

6.4 Evaluation

The following maintenance work has to be carried out by the user:

1. Check of device status
   The device status can be monitored and controlled by controlling the system itself or controlling it on-line.
2. Monthly cleaning of the device. In any case, the measuring system has to be cleaned after each measuring activity.
3. 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.
4. At intervals of longest 4 weeks, the sampling inlet has to be cleaned and the impaction plate has to be re-lubricated with grease.
5. According to the manufacturer, a flow rate 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)
7. The area around the entry nozzle above the filter tape should be cleaned every 2 months. This cleaning can normally be done together with the replacement of the filter tape.
8. The muffler at the pump should be replaced semiannually.
9. The sensors for the ambient temperature, air pressure as well as the flow rate measurement have to be re-calibrated every 6 months according to the manual.
10. 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.
11. During the annual base maintenance, it is also to pay attention to the cleaning of the sampling tube.

For the performance of the maintenance work, the instructions in the manual have to be respected. All workings can be done with common tools.

It is generally recommended to perform a self-test according to chapter 4.9 of the manual after each action, which interrupts the measurement operation.

Findings

Maintenance work can be done from outside with common tools and justifiable operating expense. The workings according to point 6, 7, 10 and 11 have to be done at a shutdown of the system. These workings are only necessary in a two month interval as well as semiannually or annually. During the remaining time, the maintenance can be basically restricted to the check of contaminations, plausibility checks and possible status/error messages.

Minimum requirement fulfilled?   yes

6.6 Presentation of test results

The operations at the devices have been carried out during the test on basis of the operations and operational procedures, described in the manual. There couldn't be noticed any difficulties when adhering to the described procedures. All maintenance work could be done with common tools without any problems.

6.1 4.1.3 Functional check

If the operation or the functional check of the measuring system requires particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.
Test gas units included in the measuring system shall indicate their operational readiness to the measuring system by a status signal and shall provide direct as well as remote control via the measuring system.
The uncertainty of the test gas unit included in the measuring system shall not exceed 1 % of reference value B_2 within three months.

6.2 Equipment

Manual, filter tape, built-in reference foil.

6.3 Performance of test

It was checked, whether all instrument functions, which are listed in the manual, are available, can be activated and are fully functional.

To check the zero point of the radiometric measurement, it is resorted to the count rates I_1 respectively I_{1x}, which are determined on a clean filter tape spot at every measurement cycle (refer to point 3.2 Functionality of the measuring system). The zero point of the radiometric measurement is thereby determined manually according to the following equation:

$$C_0[mg/m^3] = \frac{A}{Q} * \frac{K}{mu2} * \ln\left(\frac{I_1}{I_{1X}}\right)$$

with

C_0	particle mass concentration at ZP	A	particle collection area (filter spot)
Q	sampling flow rate	K, mu2	coefficients beta measurement
I_1	initial beta count rate	I_{1X}	final beta count rate

In order to check the stability of the sensitivity of the radiometric measurement, it is resorted to the count rates I_1 (clean filter spot) respectively I_2 (clean filter spot + retracted reference foil), which are determined at every measurement cycle (refer to point 3.2 Functionality of the measuring system). The mass density m [mg/cm²] of the reference foil is calculated device-internal from the determined count rates. The value is continuously compared to the nominal value ABS, which has been determined in the factory (refer to appendix B in the manual of the respective device), and in case of a deviation of >5% to the nominal value, an error message is generated.
With the aid of the reference foil, only the mass density can be determined.

The measured values, which are required for calculation / evaluation, can be continuously recorded via the serial interface #2 (printer output).

Hence there is the possibility to determine the zero point (manually) as well as the reference value (automatically) for each measurement cycle (here: once per hour). The obtained hourly values at zero point and at reference point have been compressed to suitable mean values and been evaluated (e.g. 24-h-mean for drift investigations) within the scope of the test.

6.4 Evaluation

All instrument functions, which are listed in the manual, are available and can be activated. The current status of the system is monitored continuously and is indicated by a series of different status messages (operational, alarm and error status).

The measuring system carries out by default an internal check of the zero point (zero measurement, manually evaluable) as well as of the sensitivity (measurement with reference foil, automatically evaluated) at every measurement cycle. It must be pointed out, that only the mass density can be determined by the application of the reference foil. Therefore a direct comparison with the reference values is not possible. For the purpose of evaluation, the percental changes of the determined mass densities have been calculated.

6.5 Findings

All instrument functions, listed in the manual, are available, can be activated and are functioning. The current status of the system is monitored continuously and is indicated by a series of different status messages (operational, alarm and error status.
The results of the device-internal checks of the zero point and of the radiometric measurement during the field investigations are described in chapter 6.1 5.2.9 Drift of zero point and in chapter 6.1 5.2.10 Drift of measured value in this report.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Please refer to the points
6.1 5.2.9 Drift of zero point and
6.1 5.2.10 Drift of measured value

6.1 4.1.4 Set-up times and warm-up times

The set-up times and warm-up times shall be specified in the instruction manual.

6.2 Equipment

To check this minimum requirement, a clock has been additionally provided.

6.3 Performance of test

The measuring instruments have been put into operation according the descriptions of the manufacturer. The required times for set-up time and warm-up time was recorded separately.

Necessary constructional measures in the forefront of installation, like e.g. the set-up of a breakthrough in the roof of the cabinet have not been assessed here.

6.4 Evaluation

The set-up time contains the time need for the assembling of the measuring system until the start of operation.

The measuring system has to be installed independent from atmospheric conditions, e.g. in a climate-controlled measurement cabinet. Moreover the roof-lead through of the sampling tube requires larger constructional measures at the measurement location. A non-stationary application is therefore only assumed together with the belonging peripheral devices.

The following steps for the assembling of the measuring system are generally necessary:

- Unpacking and installation of the measuring system (in a rack or on a table)
- Connection of the sampling tube + PM 10-sampling inlet
- Installation of the heating system
- Connection of the pump
- Mounting of ambient air sensor + radiation protection shield (nearby the sampling in-let)
- Mounting of air pressure sensor
- Connection of all connecting and control lines
- Connection of power supply
- Switch-on of the measuring system
- Insertion of the filter tape
- Performance of self-test according to point 4.9 in the manual
- Optional check of the tightness
- Optional connection of peripheral recording and control systems (data logger, PC with HyperTerminal) to the respective interfaces

The performance of these actions and therewith the set-up time takes 1 hour.

The warm-up time contains the time need between the start of operation of the measuring system and the readiness for measurement.

After switching on the system and the successful performed self-test, the measuring system remains in a waiting position until reaching the next hour. When reaching the hour, the next measurement cycle as described in point 3.2 Functionality of the measuring system. The sampling starts according to the set measurement time for the radiometry (during the suitability test 4 min) immediately after the radiometric measurement I_0 (zero value of filter spot for sampling).

If required, possible changes of the basic parameterization of the measuring system can likewise be performed within few minutes by personal, familiar with the devices.

6.5 Findings

The set-up times and the warm-up times have been determined.

The measuring system can be operated at different measurement sites with manageable effort. The set-up time is approximately 1 hour and the warm-up time is at maximum the time need of a complete measurement cycle (here: 60 min).

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required here.

6.1 4.1.5 Instrument design

The instruction manual shall include specifications of the manufacturer regarding the design of the measuring system. The main elements are:
Instrument shape (e.g. bench mounting, rack mounting, free mounting)
Mounting position (e.g. horizontal or vertical mounting)
Safety requirements
Dimensions
Weight
Power consumption.

6.2 Equipment

For the test, a measuring device for recording the power consumption and a balance is used.

6.3 Performance of test

The set-up of the handed over devices was compared to the description in the manuals. The mentioned power consumption was checked over 24 h during normal operation at 3 days during the field test.

6.4 Evaluation

The measuring system has to be installed in horizontal mounting position, independent from atmospheric conditions. At this, the system should be installed on an even plane (e.g. table). The installation in a 19"rack is also possible.

The dimensions and the weights of the measuring system are in compliance with the specifications in the manual.

The power consumption of the measuring system with the used pump is specified by the manufacturer with at maximum 370 W. During 3 tests, each with 24 h, this specification was checked. At no time the mentioned value was exceeded during these investigations. The mean power consumption during the investigation for a measurement cycle of 60 min (50 min sampling) was approximately 150 W.

6.5 Findings

The specifications for the instrument design, mentioned in the manual, are complete and correct.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 4.1.6 Unintended adjustment

It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation.

6.2 Equipment

No additional equipment required for the testing of this minimum requirement.

6.3 Performance of test

The operation of the measuring device is carried out via the keypad at the front panel or via the RS232-interfaces and modem from an external computer.

The menu “Setup” is completely protected by a password, except for the sub-point time setting. An alteration of the set parameters without the knowledge of the password is not possible.

An adjustment of the sensors for the ambient temperature, air pressure as well as for the flow rate measurement in the menu „Test/Flow“ as well as of the sensors for the control of the sample heater in the menu „Test/Heater“ is only possible via several key sequences.

It must be pointed out, that the current measurement cycle is interrupted by pressing the keys „Setup“, „Test“ or „Tape“ and the next measurement cycle does not begin until the following next hour.

As an outside installation of the measuring device is not possible, additional protection is given by installation at locations, to which unauthorized people have no access (e.g. locked measurement cabinet).

6.4 Evaluation

Unintended adjustment of instrument parameters is avoided by the pass word protection of the menu “Setup”. The adjustment of sensors for the flow rate measurement and for the operation of the sample heater can only be done via several key sequences. Moreover there is an additional protection against unauthorized intervention by the installation in a locked measurement cabinet.

6.5 Findings

The measurement system is protected against unintended and unauthorized adjustment of instrument parameters. Moreover the measuring system has to be locked in a measurement cabinet.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 4.1.7 Data output

The output signals shall be provided digitally (e.g. RS 232) and/or as analogue signals (e.g. 4 mA to 20 mA).

6.2 Equipment

PC with software „HyperTerminal“, data logger Yokogawa (for analogue signal)

6.3 Performance of test

The test was carried out using an electronic data recording system of the type Yokogawa (analogue output, only test in laboratory) and a PC with the software „HyperTerminal“(digital output, serial interfaces RS 232 #1 & #2).

The data recording systems were connected to the analogue as well as digital output. The test was performed by comparing the measured values from the display, analogue and digital output in the laboratory.

6.4 Evaluation

The measured signals are offered at the rear side of the instrument in the following way:

Analogue:	0-1 resp. 10 V resp. 0–16 mA / 4-20 mA concentration range selectable
Digital:	via 2xRS 232-interface - via direct or modem connection to a computer, the device can be completely controlled – e.g. it is possible to readout the buffer with all data to past measurements (serial interface #1).

The determined measured values have been output analogue as well as digital in compliance with the indicated value in the instrument buffer.

6.5 Findings

The measured signals are offered analogue (0-1 resp. 10 V resp. 0–16 mA / 4-20 mA) and digital (via RS 232).

The connection of additional measuring and peripheral devices to the respective ports of the devices is possible.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Figure 23 shows a view of the rear side of the instrument with the respective measured value outputs.

Figure 23: View on rear of the device BAM-1020

6.1 4.2 Requirements for measuring systems for mobile application

Measuring systems for mobile application shall also comply with the requirements on measuring systems for stationary application in the case of mobile application. The measuring system shall be in a permanent operational stand-by mode during mobile application, e.g. measurements in running traffic, time-limited measurements at different locations or measurements on aircraft.

6.2 Equipment

No additional equipment required for the testing of this minimum requirement.

6.3 Performance of test

Within the scope of the field test, the measuring system was tested at several field test sites.

6.4 Evaluation

The measuring systems have been designed for fixed installation in a measurement station / a measurement cabinet. A mobile application is only possible together with a measurement cabinet.

The permanent operational stand-by for time-limited measurements at different sites is ensured when considering the conditions of mounting (choice of measurement site, infrastructure).

For a mobile application, the set-up and warm-up times have to be considered beside the mounting conditions.

6.5 Findings

In the context of the field test, the measuring system was operated at several different sites. A mobile application of the measuring system was not tested within the scope of the test.

Minimum requirement fulfilled? no

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 5.1 General

The manufacturer's specifications shall not be contrary to the results of the suitability test.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

The results of the tests are compared to the specifications in the manual.

6.4 Evaluation

The detected deviations between the first draft of the manual and the real instrument layout have been corrected.

6.5 Findings

Differences between instrument layout and manuals have not been observed.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Refer to point 6.4 of this module.

6.1 5.2.1 Measuring range

The upper limit of measurement range of the measuring systems shall be greater or equal to reference value B_2.

6.2 Equipment

No additional equipment required for the testing of this minimum requirement.

6.3 Performance of test

It was tested, whether the upper limit of measuring range of the measuring system is greater or equal to the reference value B_2.

6.4 Evaluation

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/m³.

During the suitability test, the measuring range has been set to 0 – 1.000 mg/m³ = 0 – 1000 µg/m³.

Measuring range: 0 – 1.000 µg/m³ (standard)

Reference value: VDI: B_2 = 200 µg/m³.

6.5 Findings

A measuring range of 0 -1,000 µg/m³ is set by default. Other measuring ranges in the range between at minimum 0-100 µg/m³ and at maximum 0-10,000 µg/m³ are possible.

The upper limit of measuring range of the measuring system is greater than the reference value B_2.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 5.2.2 Negative output signals

Negative output signals or measured values may not be suppressed (life zero).

6.2 Equipment

No additional equipment required for the testing of this minimum requirement.

6.3 Performance of test

It has been tested during the laboratory test as well as during the field test, if the measuring system can also output negative measured values.

6.4 Evaluation

The measuring system can output negative values via the display as well as via the analogue and digital outputs.

6.5 Findings

Negative measuring signals are displayed directly and are output correctly via the respective measured value outputs by the measuring system.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 5.2.3 Analytical function

The relationship between the output signal and the value of the air quality characteristic shall be represented by the analytical function and determined by regression analysis.

6.2 Equipment

Refer to module 5.3.1.

6.3 Performance of test

For particulate measuring systems, this test has to be performed according to the minimum requirement 5.3.1 „Equivalency of the sampling system“.

6.4 Evaluation

The comparability of the measuring systems according to the minimum requirement 5.3.1 „Equivalency of the sampling system“ has been proved within the scope of the test (refer to module 5.3.1).

For the determination of the calibration respectively analytical function, it has been accessed to the complete dataset (94 valid paired values).

The characteristics of the calibration function

$$y = m * x + b$$

have been determined by linear regression. The analytical function is the reversion of the calibration function. It is:

$$x = 1/m * y - b/m$$

The slope m of the regression line characterizes the sensitivity of the measuring device; the ordinate intercept b characterizes the zero point.

There are the following characteristics, mentioned in Table 7.

Table 7: Results of the calibration and analytical function

Device-No.	Calibration function		Analytical function	
	Y = m * x + b		x = 1/m * y - b/m	
	m	b	1/m	b/m
	µg/m³ / µg/m³	µg/m³	µg/m³ / µg/m³	µg/m³
Device 1 (SN 4924)	0.9679	1.5452	1.0332	-1.5954
Device 2 (SN 4925)	0.9866	2.2503	1.0136	-2.2809

6.5 Findings

A statistically secured relationship between the reference method and the instrument reading could be proved.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Refer to module 5.3.1.

6.1 5.2.4 Linearity

Reliable linearity is given, if deviations of the group averages of measured values about the calibration function are smaller than 5 % of B_1 in the range of zero to B_1, and smaller than 1 % of B_2 in the range of zero to B_2.

6.2 Equipment

Refer to module 5.3.1.

6.3 Performance of test

For particulate measuring systems, this test has to be performed according to the minimum requirement 5.3.1 „Equivalency of the sampling system".

6.4 Evaluation

Refer to module 5.3.1.

6.5 Findings

For particulate measuring systems, this test has to be performed according to the minimum requirement 5.3.1 „Equivalency of the sampling system".

Refer to module 5.3.1.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Refer to module 5.3.1.

6.1 5.2.5 Detection limit

The detection limit of the measuring system shall be smaller or equal to reference value B_0. The detection limit shall be determined in the field.

6.2 Equipment

Filter tape

6.3 Performance of test

The determination of the detection limit has been carried out for the candidates SN 4924 and SN 4925 by evaluating the device-internal check of the zero point of the radiometric measurement while operating the measuring system in the laboratory over a period of 18 days. Hereby the count rates I_1 respectively I_{1x}, which are determined on a clean filter tape spot at every measurement cycle (refer to point 3.2 Functionality of the measuring system) have been evaluated.

The obtained hourly values at the zero point have been compressed to 24-h-mean values and have been evaluated within the scope of the test.

6.4 Evaluation

The detection limit X is determined from the standard deviation s_{x0} of the measured values at the zero point (24-h-mean of the device-internal performed zero measurements on the filter tape) of the candidates. It corresponds to the mean value of the zero measurements, added with the (multiplied with student factor) standard deviation of the mean value $\overline{x_0}$ of the measured values x_{0i} during suction of dust-free sampling air for the respective candidate.

$$X = \overline{x_0} + t_{n-1;0,95} \cdot s_{x0} \qquad \text{with} \cdot s_{x0} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

Reference value: VDI: $B_0 = 2$ µg/m³

6.5 Findings

The detection limit has been determined from the investigations to 1.7 µg/m³ for device 1 (SN 4924) and to 1.9 µg/m³ for device 2 (SN 4925).

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 8: Detection limit

		Device SN 4924	Device SN 4925
Number of values n		18	18
Mean of zero values $\overline{x_0}$	µg/m³	0.54	0.87
Standard deviation of values s_{x0}	µg/m³	0.55	0.49
Student factor $t_{n-1;0,95}$		2.12	2.12
Detection limit X	µg/m³	1.69	1.90

The single values for the determination of the detection limit can be found in annex 1 in the appendix.

6.1 5.2.6 Response time

The response time (90%-time) of the measuring system shall be smaller or equal to 5 % of the averaging time (180 s).

According to Guideline VDI Sheet 3, point 5.3, this test point is not relevant for particulate measuring systems with pre-separation, based on a physical measurement method.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Findings

Not applicable.

Minimum requirement fulfilled? -

6.6 Presentation of test results

Not applicable.

6.1 5.2.7 Dependence of the zero point on ambient temperature

The temperature dependence of the measured value at zero concentration shall not exceed the reference value B_0 if ambient temperature is changed by 15 K in the range of +5°C to +20°C or by 20 K in the range of +20°C to +40°C.

6.2 Equipment

Climate chamber for the temperature range +5 to +40 °C, filter tape.

6.3 Performance of test

For the investigation of the dependence of the zero point on the ambient temperature, the complete measuring systems have been operated in the climate chamber. For both candidates SN 4924 and SN 4925, the device-internal check of the zero point of the radiometric measurement has been determined while operating the measuring system. Hereby the count rates I_1 respectively I_{1x}, which are determined on a clean filter tape spot at every measurement cycle (refer to point 3.2 Functionality of the measuring system) have been evaluated.

The ambient temperatures in the climate chamber were varied in triple repetition in the order 20 °C – 5 °C – 20 °C – 40 °C – 20 °C. After a respective time for equilibration of approximately 3 h per temperature step, the measured values at the zero point have been recorded. The obtained hourly values at the zero point have been compressed to 7-h-mean values respectively 21-h-mean values and have been evaluated within the scope of the test. The relative humidity was kept constant.

6.4 Evaluation

The measured values for the concentration were recorded via the serial interface #2 and were evaluated. The absolute deviation in µg/m³ per temperature step, related to the start point of 20 °C, has been considered

Reference value: VDI: B_0 = 2 µg/m³.

6.5 Findings

Considering the values offered from the device, a maximum influence of the ambient temperature on the zero point of 0.7 µg/m³ could be detected.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 9: Dependence of the zero point on the ambient temperature, deviation in µg/m³, mean values of three measurements

Temperature		Deviation	
Start temperature	End temperature	Device 1 (SN 4924)	Device 2 (SN 4925)
°C	°C	µg/m³	µg/m³
20	5	0.0	0.3
5	20	0.5	0.1
20	40	0.7	0.0
40	20	0.3	0.2

Also in the single steps (21-h-mean), no deviations > 1.4 µg/m³ could be determined. The results of the 3 single measurements (21-h-mean) can be found in annex 2 in the appendix.

6.1 5.2.8 Dependence of the measured value on ambient temperature

The temperature dependence of the measured value in the range of reference value B_1 shall not exceed 5 % of the measured value if ambient temperature is changed by 15 K in the range of +5°C to +20°C or by 20 K in the range of +20°C to +40°C.

6.2 Equipment

Climate chamber for the temperature range +5 - +40 °C, built-in reference foil.

6.3 Performance of test

For the investigation of the dependence of the measured values on the ambient temperature, the complete measuring systems have been operated in the climate chamber. To check the stability of the sensitivity of the radiometric measurement for the candidates SN 4924 and SN 4925, it is resorted to the count rates I_1 (clean filter spot) respectively I_2 (clean filter spot + retracted reference foil), which are determined at every measurement cycle (refer to point 3.2 Functionality of the measuring system). The mass density m [mg/cm²] of the reference foil is calculated device-internal from the determined count rates.

The ambient temperatures in the climate chamber were varied in triple repetition in the order 20 °C – 5 °C – 20 °C – 40 °C – 20 °C. After a respective time for equilibration of approximately 3 h per temperature step, the measured values at the reference point have been recorded. The obtained hourly values at the reference point have been compressed to 7-h-mean values respectively 21-h-mean values and have been evaluated within the scope of the test. The relative humidity was kept constant .

6.4 Evaluation

The percental changing of the determined mass density value (built-in reference foil) for each temperature step, related to the start point of 20 °C, has been considered.

As remark it should be mentioned, that only masses and no concentration values can be simulated by the application of the built-in reference foil, a consideration in the range of B_1 (= 40 µg/m³) was not possible because of this reason.

6.5 Findings

There have been no deviations > 0.1 % for device 1 (SN 4924), and no deviations > 0.2 % for device 2 (SN 4925), related to the start value at 20 °C.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 10: Dependence of the sensitivity on the ambient temperature SN 4924 & SN 4925, deviation in %, mean value of three measurements

Temperature		Deviations	
		Device 1 (SN 4924)	Device 2 (SN 4925)
Start temperature °C	End temperature °C	built-in reference foil %	built-in reference foil %
20	5	0.1	0.2
5	20	0.1	0.0
20	40	0.0	-0.1
40	20	0.0	0.1

Also in the single steps, no deviations > 0.3 % could be found. The single results can be found in annex 2 in the appendix.

6.1 5.2.9 Drift of zero point

The temporal change in the measured value at zero concentration shall not exceed the reference value B_0 in 24 h and in the maintenance interval.

6.2 Equipment

Filter tape.

6.3 Performance of test

The test was carried out in the context of the field test over a time period of approximately 6 months. The daily zero point check, required in the test plan, is on principle possible for this particulate measuring system by evaluating the device-internal check of the zero point of the radiometric measurement. Hereby the count rates I_1 respectively I_{1x}, which are determined on a clean filter tape spot at every measurement cycle (refer to point 3.2 Functionality of the measuring system) are evaluated.

For the evaluation, the automatically calculated, hourly values at the zero point have been compressed to a 24-h-mean value and have been evaluated for averagely one day per week during the complete field test. Within the scope of the test, a daily evaluation of the complete dataset has been renounced due to reasons of practicability (large amount of data). However an exemplary evaluation and graphic presentation of the results for the time period from 10/03/2006 until 10/16/2006 has been carried out.

The evaluation of the internal zero point measurement leads to no interruption of the ongoing measuring operation at all.

6.4 Evaluation

The evaluation is carried out on basis of the measurement results of the regular internal zero point measurements by comparison the respective values with the measured values from the previous test and with the measured values from the initial test.

The regression analysis for the zero point drift leads to the following values for the 1-week-drift:

SN 4924: 0.0095 µg/(m³*Week) + 0.3461 µg/m³

SN 4925: 0.002 µg/(m³*Week) + 0.6847 µg/m³

Hence there are the following medium temporal changes in the maintenance interval of 4 weeks:

SN 4924: 0.384 µg/m³ in 4 weeks

SN 4925: 0.693 µg/m³ in 4 weeks

6.5 Findings

The measuring system carries out a regular device-internal check of the zero point of the radiometric measurement during each measurement cycle. This test leads to no interruption of the ongoing measuring operation at all. The obtained values, determined within the scope of the drift investigations, are within the allowed limits in the maintenance interval.

The determined single measured values are normally within the allowed limits. Merely for SN 4924, the single measured value on 08/05/2006 has been outside the allowed tolerance interval. However there has been no adjustment of the measuring system at the zero point.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 11 and Table 12 contain the determined measured values for the zero point and the calculated deviations, related to the previous value and related to the initial value in µg/m³. Figure 24 and Figure 25 show a graphic presentation of the zero point drift over the time period of testing. Figure 26 and Figure 27 show exemplarily the results of the daily evaluation of the device-internal zero point check during the time period from 10/03/2006 until 10/16/2006.

Table 11: Zero point drift SN 4924

Date	Measured value (single value)	Deviation to previous value (single value)	Deviation to start value (single value)
	µg/m³	µg/m³	µg/m³
02/11/2006	1.03	-	-
02/18/2006	1.01	-0.02	-0.02
02/25/2006	0.56	-0.45	-0.47
03/04/2006	-0.44	-1.00	-1.47
03/11/2006	-0.55	-0.11	-1.58
03/18/2006	-0.46	0.09	-1.49
03/25/2006	-0.06	0.40	-1.09
04/01/2006	0.45	0.51	-0.58
08/05/2006	2.20	1.75	1.17
08/12/2006	0.61	-1.59	-0.42
08/19/2006	1.20	0.59	0.17
08/26/2006	1.16	-0.04	0.13
09/02/2006	0.78	-0.38	-0.25
10/01/2006	0.13	0.65	-0.90
10/07/2006	0.66	0.53	-0.37
10/14/2006	0.50	0.16	-0.53
10/21/2006	-0.19	-0.69	-1.22
10/28/2006	1.47	1.66	0.44
11/04/2006	0.51	-0.96	-0.52
11/11/2006	0.20	-0.31	-0.83
11/18/2006	-0.32	-0.52	-1.35

Table 12: Zero point drift SN 4925

Date	Measured value (single value)	Deviation to previous value (single value)	Deviation to start value (single value)
	µg/m³	µg/m³	µg/m³
02/11/2006	0.44	-	-
02/18/2006	-0.08	-0.52	-0.52
02/25/2006	1.91	1.99	1.47
03/04/2006	0.45	-1.46	0.01
03/11/2006	0.23	-0.22	-0.21
03/18/2006	1.28	1.05	0.84
03/25/2006	0.25	-1.03	-0.19
04/01/2006	0.79	0.54	0.35
08/05/2006	1.08	0.29	0.64
08/12/2006	1.12	0.04	0.68
08/19/2006	-0.45	-1.57	-0.89
08/26/2006	1.47	1.92	1.03
09/02/2006	0.59	-0.88	0.15
10/01/2006	1.39	0.80	0.95
10/07/2006	1.35	-0.04	0.91
10/14/2006	0.54	-0.81	0.10
10/21/2006	0.23	-0.31	-0.21
10/28/2006	0.91	0.68	0.47
11/04/2006	0.33	-0.58	-0.11
11/11/2006	0.81	0.48	0.37
11/18/2006	0.41	-0.40	-0.03

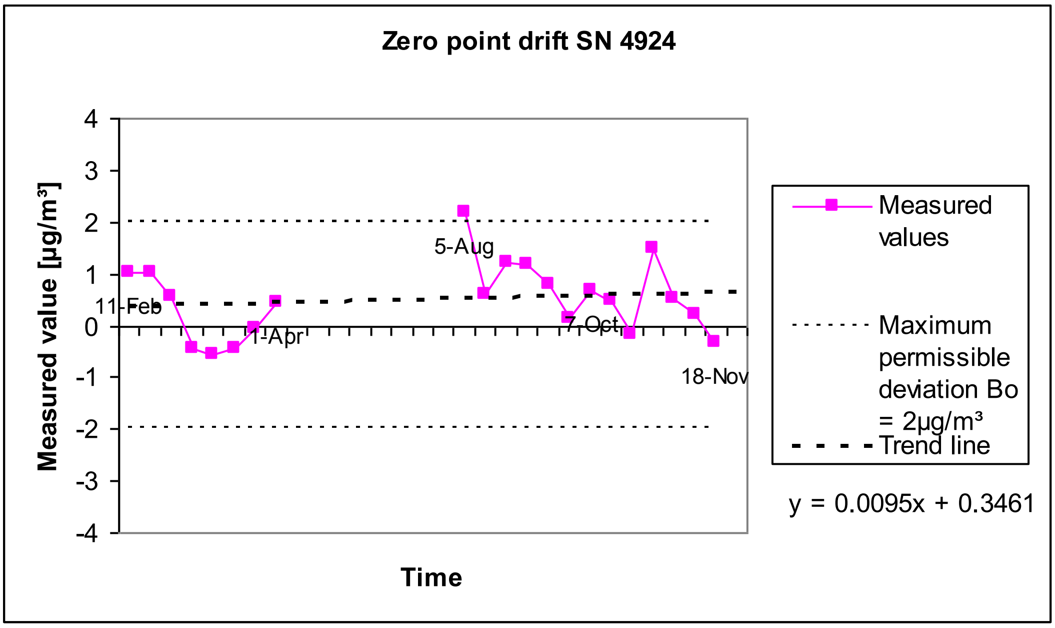

Figure 24: Zero point drift SN 4924 (complete testing period)

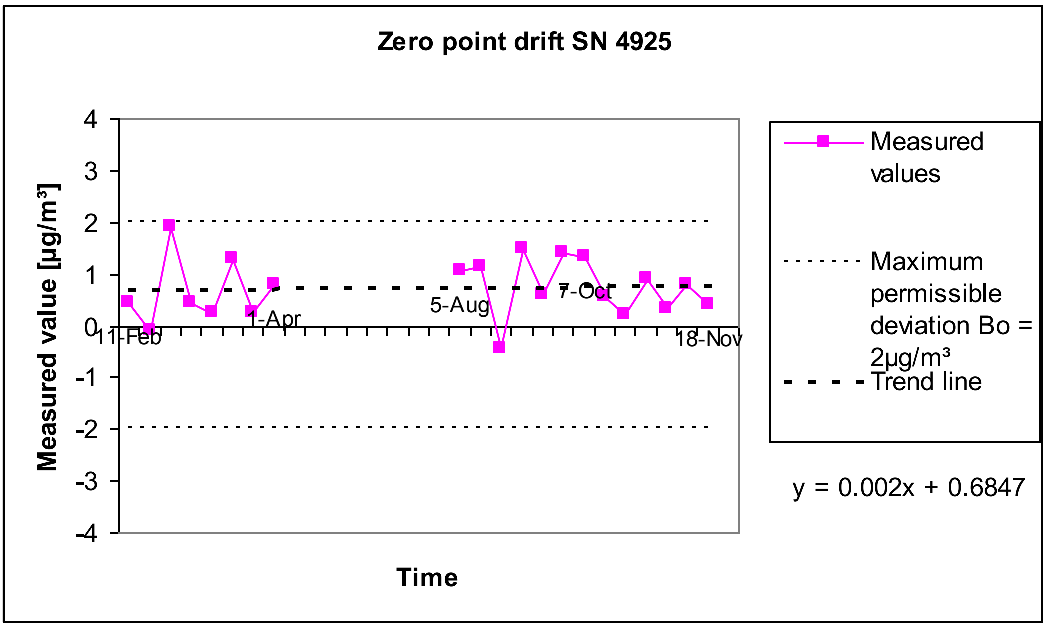

Figure 25: Zero point drift SN 4925 (complete testing period)

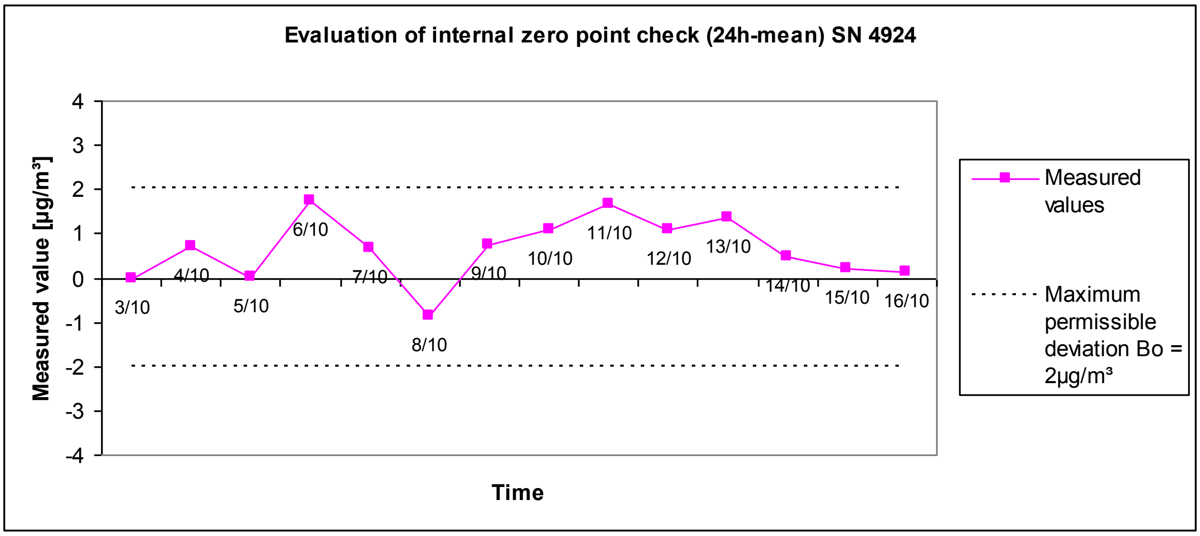

Figure 26: Zero point drift SN 4924 (10/03/2006-10/16/2006)

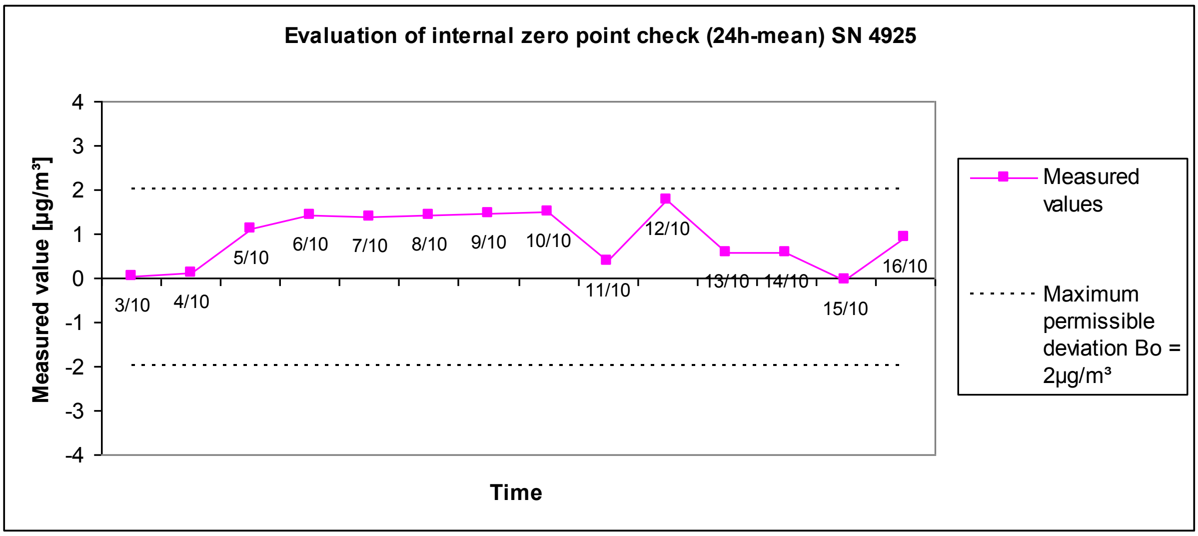

Figure 27: Zero point drift SN 4925 (10/03/2006-10/16/2006)

6.1 5.2.10 Drift of measured value

The temporal change in the measured value in the range of reference value B_1 shall not exceed 5 % of B_1 in 24 h and in the maintenance interval.

6.2 Equipment

Built-in reference foil.

6.3 Performance of test

The test has been performed within the scope of the field test over a time period of approximately 6 months. The daily reference point check, required in the test plan, is on principle possible for this particulate measuring system by evaluating the device-internal check of the stability of the sensitivity of the radiometric measurement. Hereby it is resorted to the count rates I_1 (clean filter spot) respectively I_2 (clean filter spot + retracted reference foil), which are determined at every measurement cycle (refer to point 3.2 Functionality of the measuring system). The mass density m [mg/cm²] of the reference foil is calculated device-internal from the determined count rates.

For the evaluation, the automatically calculated, hourly values at the reference point have been compressed to a 24-h-mean value and have been evaluated for averagely one day per week during the complete field test. Within the scope of the test, a daily evaluation of the complete dataset has been renounced due to reasons of practicability (large amount of data). However an exemplary evaluation and graphic presentation of the results for the time period from 10/03/2006 until 10/16/2006 has been carried out.

The evaluation of the internal reference point measurement leads to no interruption of the ongoing measuring operation at all.

6.4 Evaluation

The evaluation is carried out on basis of the measurement results of the internal reference point measurements by comparison the respective values with the measured values from the previous test and with the measured values from the initial test.

Hereby the percental changing of the determined mass density value in the interval of 1 week as well as related to the initial value has been considered

The regression analysis for the reference point drift leads to the following values for the 1-week-drift:

SN 4924: -0.0065 % / Week + 0.4619 %

SN 4925: 0.0202 % / Week - 0.1036 %

Hence there are the following medium temporal changes in the maintenance interval of 4 weeks:

SN 4924: 0.436 % in 4 weeks

SN 4925: -0.023 % in 4 weeks

As remark it should be mentioned, that only mass densities and no concentration values can be simulated by the application of the reference foil, a consideration in the range of B_1 (= 40 µg/m³) was not possible because of this reason.

6.5 Findings

The determined single measured values are normally within the allowed limits. Merely for SN 4924, the single measured value on 08/05/2006 has been outside the allowed tolerance interval. However there has been no adjustment of the measuring system at the zero point.

The measuring system carries out a regular device-internal check of the sensitivity of the radiometric measurement during each measurement cycle. This test leads to no interruption of the ongoing measuring operation at all. The values for the drift of the sensitivity, determined within the scope of the test, were at maximum 0.44 % (SN 4924) respectively -0.02 % (SN 4925) in the maintenance interval.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

The deviations of the measured values in % of the respective previous value respectively to the initial value are shown in Table 13 and in Table 14. Figure 28 and Figure 29 show a graphic presentation of the drift of the measured values (referred to the initial value) for the reference foil. Figure 30 and Figure 31 show exemplarily the results of the daily evaluation of the device-internal reference point check during the time period from 10/03/2006 until 10/16/2006.

Table 13: Drift of measured value SN 4924

Date	Measured value (single value)	Deviation to previous value (single value)	Deviation to start value (single value)
	µg/cm²	%	%
02/11/2006	829.2	-	-
02/18/2006	823.4	-0.7	-0.7
02/25/2006	822.8	-0.1	-0.8
03/04/2006	824.5	0.2	-0.6
03/11/2006	822.5	-0.2	-0.8
03/18/2006	827.4	0.6	-0.2
03/25/2006	824.2	-0.4	-0.6
04/01/2006	824.9	0.1	-0.5
08/05/2006	825.9	0.1	-0.4
08/12/2006	825.7	0.0	-0.4
08/19/2006	825.5	0.0	-0.5
08/26/2006	825.8	0.0	-0.4
09/02/2006	825.4	-0.1	-0.5
10/01/2006	823.0	-0.3	-0.8
10/07/2006	824.0	0.1	-0.6
10/14/2006	824.2	0.0	-0.6
10/21/2006	822.9	-0.1	-0.8
10/28/2006	823.7	0.1	-0.7
11/04/2006	823.9	0.0	-0.6
11/11/2006	823.7	0.0	-0.7
11/18/2006	822.5	-0.1	-0.8

Table 14: Drift of measured value SN 4925

Date	Measured value (single value)	Deviation to previous value (single value)	Deviation to start value (single value)
	µg/cm²	%	%
02/11/2006	811.3	-	-
02/18/2006	810.4	-0.1	-0.1
02/25/2006	809.1	-0.2	-0.3
03/04/2006	808.8	0.0	-0.3
03/11/2006	812.8	0.5	0.2
03/18/2006	811.1	-0.2	0.0
03/25/2006	811.6	0.1	0.0
04/01/2006	812.0	0.1	0.1
08/05/2006	815.3	0.4	0.5
08/12/2006	815.5	0.0	0.5
08/19/2006	814.4	-0.1	0.4
08/26/2006	816.4	0.2	0.6
09/02/2006	814.8	-0.2	0.4
10/01/2006	814.4	-0.1	0.4
10/07/2006	814.6	0.0	0.4
10/14/2006	813.5	-0.1	0.3
10/21/2006	812.9	-0.1	0.2
10/28/2006	813.7	0.1	0.3
11/04/2006	813.6	0.0	0.3
11/11/2006	813.4	0.0	0.3
11/18/2006	815.7	0.3	0.5

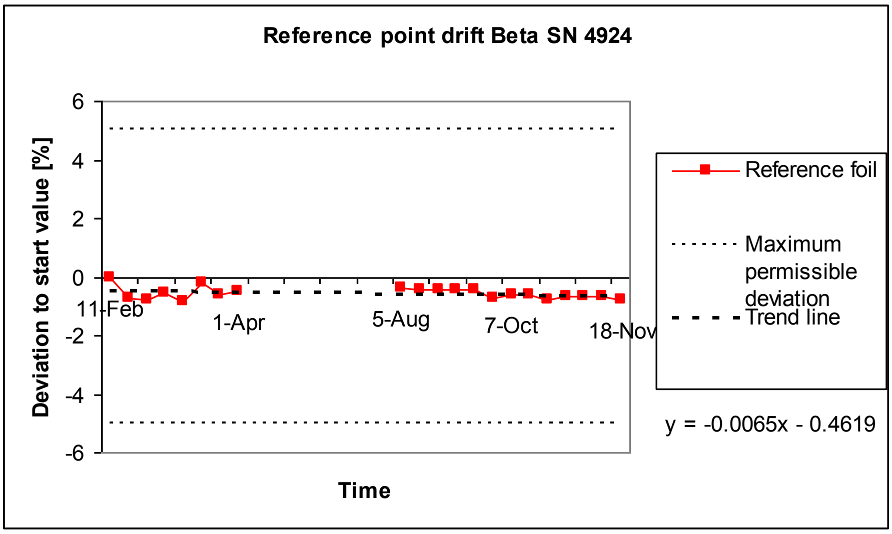

Figure 28: Drift of measured value SN 4924 (complete testing period)

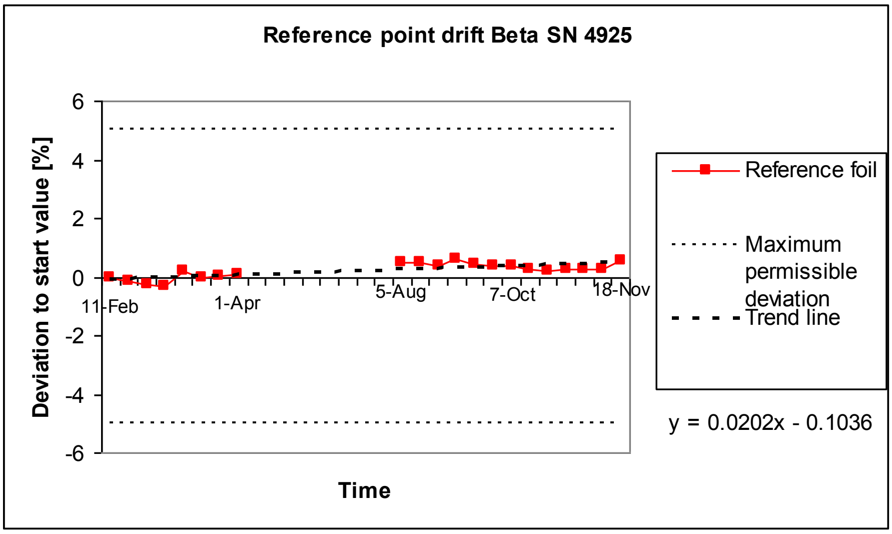

Figure 29: Drift of measured value SN 4925 (complete testing period)

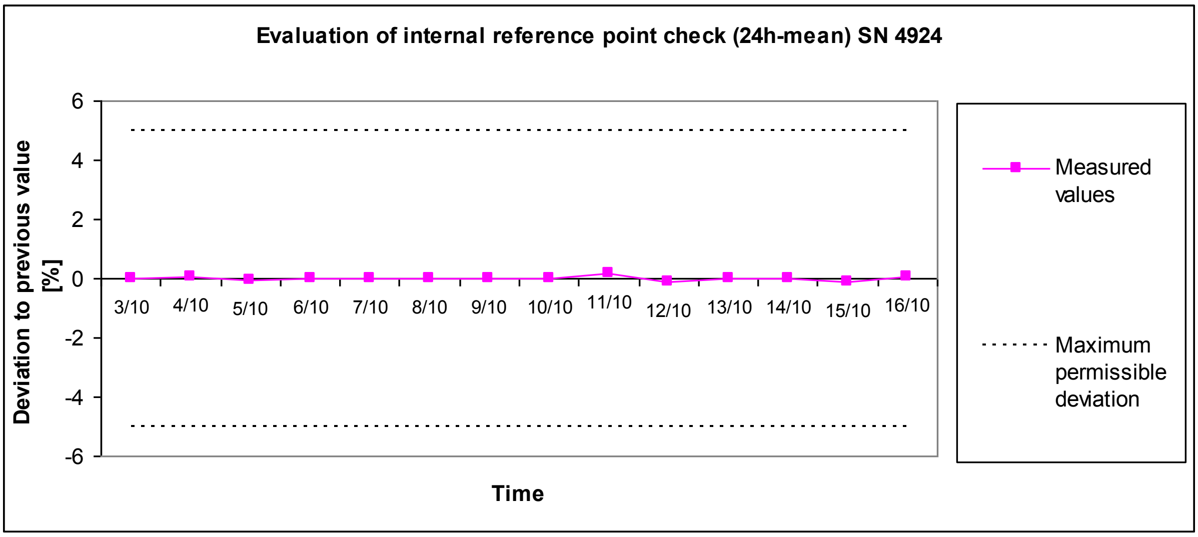

Figure 30: Drift of measured value SN 4924 (10/03/2006-10/16/2006)

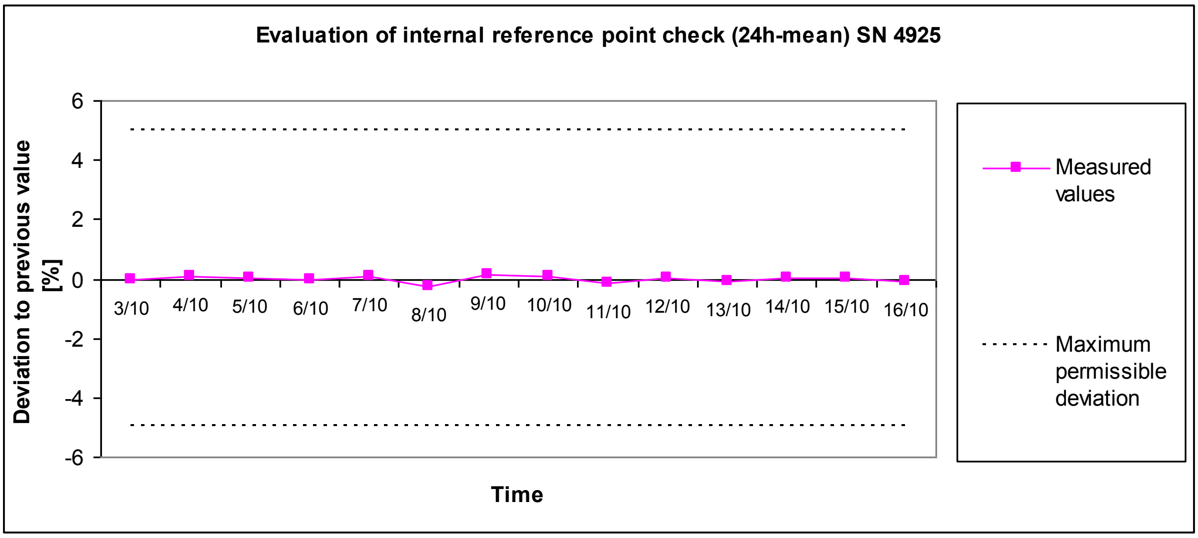

Figure 31: Drift of measured value SN 4925 (10/03/2006-10/16/2006)

6.1 5.2.11 Cross-sensitivity

The absolute values of the sum of the positive and the sum of negative deviations caused by cross-sensitivities of interfering components in the measured sample shall not exceed B_0 at the zero point and shall not exceed 3 % of B_2 in the range of B_2. The concentration of interfering components shall correspond to the B_2 value of the respective interfering component. If reference values have not been specified, the test institute shall specify and declare suitable reference values in agreement with other test institutes.

For particulate measuring systems, this test point is not relevant. Minimum requirement 5.3.4. is essential. The results to these investigations can therefore be found in module 5.3.4.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Findings

Not applicable.

Minimum requirement fulfilled? -

6.6 Presentation of test results

Not applicable.

6.1 5.2.12 Reproducibility R_D

The reproducibility R_D of the measuring system shall be determined by parallel measurements with two identical measuring systems and shall be at least equal to 10. B_1 shall be used as the reference value.

6.2 Equipment

For the determination of the reproducibility R_D, the instruments mentioned in chapter 5 have additionally been used.

6.3 Performance of test

The reproducibility R_D is defined as the value, from which two stochastically chosen single values, determined under comparison conditions, differ at the most. The reproducibility R_D was determined with two identical and parallel operated devices during the field test. For this, measurement data from the entire field investigation was used .

The field investigations at the three different test sites were performed with an US-PM10-sampling inlet (BX-802). After having finished these investigations, the candidates have been additionally operated with the EU-PM10-sampling inlet (BX-809) at the field test site Cologne, Frankfurter Str. and have been separately evaluated. Target of these additional investigations has been the proof that the results, obtained with both different types of sampling inlets, do not differ significantly from each other and thus the operation of the system is basically possible with both types of sampling inlets.

6.4 Evaluation

The reproducibility R_D is calculated as follows:

$$R = \frac{B_1}{U} \geq 10 \qquad \text{with} \qquad U = \pm s_D \cdot t_{(n;0,95)} \quad \text{and} \quad s_D = \sqrt{\frac{1}{2n} \cdot \sum_{i=1}^{n} (x_{1i} - x_{2i})^2}$$

- R = Reproducibility R_D at B_1
- U = Uncertainty
- B_1 = 40 µg/m³ (VDI)
- s_D = Standard deviation from paired measurements
- n = Number of paired measurements
- $t_{(n;0,95)}$ = Student factor for 95% confidence
- x_{1i} = Measured signal of device 1 (e.g. SN 4924) at i-th concentration
- x_{2i} = Measured signal of device 2 (e.g. SN 4925) at i-th concentration

.

6.5 Findings

The reproducibility R_D was at minimum 16 during the field test.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

The results of the investigations are summed up in Table 15. The graphic presentations can be found in Figure 44 to Figure 48.

Remark: The determined uncertainties are referred to the reference value B_1 for each test site:

Table 15: Concentration mean values, standard deviation, range of uncertainty and reproducibility R in field

Test site	No.	$\bar{c}$ (SN 4924)	$\bar{c}$ (SN 4925)	$\bar{c}_{ges}$	s_D	t	U	R
		µg/m³	µg/m³	µg/m³	µg/m³		µg/m³	
Cologne, Parking lot	52	25.2	26.6	25.9	1.267	2.007	2.54	16
Titz-Roedingen	37	24.0	24.9	24.5	0.795	2.026	1.61	25
Cologne, Frankfurter Str.	28	26.7	27.9	27.3	1.074	2.049	2.20	18
All test sites	117	24.8	26.0	25.4	1.000	1.980	1.98	20
additional Cologne, Frankfurter Str. (EU-inlet)	26	25.7	25.6	25.7	0.800	2.056	1.64	24

- $\bar{c}$ (SN 4924): Mean value of the concentrations device SN 4924
- $\bar{c}$ (SN 4925): Mean value of the concentrations device SN 4925
- $\bar{c}_{ges}$: Mean value of the concentrations of the devices SN 4924 & SN 4925

Single values can be found in annex 4 in the appendix.

6.1 5.2.13 Hourly averages

The measurement method shall allow for formation of hourly averages.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

It was checked, whether the measuring system allows the formation of hourly averages.

6.4 Evaluation

According to the valid Guideline [7], the limit values for suspended particulate matter PM10 are to refer to a minimum averaging period of 24 hours. A formation of hourly averages is therefore not necessary for measuring systems for monitoring this limit value. The tested measuring systems operates by default with a measurement cycle of 60 min and thus outputs every hour a new measured value. Hence the measuring system allows an on-line measurement of the particulate concentrations with hourly resolution.

6.5 Findings

The formation of hourly averages for the component SPM PM10 is not necessary for the monitoring of the relevant limit values, but possible.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

In the following figures, the course of the suspended particulate matter concentrations during the time period from 10/03/2006 until 10/16/2006 (Cologne, Frankf. Str.) as well as the correlation between both candidates on basis of 1 h-mean values is shown. The suitability of the measuring system for on-line measurement of the particulate concentrations with hourly resolution and therewith the possibility to supply information on the time courses of SPM concentrations is obviously demonstrated.

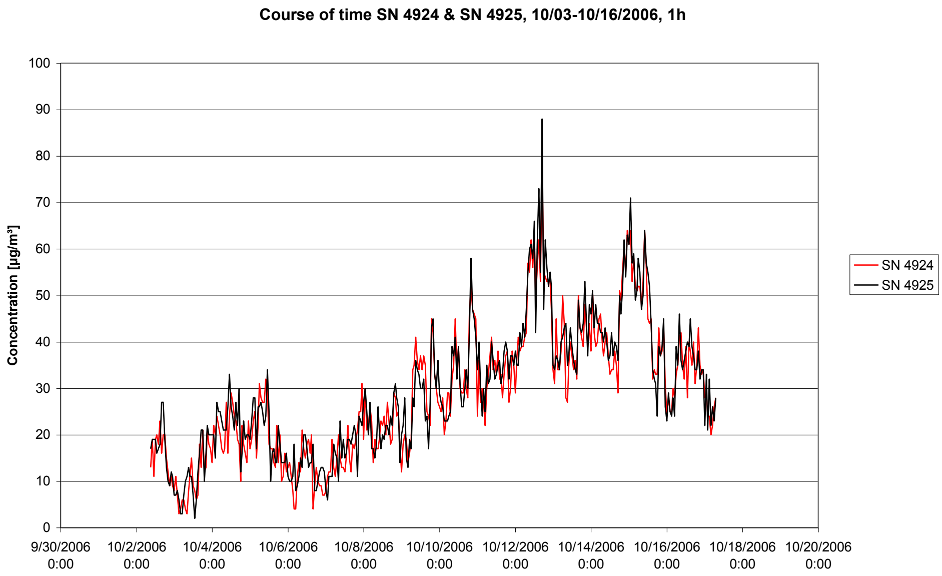

Figure 32: Course of time of suspended particulate matter concentration PM10 from 10/03/2006 until 10/16/2006, 1 h-measured values

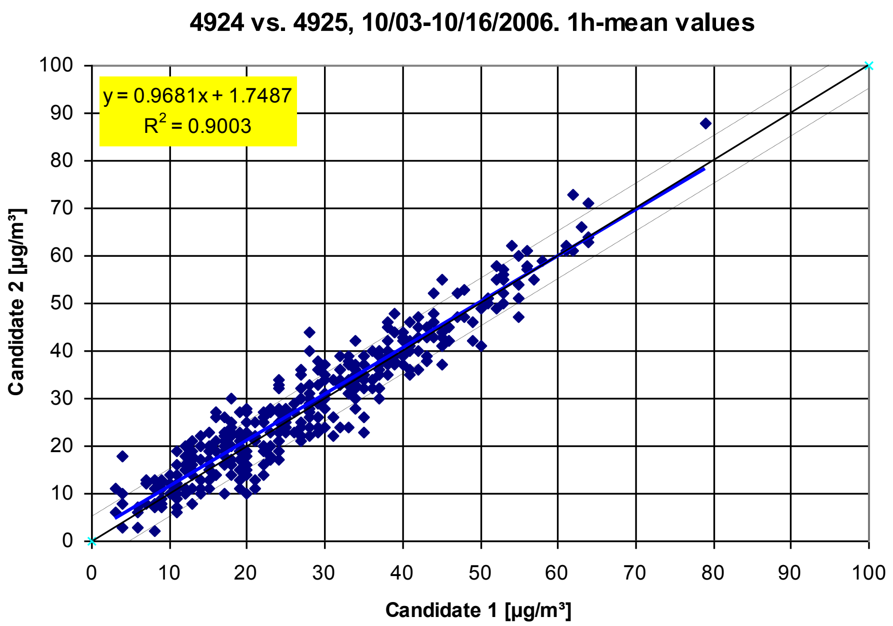

Figure 33: SN 4924 vs. SN 4925, 10/03/2006 until 10/16/2006, 1 h-measured values

6.1 5.2.14 Mains voltage and frequency

The change in the measured values at reference value B_1 caused by normal changes in the mains voltage in the interval (230 +15/-20) V shall not exceed B_0. In addition, for mobile applications the change in the measured value caused by changes in frequency of the mains voltage in the interval (50 ± 2) Hz shall not exceed B_0.

6.2 Equipment

Adjustable isolating transformer, filter tape, built-in reference foil.

6.3 Performance of test

For the investigation of the dependence of the measured signal on the mains voltage, the mains voltage has been reduced to 210 V, starting at 230 V and afterwards increased to 245 V via the intermediate stage 230 V.

To check the dependence of the zero point on the mains voltage for the candidates SN 4924 and SN 4925, the device-internal check of the zero point of the radiometric measurement has been determined while operating the measuring system. Hereby the count rates I_1 respectively I_{1x}, which are determined on a clean filter tape spot at every measurement cycle (refer to point 3.2 Functionality of the measuring system) have been evaluated.

To check the dependence of the measured values on the mains voltage for the candidates SN 4924 and SN 4925, it is resorted to the count rates I_1 (clean filter spot) respectively I_2 (clean filter spot + retracted reference foil), which are determined at every measurement cycle (refer to point 3.2 Functionality of the measuring system). The mass density m [mg/cm²] of the reference foil is calculated device-internal from the determined count rates.

As the mobile application of the measuring system is not planned, the separate investigation of the dependence of the measured signal on the power frequency has been renounced.

6.4 Evaluation

For the investigations at the zero point, the measured values at the different mains voltages have been recorded. The absolute deviation in µg/m³ per test step, related to the start point of 230 V.

At the reference point, the percental changing of the determined mass density value for each test step, related to the start point of 230 V has been considered.

As remark it should be mentioned, that only mass densities and no concentration values can be simulated by the application of the reference foil, a consideration in the range of B_1 (= 40 µg/m³) was not possible because of this reason.

6.5 Findings

The evaluation of the minimum requirement was performed on basis of the above mentioned instructions.

Through changes in the mains voltage, maximum deviations of -1.6 µg/m³ at the zero point and maximum 0.2 % at the tested reference points could be detected.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 16 to Table 17 show a recapitulating presentation of the test results.

Table 16: Dependence of the zero point on mains voltage, deviation in µg/m³

Mains voltage		Deviation	
Start voltage	End voltage	Device 1 (SN 4924)	Device 2 (SN 4925)
V	V	µg/m³	µg/m³
230	210	0.3	-0.1
210	230	-1.6	-0.4
230	245	-0.7	-0.4
245	230	0.4	0.7

Table 17: Dependence of the measured value on mains voltage, deviation in %

Mains voltage		Deviation	
		Device 1 (SN 4924)	Device 2 (SN 4925)
Start voltage	End voltage	Reference foil	Reference foil
V	V	%	%
230	210	0.1	0.0
210	230	0.2	-0.1
230	245	0.0	-0.1
245	230	0.1	0.0

Single value can be found in annex 3 in the appendix.

6.1 5.2.15 Failure in mains voltage

In case of malfunction of the measuring system or failure in the mains voltage, uncontrolled emission of operation and calibration gas shall be avoided. The instrument parameters shall be secured by buffering against loss caused by failure in the mains voltage. When mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement according to the operating instructions.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

A power loss has been simulated and it has been checked, whether the device remains undamaged and whether it is ready for measurement after return of power supply.

6.4 Evaluation

As the devices need neither operation nor calibration gases, an uncontrolled emission of gases is not possible.

In case of a power loss, the measuring systems restarts independently the next measurement cycle and thus again the measuring operations with reaching the next hour (refer to point 6.1 4.1.4 Set-up times and warm-up times).

6.5 Findings

All instrument parameters are protected against loss by buffering.
The measuring system is in normal operating condition after return of power supply and continues independently the measurements with reaching the next hour.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 5.2.16 Operating states

Measuring systems shall be able to telemetrically transmit important operating states by status signals.

6.2 Equipment

Modem, PC for data acquisition (RS 232-host-device).

6.3 Performance of test

A modem has been connected to the measuring system. By remote data recording, i.e. the status signals of the device have been recorded.

6.4 Evaluation

The measuring system allows the complete telemetric check and control of the measuring system. There is a series of read, write and control commands available. A complete overview can be found in the manual of the measuring system.

6.5 Findings

The measuring systems can be controlled and monitored extensively from an external PC via a modem.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 5.2.17 Switch-over

Switch-over between measurement and functional check and/or calibration shall be possible telemetrically by computer control or manual intervention.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

The measuring device can be monitored as well as partly controlled by the user at the device or by telemetric remote control. The internal checks of the zero and reference point are an integral part of each measurement cycle and therefore must be merely recorded via the printer output during operation.

Some function, i.e. the performance of the extensive self-test of the measuring system, can only be activated directly at the device.

6.4 Evaluation

All operational procedures can be monitored as well by the user at the device as by telemetric remote control. The internal checks of the zero and reference point are an integral part of each measurement cycle and therefore must be merely recorded via the printer output during operation.

6.5 Findings

Generally all necessary operations for functional check and calibration can be monitored directly at the device or via telemetric remote control.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 5.2.18 Availability

The availability of the measuring system shall be at least 90 %.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

Start time and end time of the investigations of availability are defined by start time and end time at each of the four field test sites. Therefore all interruptions during the test, e.g. by malfunctions or maintenance work, are recorded.

6.4 Evaluation

Table 18 and Table 19 show a record of the operation, maintenance and malfunction times. The measuring systems have been operated over a time period of 147 measurement days during the field test. Losses, caused by external influences, which cannot be charged to the device itself, have been recorded on 07/28/2007 and 07/29/2006 (48 h because of power loss) and on 08/30/2006 (24 h because of the installation of an electric meter). The total operating time is thereby reduced to 144 measurement days.

The regular care of the sampling inlets in the maintenance interval (approx. every 4 weeks, 5 times during the test), the replacement of the filter tape (approx. every 2 months, 2 times during the test) as well as the check of the sampling flow rates before the field test sites Titz-Roedingen and Cologne, Frankf. Str. have lead in each case to losses of less than 1 h per device (in total 9 times). These times have been evaluated as outage times of respectively 1 h per date, however they have not been regarded for the formation of the respective daily mean values. Merely at the test site Cologne, parking lot on 02/14/2006, the required actions have taken more than 1 h due to organizational reasons and the measured values of this day have been rejected. This outage of 24 h is not to charge to the device, but is caused by the organization and performance of the test itself.

No malfunctions of the devices have been observed.

6.5 Findings

The availability was 99.7 % for both devices without outages, caused by testing, respectively 99.0 % incl. outages, caused by testing.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 18: Determination of availability (without outages, caused by testing)

		Device 1 (SN 4924)	Device 2 (SN 4925)
Operating time	h	3456	3456
Outage time	h	-	-
Maintenance time	h	10	10
Actual operating time	h	3446	3446
Availability	%	99.7	99.7

Table 19: Determination of availability (incl. outages, caused by testing)

		Device 1 (SN 4924)	Device 2 (SN 4925)
Operating time	h	3456	3456
Outage time	h	-	-
Maintenance time	h	9 + 24	9 + 24
Actual operating time	h	3423	3423
Availability	%	99.0	99.0

6.1 5.2.19 Efficiency of the converter

In case of measuring systems with a converter, the efficiency of the converter shall be at least 95 %.

According to Guideline VDI Sheet 3, point 5.3, this test point is not relevant for particulate measuring systems with pre-separation, based on a physical measurement method for mass determination.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Findings

Not applicable.

Minimum requirement fulfilled? not applicable

6.6 Presentation of test results

Not applicable.

6.1 5.2.20 Maintenance interval

The maintenance interval of the measuring system shall be determined and specified. The maintenance interval should be 28 days, if possible, but at least 14 days.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

For this minimum requirement it was investigated, which maintenance work in which time intervals is required for a proper functional efficiency of the measuring system. Furthermore the results of the drift determination for zero and reference point according to module 5.2.9 respectively module 5.2.10 have been taken into account to determine the maintenance interval.

6.4 Evaluation

There have been observed no unallowable drift effects during a time period of 4 weeks. The maintenance interval is defined by the accruing maintenance work. To ensure a proper functional efficiency of the measuring system, all instrument functions should be checked latest every 4 weeks (refer to module 4.1.2).

Within the operational time, the maintenance can basically be restricted to the check for contaminations, plausibility checks and possible status / error messages.

6.5 Findings

The maintenance interval is defined by the accruing maintenance work and it is 4 weeks.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

The necessary maintenance workings can be found in the module 4.1.2 in this report and in the chapters 10 in the manual.

6.1 5.2.21 Overall uncertainty

The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the EU Daughter Directives on air quality [G11 to G13].

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

The expanded overall uncertainty of the measuring system has been determined for single values in the range of concentrations of the short-time ambient air quality limit value and for mean values in the range of concentrations of the long-time ambient air quality limit value. The performance characteristics (laboratory test and field test with US-sampling inlet), determined in the suitability test, have been compiled.

6.4 Evaluation

The expanded overall uncertainty of the measuring system was determined according Guideline VDI 4202, Sheet 1, Annex C [1].

6.5 Findings

For the calculation of the expanded measurement uncertainties, the single results from the respective test points have been recapitulating assessed. As far as there have been several independent results from the single investigations available, the respective most disadvantageous value has been used.

The overall uncertainties have been 7.23 % respectively 7.89 % for U(c) and 7.44 % respectively 8.28 % for $U(\bar{c})$.

Single values can be found in Table 20 to Table 23. The obtained values are all below the required overall uncertainties of 25 %.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 20: Expanded measurement uncertainty U(c) for the measuring system SN 4924 Reference value: 50 µg/m³

Performance characteristics for Device SN 4924	**Requirement**	**Result**		**Uncertainty u**	**Square of uncertainty u²**
				µg/m³	(µg/m³)²
Reproducibility R	≥ 10	20		1.00	1.00
Confidence interval CI_{95} according to EN 12341	≤ 5 µg/m³	2.23	µg/m³	1.29	1.66
Temperature dependence at zero point	≤ 2 µg/m³	0.70	µg/m³	0.40	0.16
Temperature dependence at ref. point (Beta)	≤ 5 % of B1	0.04	µg/m³	0.02	0.00
Drift at zero point	≤ 2 µg/m³	0.38	µg/m³	0.22	0.05
Drift of measured value	≤ 5 % of B1	0.17	µg/m³	0.10	0.01
Mains voltage (measured value)	≤ 2 µg/m³	0.08	µg/m³	0.05	0.00
Cross-sensitivities	≤ 6 µg/m³	0.40	µg/m³	0.23	0.05
Uncertainty of test standard	≤ 1 µg/m³	1.00	µg/m³	0.58	0.33
				Σu²	3.27
				U(c) = 2u(c)	3.62
				U(c) / Ref.	7.23

Table 21: Expanded measurement uncertainty U(c) for the measuring system SN 4925 Reference value: 50 µg/m³

Performance characteristics for Device SN 4925	**Requirement**	**Result**		**Uncertainty u**	**Square of uncertainty u²**
				µg/m³	(µg/m³)²
Reproducibility R	≥ 10	20		1.00	1.00
Confidence interval CI_{95} according to EN 12341	≤ 5 µg/m³	2.23	µg/m³	1.29	1.66
Temperature dependence at zero point	≤ 2 µg/m³	0.30	µg/m³	0.17	0.03
Temperature dependence at ref. point (Beta)	≤ 5 % of B1	0.08	µg/m³	0.05	0.00
Drift at zero point	≤ 2 µg/m³	0.69	µg/m³	0.40	0.16
Drift of measured value	≤ 5 % of B1	-0.01	µg/m³	-0.01	0.00
Mains voltage (measured value)	≤ 2 µg/m³	-0.04	µg/m³	-0.02	0.00
Cross-sensitivities	≤ 6 µg/m³	1.46	µg/m³	0.84	0.71
Uncertainty of test standard	≤ 1 µg/m³	1.00	µg/m³	0.58	0.33
				Σu²	3.89
				U(c) = 2u(c)	3.95
				U(c) / Ref.	7.89

Table 22: Expanded measurement uncertainty $U(\bar{c})$ for the measuring system SN 4924 Reference value: 40 µg/m³

Performance characteristics for Device SN 4924	Uncertainty (single value)	Time basis	Number nk	Square of uncertainty (mean value)
				(µg/m³)²
Reproducibility R	1.00	24 h	365	0.003
Confidence interval CI_{95} according to EN 12341	1.29	1 year	1	1.658
Temperature dependence at zero point	0.40	1 year	1	0.163
Temperature dependence at ref. point (Beta)	0.02	1 year	1	0.001
Drift at zero point	0.22	1 week	52	0.001
Drift of measured value	0.10	1 week	52	0.000
Mains voltage (measured value)	0.05	1 year	1	0.002
Cross-sensitivities	0.23	1 year	1	0.053
Uncertainty of test standard	0.58	1 year	1	0.333
			$\Sigma u_m^2(c_k)$	2.214
			$U(\bar{c}) = 2u(\bar{c})$	2.98
			$\frac{U(\bar{c})}{\text{Reference}}$	7.44

Table 23: Expanded measurement uncertainty $U(\bar{c})$ for the measuring system SN 4925 Reference value: 40 µg/m³

Performance characteristics for Device SN 4925	Uncertainty (single value)	Time basis	Number nk	Square of uncertainty (mean value)
				(µg/m³)²
Reproducibility R	1.00	24 h	365	0.003
Confidence interval CI_{95} according to EN 12341	1.29	1 year	1	1.658
Temperature dependence at zero point	0.17	1 year	1	0.030
Temperature dependence at ref. point (Beta)	0.05	1 year	1	0.002
Drift at zero point	0.40	1 week	52	0.003
Drift of measured value	-0.01	1 week	52	0.000
Mains voltage (measured value)	-0.02	1 year	1	0.001
Cross-sensitivities	0.84	1 year	1	0.711
Uncertainty of test standard	0.58	1 year	1	0.333
			$\Sigma u_m^2(c_k)$	2.740
			$U(\bar{c}) = 2u(\bar{c})$	3.31
			$\frac{U(\bar{c})}{\text{Reference}}$	8.28

6.1 5.3.1 Equivalency of the sampling system

The equivalency between the PM10 sampling system and the reference method according to DIN EN 12 341 [T5] shall be demonstrated.

6.2 Equipment

For this test point, the instruments mentioned in point 5 of the report at hand have been additionally used.

6.3 Performance of test

The test work has been performed in the field test at different test sites according to chapter 4 of this report. During the test, different seasons and different PM10-concentrations have been taken into consideration.

For every test site, at least 15 valid data pairs have been determined.

The field investigations at the three different test sites were performed with an US-PM10-sampling inlet (BX-802). After having finished these investigations, the candidates have been additionally operated with the EU-PM10-sampling inlet (BX-809) at the field test site Cologne, Frankfurter Str. and have been separately evaluated. Target of these additional investigations has been the proof that the results, obtained with both different types of sampling inlets, do not differ significantly from each other and thus the operation of the system is basically possible with both types of sampling inlets.

6.4 Evaluation

Requirement of EN 12341

The calculated functional relationship y = f(x) between concentration values measured with candidate sampler (y) and concentration values measured with reference sampler (x) has to be limited by a two-sided acceptance envelope. This acceptance envelope is given through:

$y = (x \pm 10)$ µg/m³ for concentration average values $\leq$ 100 µg/m³ and

$y = 0.9x$ µg/m³ respectively $1.1x$ µg/m³ for concentration average values > 100 µg/m³

Furthermore the variance coefficient R^2 of the calculated reference-equivalence-function has to be ≥ 0.95.

The test procedure regards the functional relationship between the concentration values, which have been determined through double measurements with the candidate and the reference sampler. Ideally both instruments sample the same suspended particulate matter fraction, thus we have the relationship y = x. The evaluation process is as follows.

For every single test site and, after summary of the measurement data from all test sites, for all four test sites together, a linear regression analysis with the measurement data has been made.

One receives for every measurement value y_i of the candidate sampler i and the concentration x, measured with the reference sampler – both in µg/m³ - a reference-equivalence-function according to the general relation:

$$y_i = m \cdot x + b \qquad \text{with i = candidate BAM-1020}$$

6.5 Findings

The reference-equivalence functions are bounded within the limits of the acceptance envelope. Furthermore the variance coefficient R^2 of the determined reference-equivalence functions is ≥ 0.95 for the respective concentration range. This is also fulfilled for all single test sites as well as for the additional investigations with the EU-sampling inlet at test site Cologne, Frankf. Str..

Minimum requirement fulfilled? yes

6.6 Presentation of test results

The results of the linear regression analysis are summarized in Table 24 and in Table 25. The graphic presentation can be found in Figure 34 to Figure 43. Together with the linear regression curve of the instruments, the ideal curve y = x and the two-sided acceptance envelope are shown. All single values for the candidates as well as for the reference samplers can be found, separately for each test site, in annex 4.

Table 24: Results of the linear regression analysis of the measurements with candidate SN 4924 at the three test sites

SN 4924	Number of values N	Slope m	Ordinate intercept b	R^2
Cologne, parking lot	29	0.926	2.647	0.959
Titz-Roedingen	37	1.04	0.805	0.964
Cologne, Frankfurter Str.	28	1.01	0.891	0.958
Total	94	0.968	1.545	0.952
additional Cologne, Frankfurter Str., EU-inlet	26	1.022	0.449	0.947

Table 25: Results of the linear regression analysis of the measurements with candidate SN 4925 at the three test sites

SN 4925	Number of values N	Slope m	Ordinate intercept b	R^2
Cologne, parking lot	29	0.972	3.081	0.969
Titz-Roedingen	37	1.04	1.716	0.963
Cologne, Frankfurter Str.	28	1.009	0.284	0.962
Total	94	0.987	2.250	0.958
additional Cologne, Frankfurter Str., EU-inlet	26	0.965	0.930	0.966

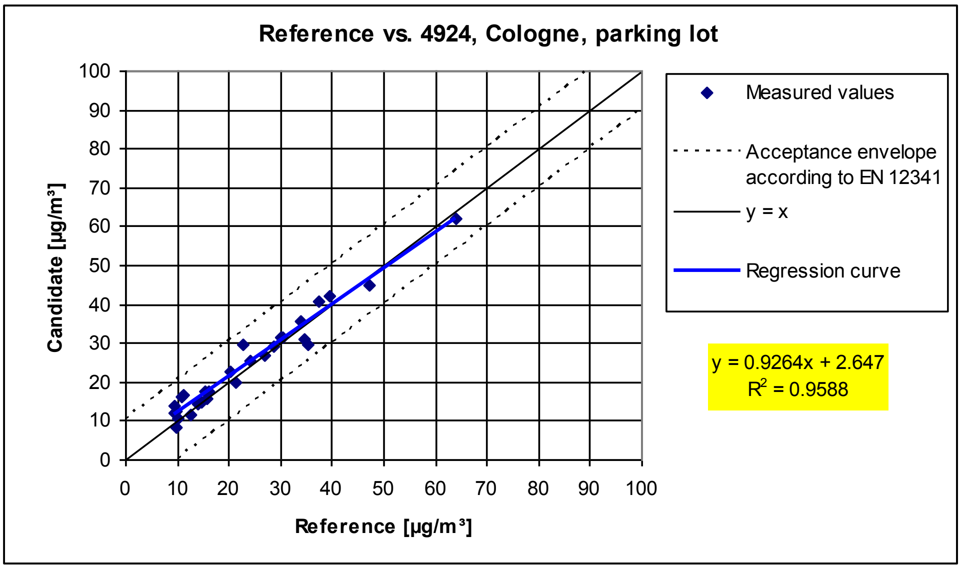

Figure 34: Reference-equivalence-function SN 4924, test site Cologne, parking lot

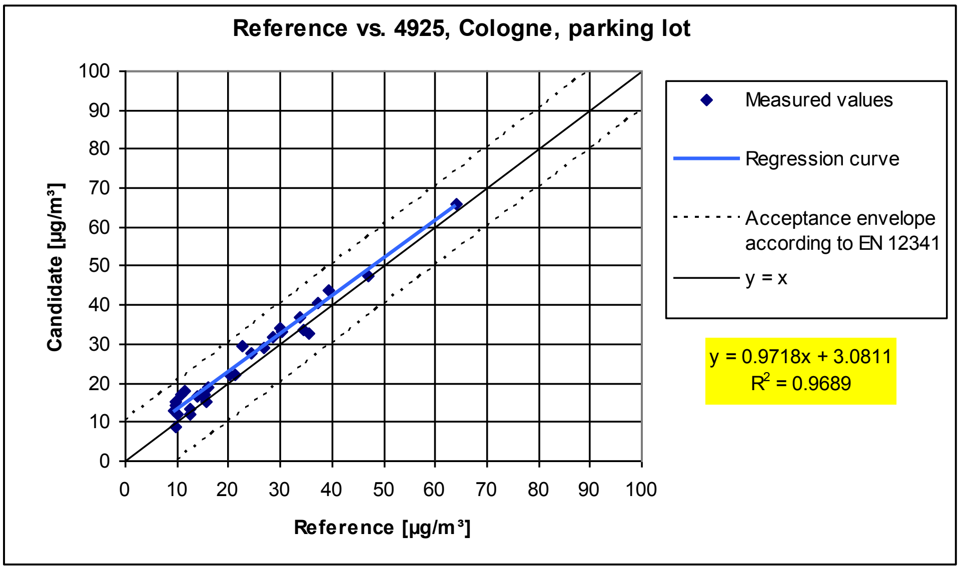

Figure 35: Reference-equivalence-function SN 4925, test site Cologne, parking lot

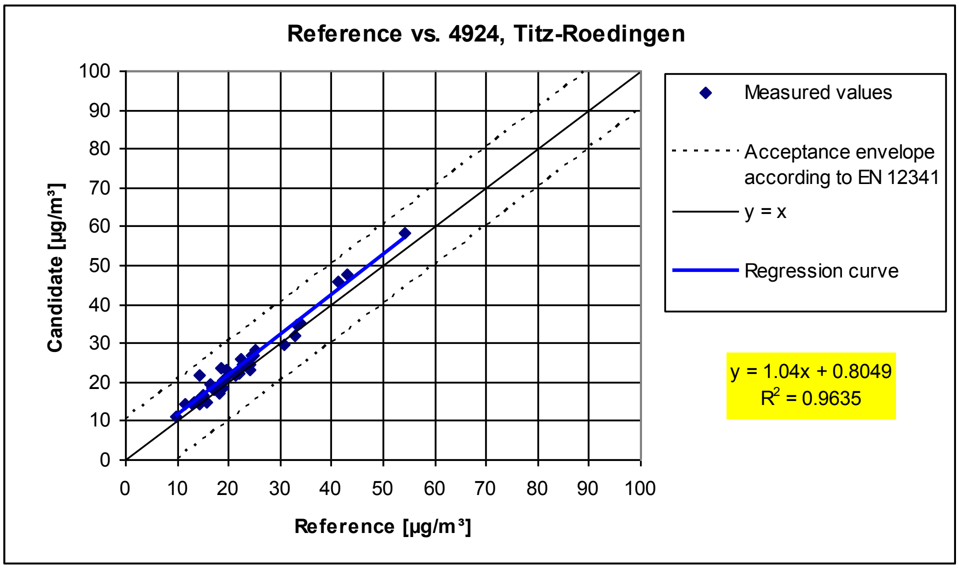

Figure 36: Reference-equivalence-function SN 4924, test site Titz-Roedingen

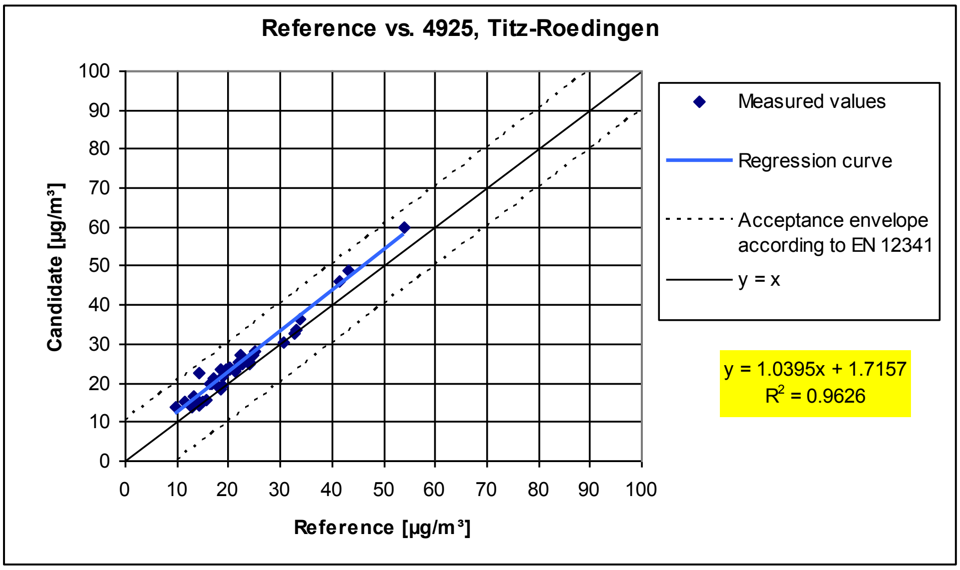

Figure 37: Reference-equivalence-function SN 4925, test site Titz-Roedingen

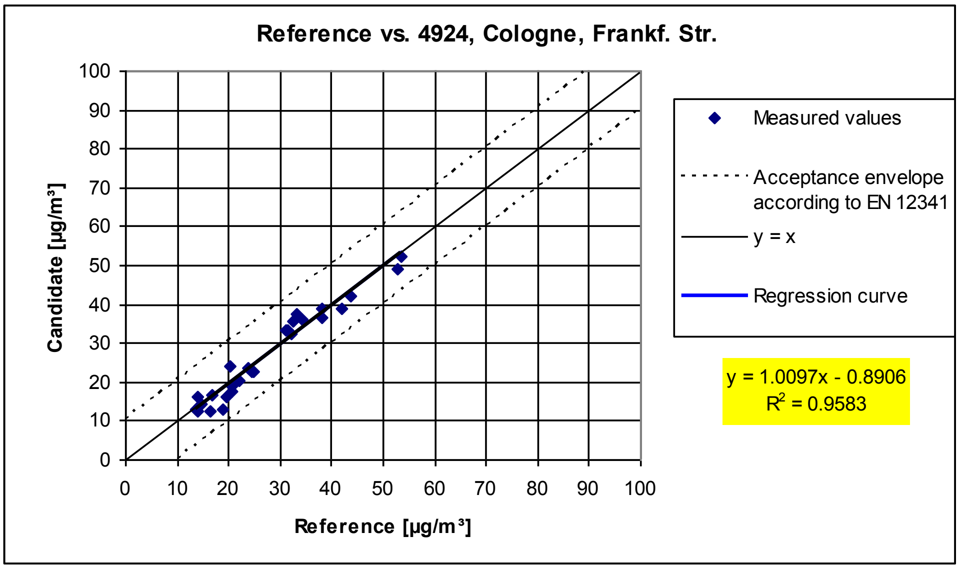

Figure 38: Reference-equivalence-function SN 4924, test site Cologne, Frankfurter Str.

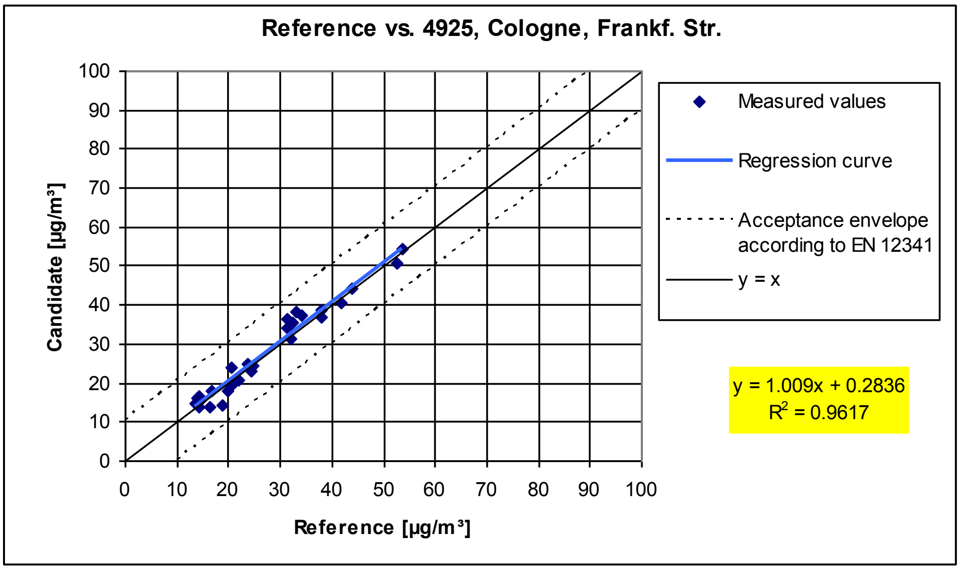

Figure 39: Reference-equivalence-function SN 4925, test site Cologne, Frankfurter Str.

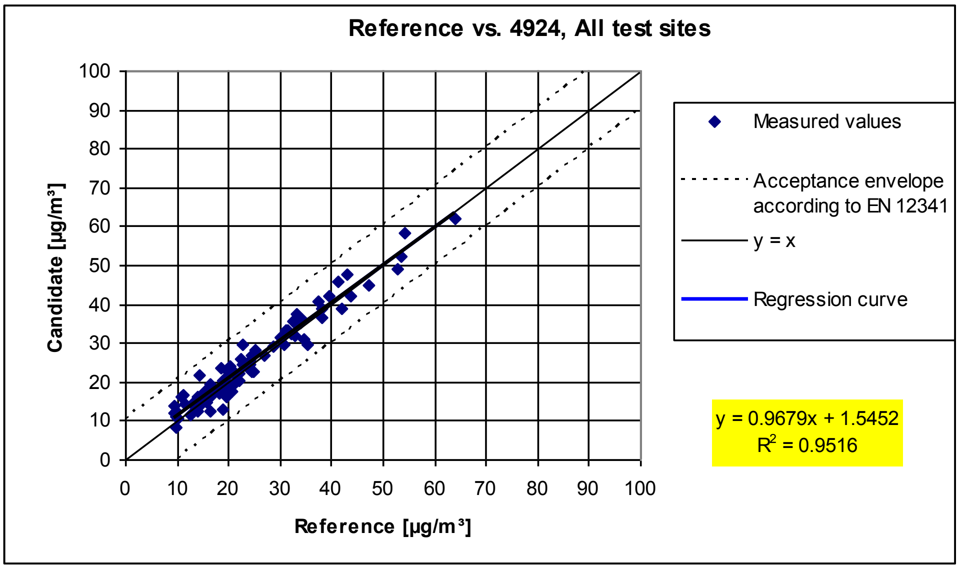

Figure 40: Reference-equivalence-function SN 4924, all test sites

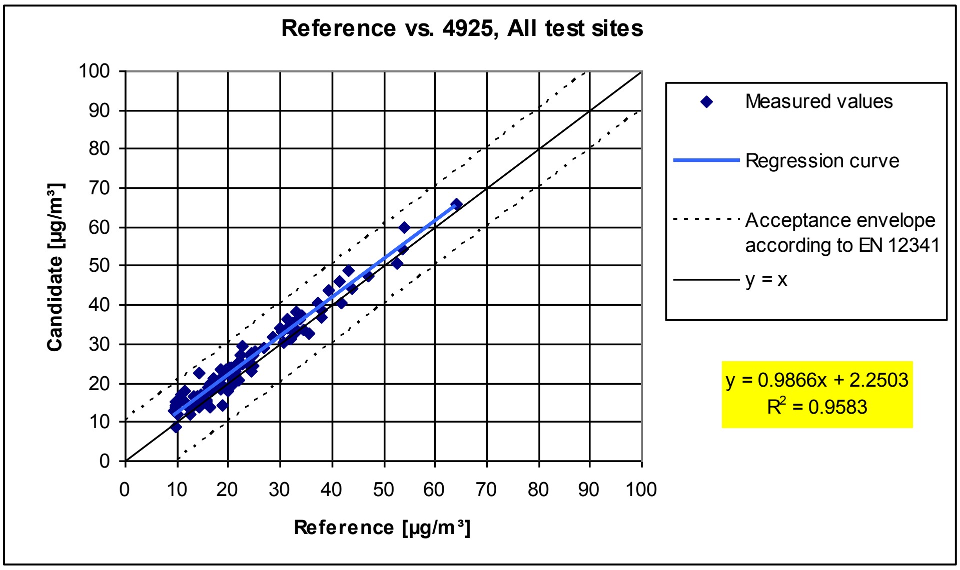

Figure 41: Reference-equivalence-function SN 4925, all test sites

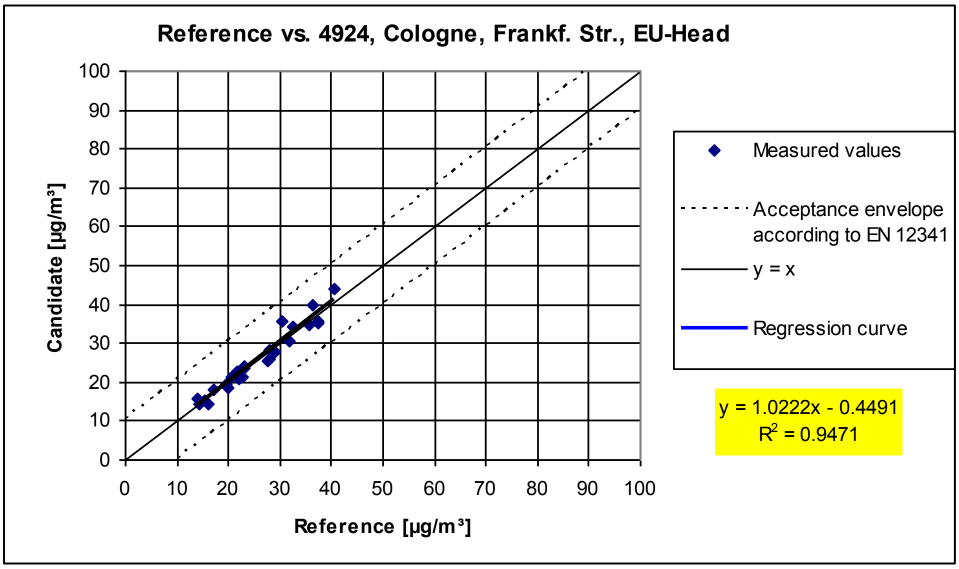

Figure 42: Reference-equivalence-function SN 4924, additional test site “Cologne, Frankfurter Str.” with EU-sampling inlet

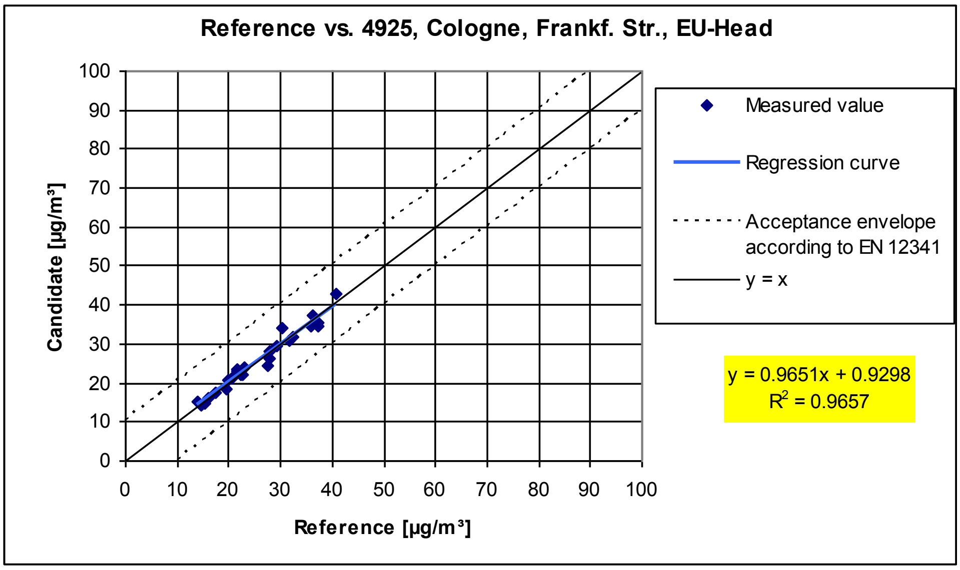

Figure 43: Reference-equivalence-function SN 4925, additional test site “Cologne, Frankfurter Str.” with EU-sampling inlet

6.1 5.3.2 Reproducibility of the sampling systems

The PM10 sampling systems of two identical systems under test shall be reproducible among themselves according to DIN EN 12 341 [T5]. This shall be demonstrated in the field test.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

The test work has been performed in the field test at different test sites. During the test, different seasons, different PM10-concentrations as well as different ratios between TSP and PM10 have been taken into consideration.

For every test site, at least 15 valid data pairs have been determined.

The field investigations at the three different test sites were performed with an US-PM10-sampling inlet (BX-802). After having finished these investigations, the candidates have been additionally operated with the EU-PM10-sampling inlet (BX-809) at the field test site Cologne, Frankfurter Str. and have been separately evaluated. Target of these additional investigations has been the proof that the results, obtained with both different types of sampling inlets, do not differ significantly from each other and thus the operation of the system is basically possible with both types of sampling inlets.

6.4 Evaluation

The two-sided acceptance envelope CI_{95} , calculated from the concentration average values measured with the candidate samplers, may not exceed a value of 5 µg/m³ for concentration average values ≤ 100 µg/m³ and of 0.05 for concentration average values > 100 µg/m³.

The demonstration of the comparability of the candidate samplers is focusing on the differences D_i of the concentration values Y_i of the candidate samplers. Ideally both candidate samplers are equal and thus sample the same suspended particulate matter fraction, implying $D_i = 0$. The procedure is as follows:

First the average concentrations Y_i of the i-th parallel measurement of the candidate samplers are calculated. Following the average concentrations Y_i are divided into two separated data sets:

a) Data set with $Y_i \leq 100$ µg/m³ with number of paired values $n_{\leq}$ and
b) Data set with $Y_i > 100$ µg/m³ with number of paired values $n_{>}$

Re a):

The absolute standard deviation s_a is calculated from the paired values of the data set with $Y_i \leq 100$ µg/m³:

$$s_a = \sqrt{(\sum D_i^2 / 2n_{\leq})}$$

The corresponding Student factor $t_{f_{\leq};0,975}$, defined as the 0.975 quantile of the two-sided 95 % confidence interval of the Student t-distribution with $f_{\leq} = n_{\leq} - 2$ degrees of freedom is used.

The two-sided confidence interval CI_{95} for the average concentration values ≤ 100 µg/m³ is then calculated as follows:

$$CI_{95} = s_a \cdot t_{f_{\leq};0{,}975}$$

Re b):

The relative standard deviation s_r is calculated from the paired values of the data set with Y_i > 100 µg/m³ as follows:

$$s_r = \sqrt{\left(\sum (D_i / Y_i)^2 / 2n_{>}\right)}$$

Again the corresponding Student factor $t_{f_{\leq};0{,}975}$, defined as the 0.975 quantile of the two-sided 95 % confidence interval of the Student t-distribution with $f_{\leq} = n_{\leq} - 2$ degrees of freedom is used.

The two-sided confidence interval CI_{95} for the average concentration values > 100 µg/m³ is then calculated as follows:

$$CI_{95} = s_r \cdot t_{f_{>};0{,}975}$$

During the field test, no concentration values > 100 µg/m³ have been measured. A statistical evaluation for this concentration range is not possible due to this reason. Therefore an assessment according to b) is omitted.

6.5 Findings

For all investigated test sites, it is imperative:

The two-sided confidence interval CI_{95} is, with maximum 2.54 µg/m³, below the specified level of 5 µg/m³. This is also fulfilled for all single test sites as well as for the additional investigations with the EU-sampling inlet at test site Cologne, Frankf. Str.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 26 shows the calculated values for the standard deviation s_a and the two-sided confidence interval CI_{95}. The graphic presentation can be found in Figure 44 to Figure 48. Together with the linear regression curve of the instruments (determined by linear regression analysis), the ideal curve y = x and the two-sided acceptance envelope are shown. All single values can be found in annex 4.

Table 26: Two-sided 95%-confidence interval CI_{95} for the candidates SN 4924 and SN 4925

Candidates	Test site	Number of values	Standard deviation s_a	Student-factor t_f	Confidence interval CI_{95}
SN			µg/m³		µg/m³
4924 / 4925	Cologne, parking lot	52	1.27	2.009	2.54
4924 / 4925	Titz-Roedingen	37	0.93	2.030	1.89
4924 / 4925	Cologne, Frankf. Str.	28	1.07	2.056	2.21
4924 / 4925	Total	117	1.12	1.981	2.23
4924 / 4925	additional Cologne, Frankf. Str., EU-inlet	26	0.80	2.064	1.65

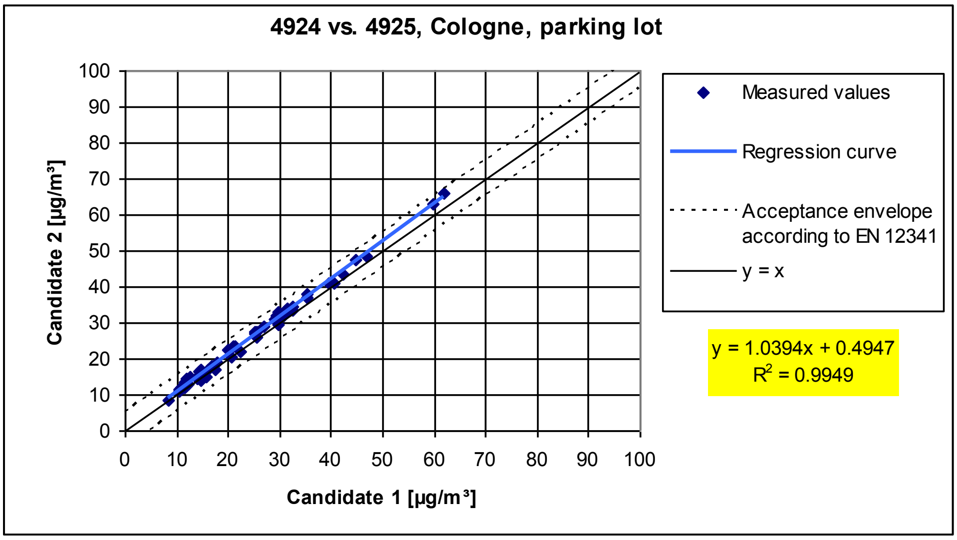

Figure 44: Result of the parallel measurements with the candidates SN 4924 / SN 4925, test site Cologne, parking lot

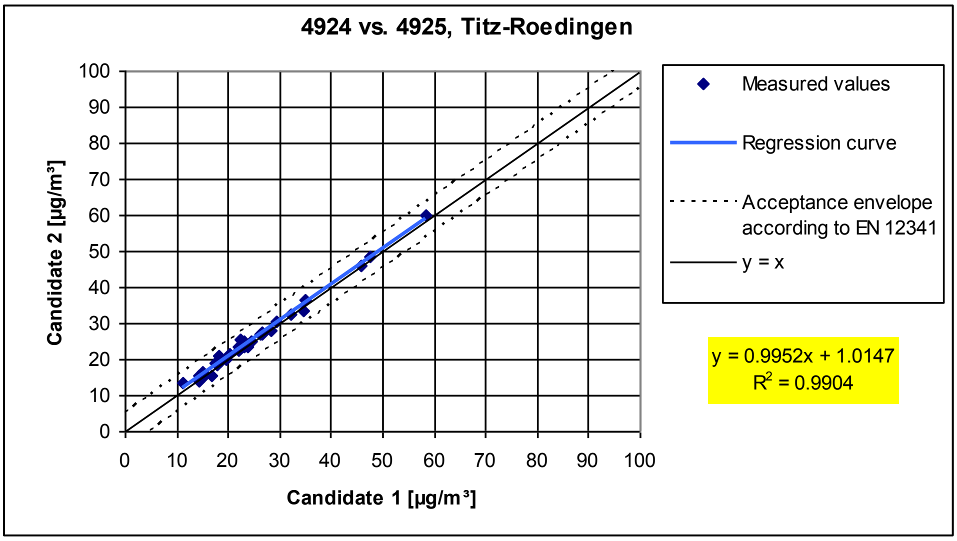

Figure 45: Result of the parallel measurements with the candidates SN 4924 / SN 4925, test site Titz-Roedingen

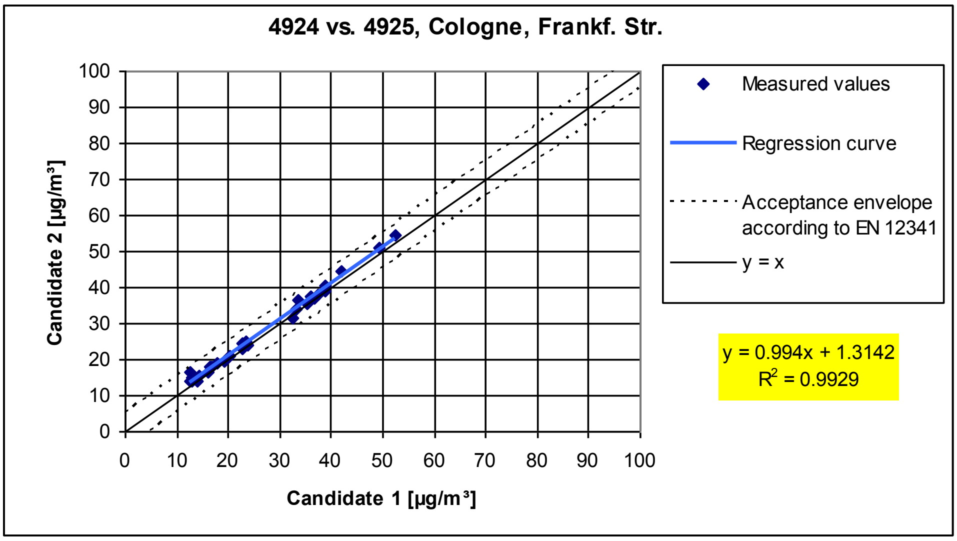

Figure 46: Result of the parallel measurements with the candidates SN 4924 / SN 4925, test site Cologne, Frankfurter Str.

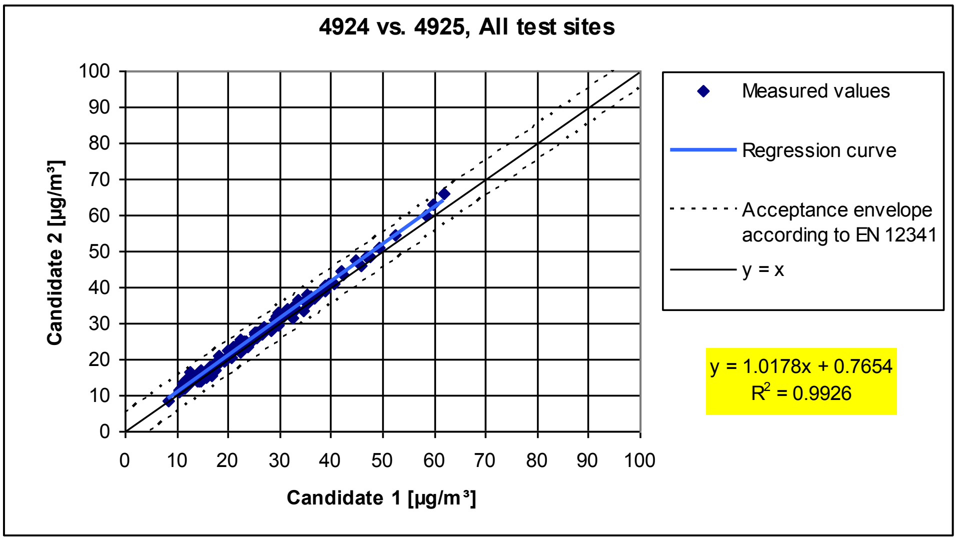

Figure 47: Result of the parallel measurements with the candidates SN 4924 / SN 4925, all test sites

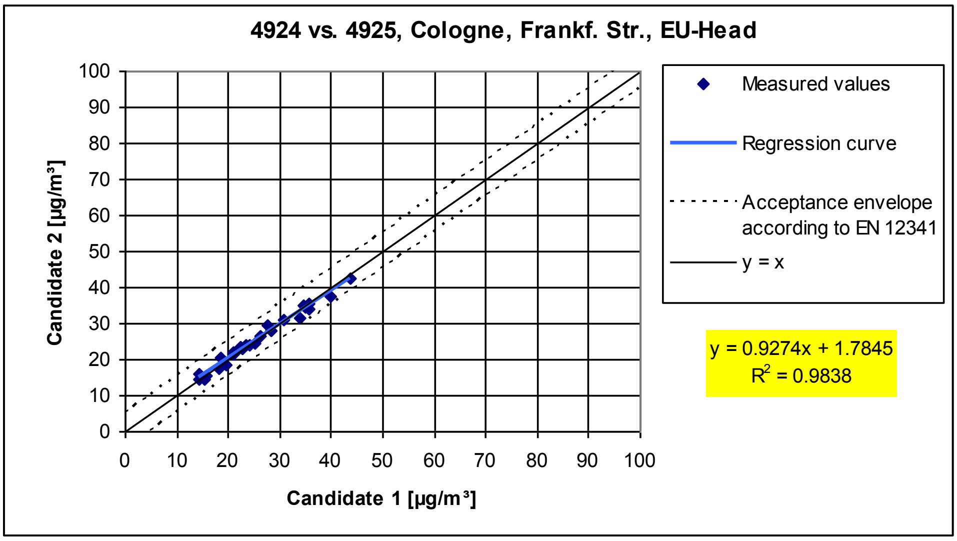

Figure 48: Result of the parallel measurements with the candidates SN 4924 / SN 4925, additional test site Cologne, Frankfurter Str. with EU-sampling inlet

6.1 5.3.3 Calibration

The PM10 systems under test shall be calibrated in the field test by comparison measurements with a reference method according to DIN DIN EN 12341 [T5]. Here, the relationship between the output signal and the gravimetrically determined reference concentration shall be determined as a steady function.

The results of these investigations can be found in module 5.2.3.

6.2 Equipment

Refer to module 5.2.3.

6.3 Performance of test

Refer to module 5.2.3.

6.4 Evaluation

Refer to module 5.2.3.

6.5 Findings

Refer to module 5.2.3.

Minimum requirement fulfilled? -

6.6 Presentation of test results

Refer to module 5.2.3.

6.1 5.3.4 Cross-sensitivity

The interference caused by moisture in the sample shall not exceed 10 % of B_1 in the range of B_1. In case of a heated sampling line, the reproducibility to the gravimetric reference method shall be determined at the specified temperature.

6.2 Equipment

Not required for this minimum requirement.

6.3 Performance of test

The determination of an interfering influence through the air humidity, which is contained in the medium being measured, under laboratory conditions was renounced, because a test at the zero point did not lead to a reliable statement and at the reference point (in the range of B1) it cannot be carried out in a secured way.

Alternatively, the differences between the determined reference value (= nominal value) and the measured value of the respective candidate system have been calculated during the field test for days with a relative humidity > 70 % and the mean difference has been set as a conservative estimation of the interfering effect through the air humidity, which is contained in the medium being measured.

Additionally, the reference-equivalence functions for both candidate systems have been determined from the field investigations for days with a relative humidity > 70 %.

The investigations on the basis of the field test have been restricted to the measured data that have been obtained while using the US-sampling inlet.

During the entire field investigations, the sample heater BX-830 has been activated.

The control of the heater is done exclusively via the control variable relative humidity RH at the filter tape (factory setting: 45 %).

6.4 Evaluation

The mean difference between the determined reference value (= nominal value) and the measured value of the respective candidate system have been calculated from the field test investigations for days with a relative humidity > 70 %.

Reference value: VDI: B_1 = 40 µg/m³ 10 % of B_1 = 4 µg/m³

Furthermore it has been investigated, if the comparability of the candidate systems with the reference method according to Guideline DIN EN 12341 is also given for the case, that the measured values have been determined at days a relative humidity > 70 %.

6.5 Findings

No interfering influence > 1.46 µg/m³ deviation from the nominal value on the measured signal through the air humidity, which is contained in the medium being measured could be detected. During the field test, it could be observed no negative influence on the measured values during varying relative air humidity and activated heating system. The comparability of the candidate systems to the reference method according to Guideline DIN EN 12341 is also given for days with a relative humidity > 70 %.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 27 shows a recapitulating presentation.

Table 27: Deviation between reference measurement and candidate on days with a relative humidity > 70 %

Field test, days with relative humidity >70%				
		Reference	SN 4924	SN 4925
Mean	µg/m³	22.7	23.1	24.2
Deviation to mean value reference in µg/m³	µg/m³	-	0.4	1.46
Deviation in % of the mean value reference	%	-	1.7	6.4
Deviation in % of B1	%	-	1.0	3.6

Single values can be found in the annexes 4 and 5 in the appendix.

The graphic presentation of the measured values at days with a relative humidity > 70 % is shown in Figure 49 and in Figure 50. Single values can be found in the annexes 4 and 5 in the appendix.

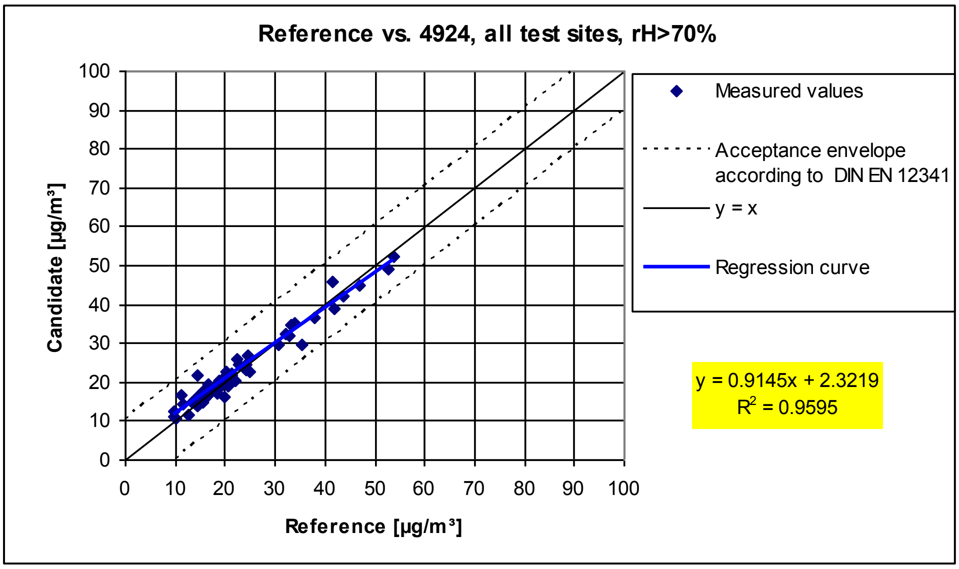

Figure 49: Reference-equivalence-function SN 4924, rel. air humidity > 70 %, all test sites

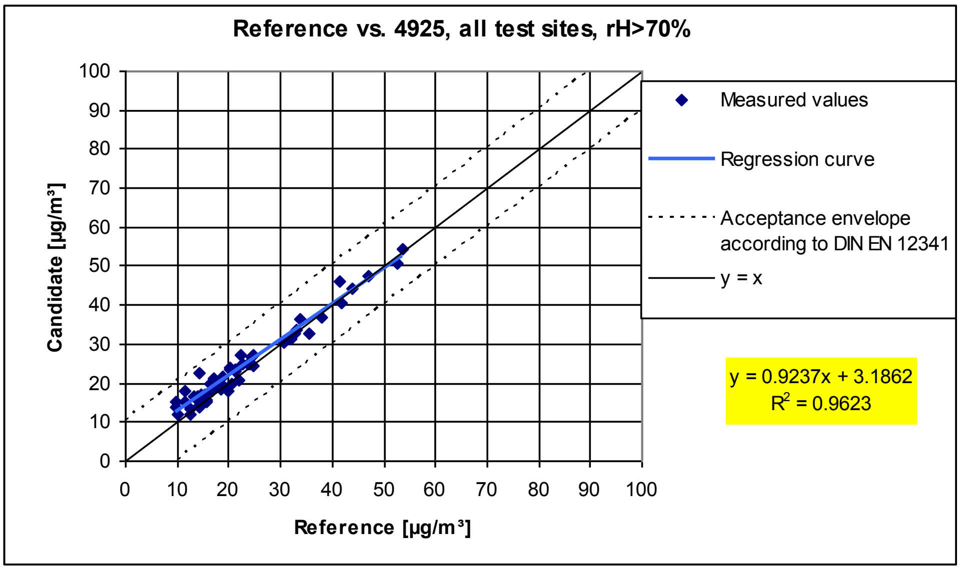

Figure 50: Reference-equivalence-function SN 4925, rel. air humidity > 70 %, all test sites

6.1 5.3.5 Daily averages

The measuring system shall allow for formation of daily averages. In case of filter changes, the time needed for the filter changes shall not exceed 1 % of the averaging time.

6.2 Equipment

For this test, a clock has been additionally provided.

6.3 Performance of test

It has been checked, whether the measuring system allows the formation of a daily average. The time need for a filter change has been determined.

6.4 Evaluation

The measuring system operates by default with a measurement cycle of 60 min. After each measurement cycle, the filter tape is moved forward for one position. The data of each measurement cycle are stored and are available for the user for further processing. Furthermore the measuring system allows the formation of a 24-h-mean value, which is output in the daily protocol via the serial interface.

Within the scope of the suitability test, the cycle time has been set to 60 min with a time need for the radiometric measurement of respectively 4 min.

The cycle time therefore consists of 2 x 4 min for the radiometric measurement (I_0 & I_3) as well as approx. 1-2 min for filter tape movements. Hence the sampling time is approx. 51 min per hour.

Thus the available sampling time per measurement cycle is approx. 85 % of the total cycle time. The results from the field investigations according to point 6.1 5.3.1 Equivalency of the sampling system in this report show, that the comparability of the candidates with the reference method could be securely proved in case of this system configuration and thus the formation of daily mean values is securely possible.

6.5 Findings

With the described system configuration and with a measurement cycle of 60 min, the formation of valid daily averages on the basis of 24 single measurements is possible.

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Not required for this minimum requirement.

6.1 5.3.6 Constancy of sample volumetric flow

The sample volumetric flow averaged over the sampling time shall be constant within ± 3 % of the rated value. All instantaneous values of the sample volumetric flow shall be within a range of ± 5 % of the rated value during sampling.

6.2 Equipment

Inlet adapter BX-305, flow meter according to point 4.

6.3 Performance of 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 h (=6 measurement cycles).

6.4 Evaluation

From the determined measured values for the flow rate, the mean value, the standard deviation as well as maximum and minimum value have been determined.

6.5 Findings

The results of the check of the sample volumetric flow, carried out before each field test site, are shown in Table 28.

Table 28: Results of sampling flow rate check

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-Roedingen	16.51	-1.0	17.09	2.5
Cologne, Frankfurter Str.	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.

Minimum requirement fulfilled?   yes

6.6 Presentation of test results

The determined characteristics for the flow rate are presented in Table 29 and in Table 30. Figure 51 and Figure 52 show a graphic presentation of the flow rate measurements at both candidate systems SN 4924 and SN 4925.

Table 29: Characteristics for the flow rate 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 30: Characteristics for the flow rate 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

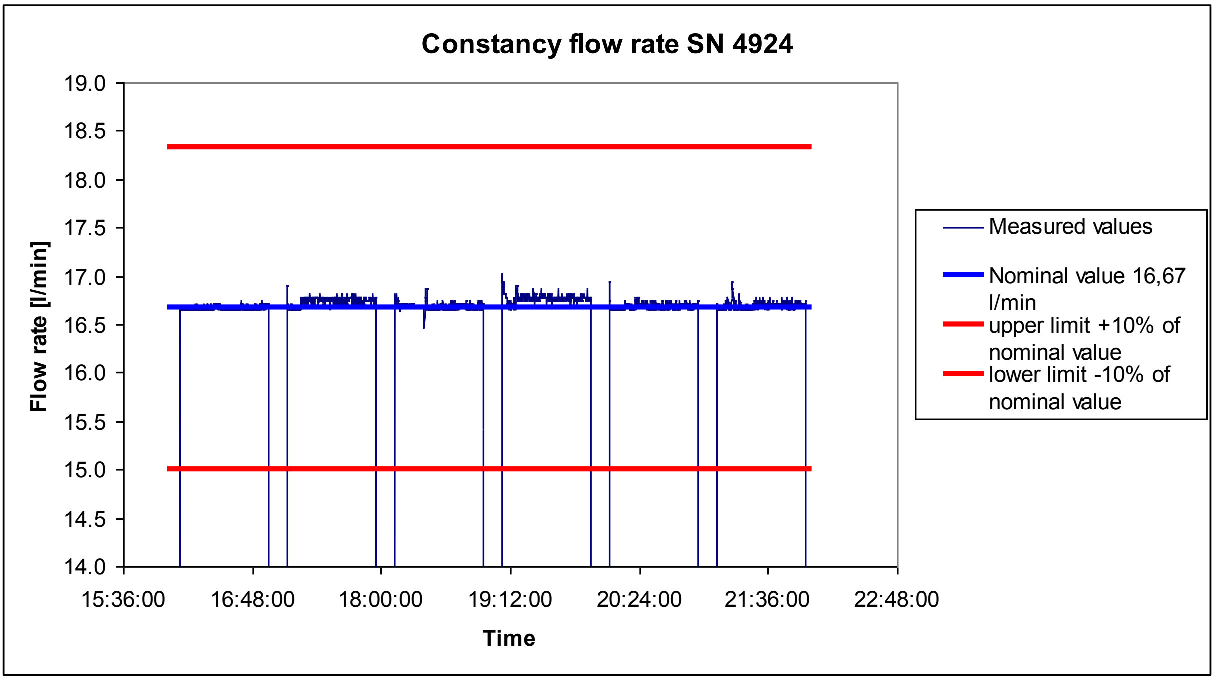

Figure 51: Flow rate at candidate SN 4924

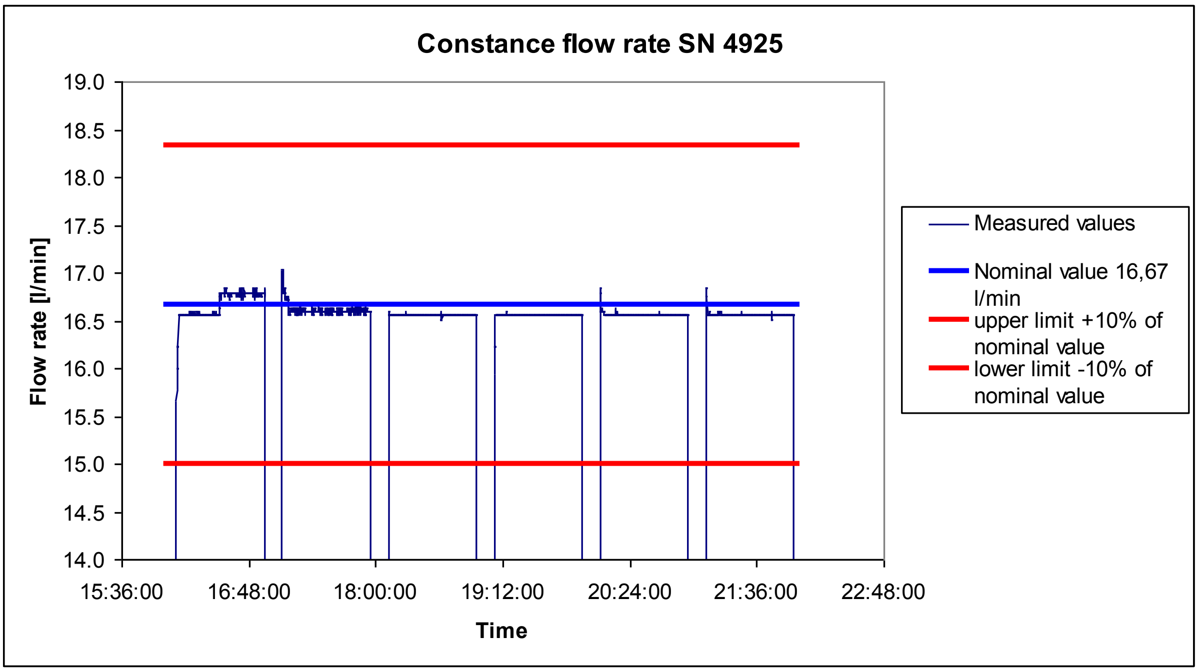

Figure 52: Flow rate at candidate SN 4925

6.1 5.3.7 Tightness of the sampling system

The complete sampling system shall be checked for tightness. Leakage shall not exceed 1 % of the sample volume sucked.

6.2 Equipment

Inlet adapter BX-305.

6.3 Performance of 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 switched-off pump (zero point of flow rate measurement), measured in the device, and the measured flow rate with sealed instrument inlet.

The procedure has been repeated three times.

6.4 Evaluation

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

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

6.5 Findings

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

Minimum requirement fulfilled? yes

6.6 Presentation of test results

Table 31 contains the determined values from the tightness test.

Table 31: Determination of leak rate

	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

6.1 5.4 Requirements for multiple-component measuring systems

Multiple-component measuring systems shall comply with the requirements set for each component, also in the case of simultaneous operation of all measuring channels. In case of sequential operation, the formation of hourly averages shall be possible.

6.2 Equipment

Not applicable.

6.3 Performance of test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Findings

Not applicable.

Minimum requirement fulfilled? -

6.6 Presentation of test results

Not applicable.

7 Additional test criteria according to Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“

7.1 Determination of the between-instrument uncertainty u_{bs} [9.5.2.1]

The between-sampler uncertainty u_{bs} has to be determined according to point 9.5.2.1 of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“.

7.2 Equipment

Not required for this minimum requirement.

7.3 Performance of test

The investigations according to the Guidance "Demonstration of Equivalence of Ambient Air Monitoring Methods" have been carried out exemplarily on the basis of the measured data according to [1], [2] and [3], obtained during the field test. Hereby the investigations have been performed deviant to the requirement of the Guidance only at three instead of four field test sites and with less than respectively 40 valid paired measurements per field test site.

The test work has been performed in the field test at three different test sites. During the test, different seasons, different PM10-concentrations as well as different ratios between TSP and PM10 have been taken into consideration.

For every test site, at least 15 valid data pairs have been determined. From the entire data set (3 test sites), in total 32 % of the measured values are above 50 % of the limit value for the daily mean of 50 µg/m³ for PM10. The measured concentrations have been referred to ambient conditions.

7.4 Evaluation

According to **point 9.5.2.1** of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“, it is imperative:

The between-instrument uncertainty u_{bs} shall be ≤ 3 µg/m³. An uncertainty larger than 3 µg/m³ between the candidate systems is an indication of unsuitable performance of one or both instruments and that the equivalence cannot be declared.

The uncertainty is hereby determined for:

- each test site separately
- all test sites together
- 1 data set with measured values ≥ 50 % of the limit value for the daily average of 50 µg/m³ for PM10 (basis: mean values of reference measurement)
- 1 data set with measured values < 50 % of the limit value for the daily average of 50 µg/m³ for PM10 (basis: mean values of reference measurement)

The between-instrument uncertainty u_{bs} is calculated from the differences of all 24-hour results of the candidate systems operated in parallel 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 parallel measurements for a single 24-hour period i

n = number of 24-hour measurement results

7.5 Findings

The between-instrument uncertainty u_{bs} is with at maximum 1.22 µg/m³ below the required value of 3 µg/m³.

Minimum requirement fulfilled? yes

7.6 Presentation of test results

Table 32 shows the calculated values for the between-instrument uncertainty u_{bs}. The graphic presentation can be found in Figure 53 to Figure 58.

Table 32: Between-instrument uncertainty u_{bs} for the candidates SN 4924 and SN 4925

Candidates	Test sites	No. of values	Uncertainty u_{bs}
SN			µg/m³
4924 / 4925	Cologne, parking lot	52	1.22
4924 / 4925	Titz-Roedingen	37	0.86
4924 / 4925	Cologne, Frankf. Str.	28	0.99
4924 / 4925	All test sites	117	1.07
4924 / 4925	Values ≥ 50 % of limit value (≥ 25 µg/m³)	30	1.22
4924 / 4925	Values < 50 % of limit value (< 25 µg/m³)	64	0.95
4924 / 4925	additional Cologne, Frankf. Str., EU-inlet	26	0.74

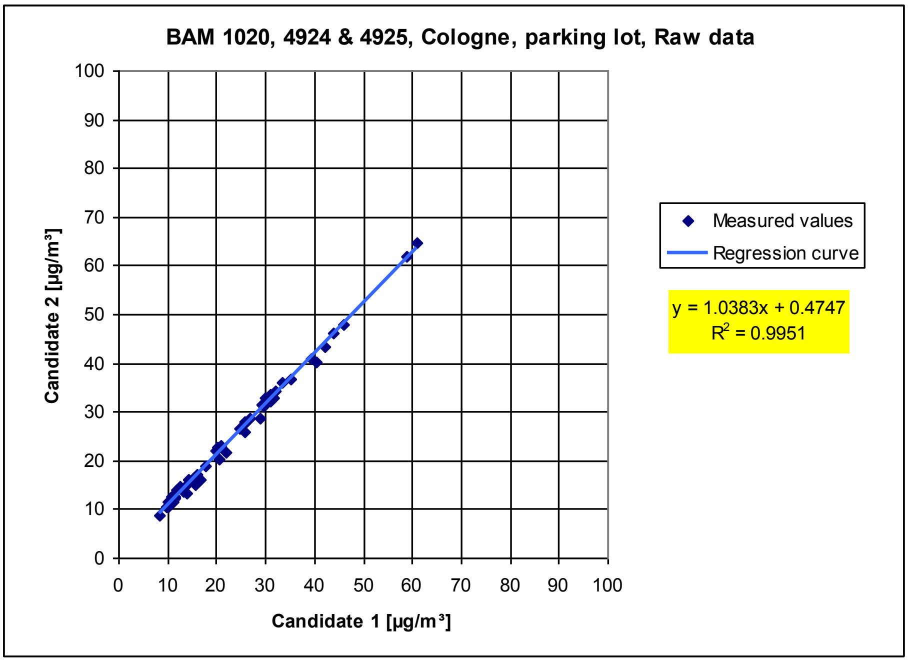

Figure 53: Result of the parallel measurements with the candidates SN 4924 / SN 4925, test site Cologne, parking lot

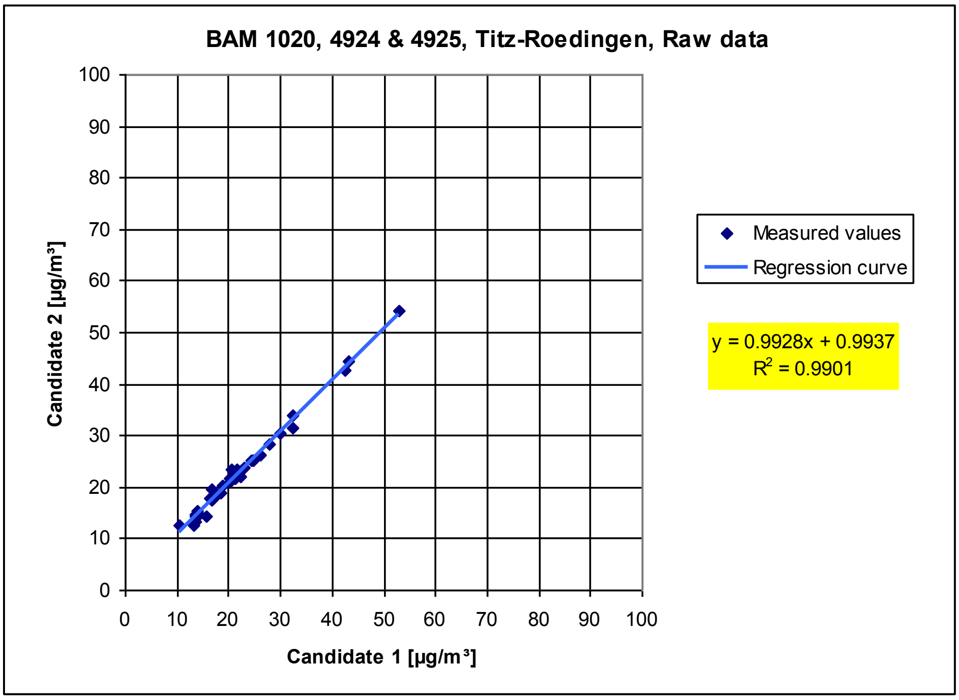

Figure 54: Result of the parallel measurements with the candidates SN 4924 / SN 4925, test sites Titz-Roedingen

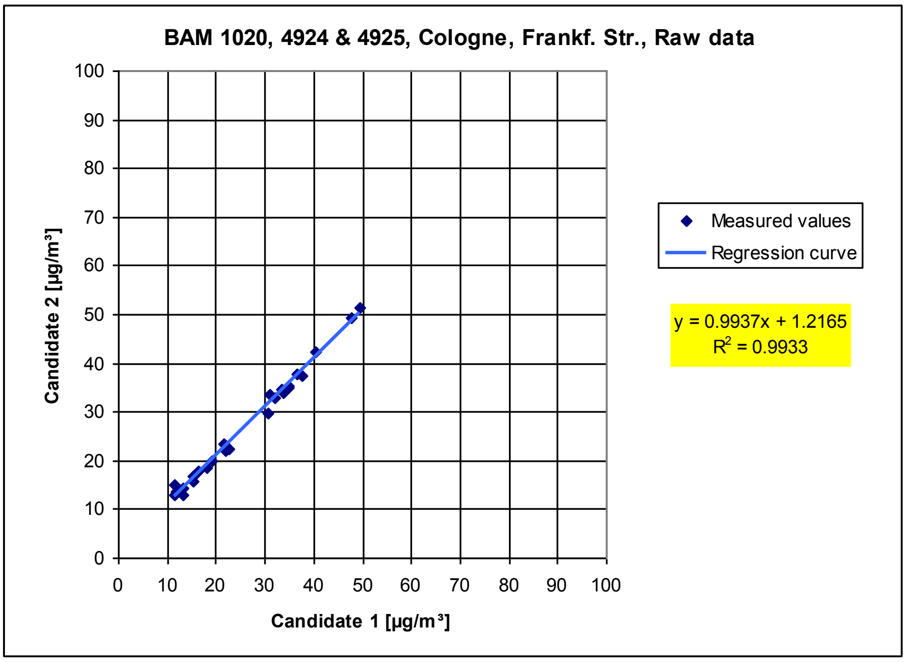

Figure 55: Result of the parallel measurements with the candidates SN 4924 / SN 4925, test site Cologne, Frankfurter Str.

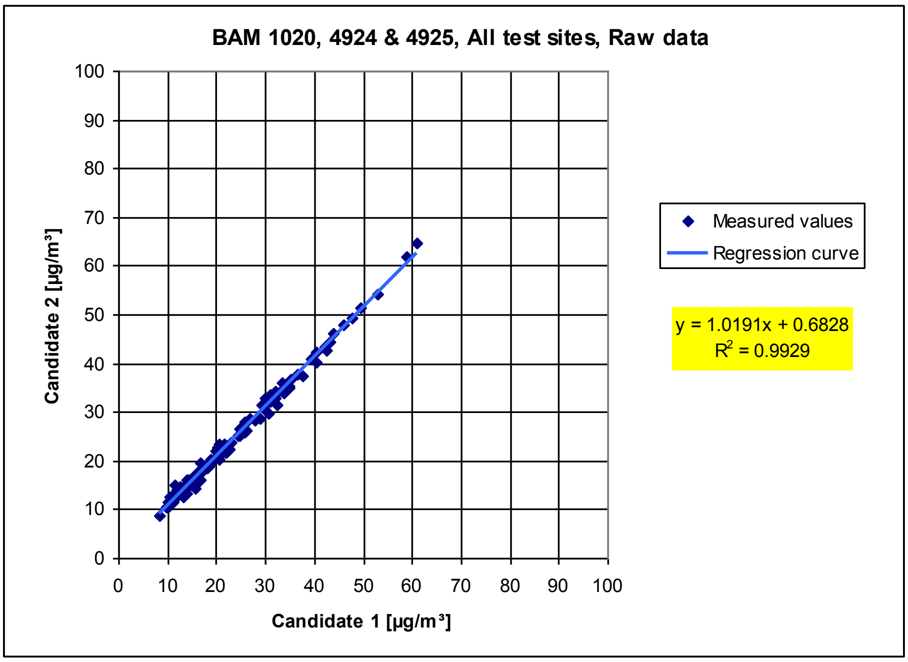

Figure 56: Result of the parallel measurements with the candidates SN 4924 / SN 4925, all test sites

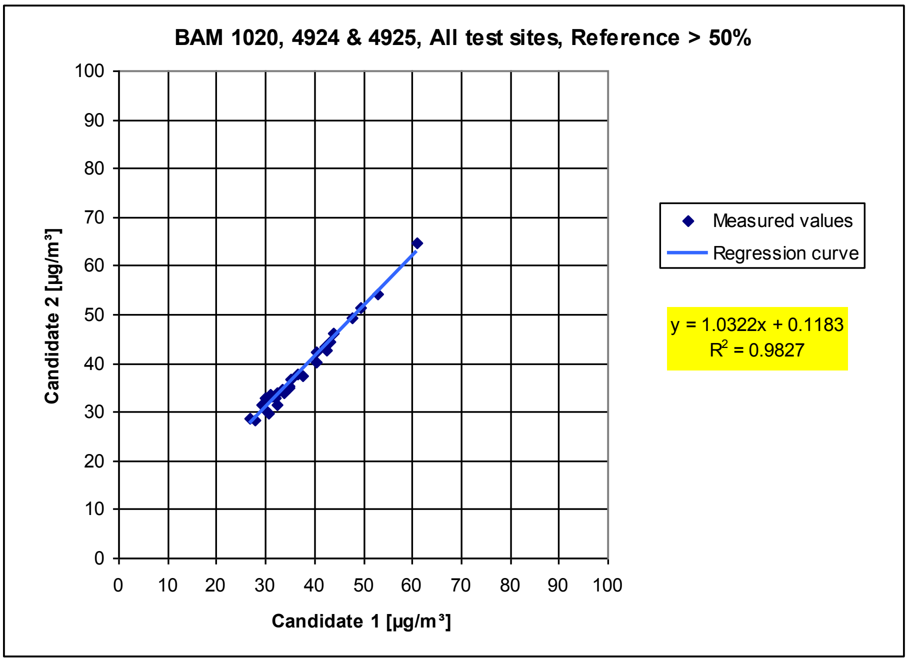

Figure 57: Result of the parallel measurements with the candidates SN 4924 / SN 4925, all test sites, values ≥ 50 % limit value (≥ 25 µg/m³)

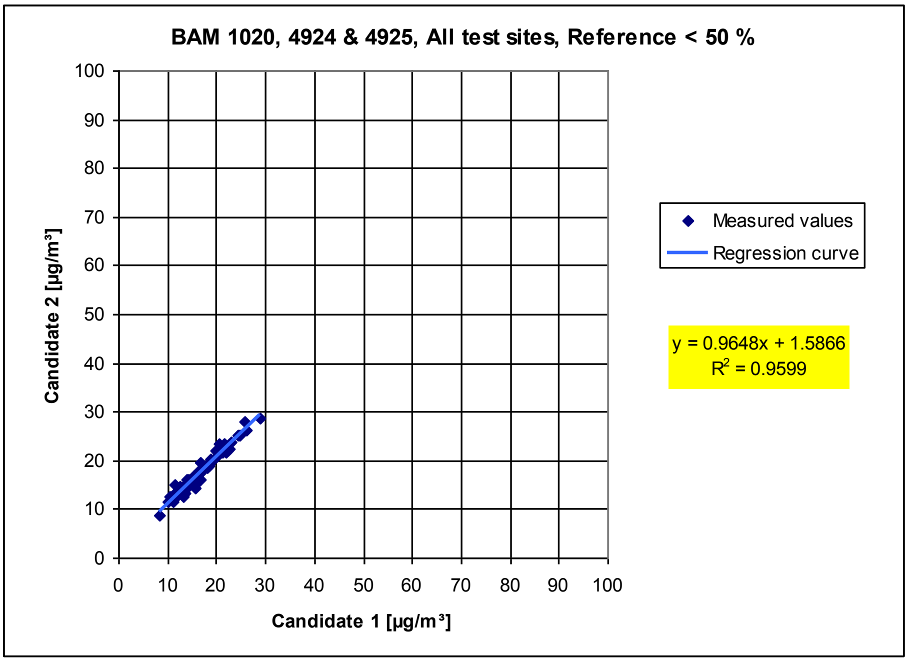

Figure 58: Result of the parallel measurements with the candidates SN 4924 / SN 4925, all test sites, values < 50 % limit value (< 25 µg/m³)

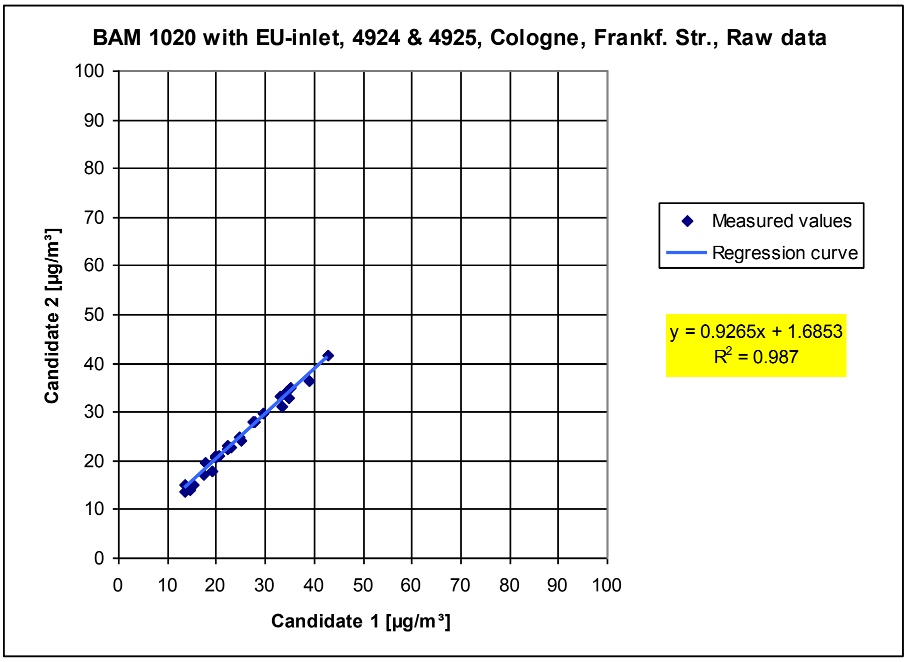

Figure 59: Result of the parallel measurements with the candidates SN 4924 / SN 4925, additional test site Cologne, Frankfurter Str. with EU-sampling inlet

7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6]

The equivalency of the candidate instruments to the reference method has to be demonstrated according to the points 9.5.2.2 to 9.5.4 of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“. The highest resulting expanded uncertainty of the candidate method is to compare with the requirements on the data quality of ambient air measurements according to EU-guideline [7].

7.2 Equipment

For this test point, the instruments mentioned in point 5 of the report at hand have been additionally used.

7.3 Performance of test

The investigations according to the Guidance “Demonstration of Equivalence of Ambient Air Monitoring Methods” have been carried out exemplarily on the basis of the measured data according to [1], [2] and [3], obtained during the field test. Hereby the investigations have been performed deviant to the requirement of the Guidance only at three instead of four field test sites and with less than respectively 40 valid paired measurements per field test site.

The test work has been performed in the field test at four different test sites. During the test, different seasons, different PM10-concentrations as well as different ratios between TSP and PM10 have been taken into consideration.

For every test site, at least 15 valid data pairs have been determined. From the entire data set (3 test sites), in total 32 % of the measured values are above 50 % of the limit value for the daily mean of 50 µg/m³ for PM10. The measured concentrations have been referred to ambient conditions.

7.4 Evaluation

[Point 9.5.2.2] The check of the uncertainty between the reference instruments u_{ref} operated in parallel is prefixed to the calculation of the expanded uncertainty of the candidate systems. The uncertainty between the reference instruments u_{ref} operated in parallel is determined analogically to the between-instrument uncertainty of the candidate systems as shall be ≤ 2 µg/m³. The results of the evaluation are shown in point 7.6 of this test point.

To assess the comparability of the candidates y with the reference method x, a linear relation $y_i = a + bx_i$ between the measured results of both methods is assumed. The relation between the average results of the reference instruments and of the candidates is established by orthogonal regression [9].

The regression is calculated for:

- each test site separately
- all test sites together
- 1 data set with measured values ≥ 50 % of the limit value for the daily average of 50 µg/m³ for PM10 (basis: mean values of reference measurement)

For further evaluations, the uncertainty of the results u_{c_s} of the candidate system from the comparison with the reference method is described by the following equation, which describes u_{c_s} as a function of the PM concentration x_i.

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

with RSS = sum of (relative) residues resulting from orthogonal regression

$u(x_i)$ = random uncertainty of the reference method; as such, the value of u_{bs} calculated for the application of the reference method is these tests may be used (refer to point 7.1 Determination of the between-instrument uncertainty u_{bs})

Algorithms for the calculation of the ordinate intercept a as well as of the slope b and their variances by orthogonal regression are described in detail in annex B of [9].

The sum of the (relative) residues RSS is calculated using the following equation:

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

The uncertainty u_{c_s} is calculated for:

- each test site separately
- all test sites together
- 1 data set with measured values ≥ 50 % of the limit value for the daily average of 50 µg/m³ for PM10 (basis: mean values reference measurement)

[Point 9.5.3] For all datasets the combined relative uncertainty of the candidate systems $w_{c,CM}$ is calculated by combining the contributions found in 9.5.2.1 and 9.5.2.2 as follows:

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

For each of the data sets the uncertainty at the daily limit value $w_{c,CM}$ is calculated by taking as y_i the concentration at the limit value.

[Point 9.5.4] For each of the datasets the expanded relative uncertainty of the results of the candidate systems is calculated by multiplying $w_{c,CM}$ by a coverage factor k according to the following equation:

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

In practice, k=2 for large n.

[Point 9.6] The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality for ambient air quality measurements according to EU-Guideline [7]. Two cases 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 defined expanded relative uncertainty W_{dqo} is 25 % for PM [7].

7.5 Findings

The determined uncertainties W_{CM} are below the set expanded relative uncertainty W_{dqo} of 25 % for PM for all regarded datasets without the application of correction factors.

Minimum requirement fulfilled? yes

7.6 Presentation of test results

Table 33 gives an overview on the between-instrument uncertainties u_{ref} for the reference instruments form the field investigations. In Table 34 a recapitulating presentation of the results for the expanded measurement uncertainties W_{CM} from the field investigations is shown. Table 35 to Table 39 show the results of the evaluations for the single datasets.

Table 33: Uncertainty between the reference instruments u_{ref}

Reference instruments	Test site	No. of values	Uncertainty u_{bs}
No.			µg/m³
1 / 2	Cologne, parking lot	29	0.55
1 / 2	Titz-Roedingen	37	0.65
1 / 2	Cologne, Frankf. Str.	28	1.02
1 / 2	All test sites	94	0.76
1 / 2	additional Cologne, Frankf. Str., candidates with EU-inlet	26	1.49

The uncertainty between the reference instruments u_{ref} is < 2 µg/m³ for all test sites.

Table 34: Compilation and evaluation of the expanded measurement uncertainties W_{CM} from the field investigations, raw data

Test site	**Slope b** (µg/m³)/(µg/m³)	**Ordinate intercept a** µg/m³	**u_{c_s} at limit value** µg/m³	**w_{CM}** %	**W_{CM}** %	**$W_{CM} \leq W_{dqo}$** (W_{dqo} = 25 %)
Cologne, parking lot	0.97	2.46	2.49	4.98	9.95	yes
Titz-Roedingen	1.06	0.85	3.97	7.93	15.87	yes
Cologne, Frankf. Str.	1.02	-0.70	1.90	3.79	7.58	yes
All test sites	0.99	1.41	2.40	4.81	9.61	yes
Values ≥ 50 % limit value (≥ 25 µg/m³)	0.99	1.45	2.31	4.62	9.23	yes
additional Cologne, Frankf. Str., EU-inlet	1.01	-0.90	0.91	1.82	3.63	yes

Table 35: Comparison candidate with reference, test site Cologne, parking lot

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	Cologne, parking lot	Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.97**	**not significant**		
Uncertainty of b	**0.03**			
Ordinate intercept a	**2.46**	**significant**		
Uncertainty of a	**0.86**			
Results of the equivalence test				
Deviation at limit value	**0.87**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**2.49**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**4.98**	**%**		
Expanded measurement uncertainty W_{CM}	**9.95**	**%**		
Status equivalence test	**pass**			

Table 36: Comparison candidate with reference, test site Titz-Roedingen

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	Titz-Roedingen	Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.06**	**not significant**		
Uncertainty of b	**0.03**			
Ordinate intercept a	**0.85**	**not significant**		
Uncertainty of a	**0.75**			
Results of the equivalence test				
Deviation at limit value	**3.62**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**3.97**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**7.93**	**%**		
Expanded measurement uncertainty W_{CM}	**15.87**	**%**		
Status equivalence test	**pass**			

Table 37: Comparison candidate with reference, test site Cologne, Frankfurter Str.

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	Cologne, Frankf. Str.	Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.02**	**not significant**		
Uncertainty of b	**0.04**			
Ordinate intercept a	**-0.70**	**not significant**		
Uncertainty of a	**1.01**			
Results of the equivalence test				
Deviation at limit value	**0.40**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.90**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**3.79**	**%**		
Expanded measurement uncertainty W_{CM}	**7.58**	**%**		
Status equivalence test	**pass**			

Table 38: Comparison candidate with reference, all test sites

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	All test sites	Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.99**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**1.41**	**significant**		
Uncertainty of a	**0.52**			
Results of the equivalence test				
Deviation at limit value	**1.13**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**2.40**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**4.81**	**%**		
Expanded measurement uncertainty W_{CM}	**9.61**	**%**		
Status equivalence test	**pass**			

Table 39: Comparison candidate with reference, all test sites, values ≥ 50 % limit value (≥ 25 µg/m³)

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	All test sites	Limit value	50	µg/m³
Status of measured values	Reference > 50%	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.99**	**not significant**		
Uncertainty of b	**0.05**			
Ordinate intercept a	**1.45**	**not significant**		
Uncertainty of a	**1.88**			
Results of the equivalence test				
Deviation at limit value	**0.97**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**2.31**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**4.62**	**%**		
Expanded measurement uncertainty W_{CM}	**9.23**	**%**		
Status equivalence test	**pass**			

Table 40: Comparison candidate with reference, additional test site Cologne, Frankfurter Str. with EU-sampling inlet

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020 with EU-inlet	SN	4924 & 4925	
Test site	Cologne, Frankf. Str.	Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.01**	**not significant**		
Uncertainty of b	**0.04**			
Ordinate intercept a	**-0.90**	**not significant**		
Uncertainty of a	**1.10**			
Results of the equivalence test				
Deviation at limit value	**-0.52**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**0.91**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**1.82**	**%**		
Expanded measurement uncertainty W_{CM}	**3.63**	**%**		
Status equivalence test	**pass**			

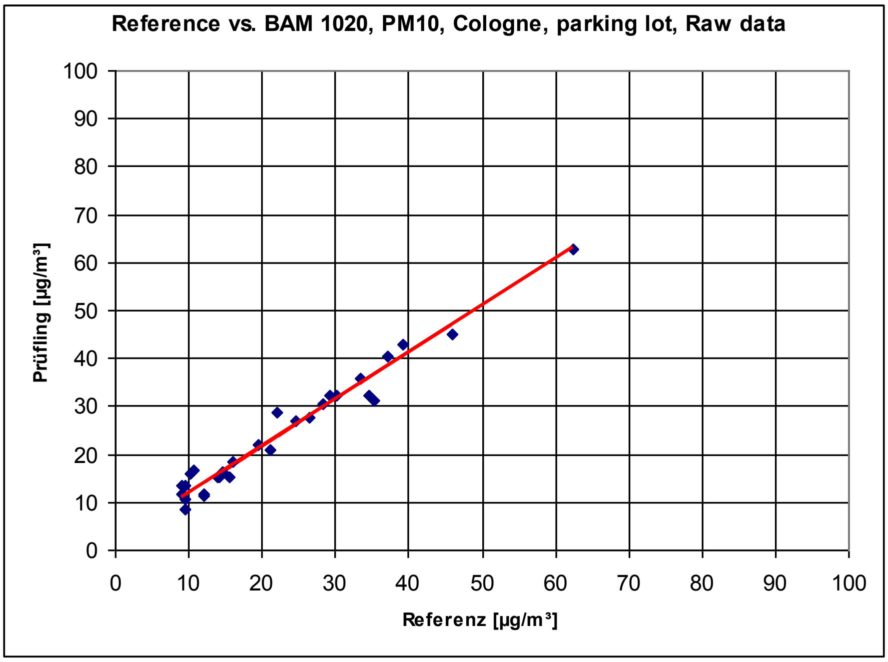

Figure 60: Reference vs. candidate, test site Cologne, parking lot

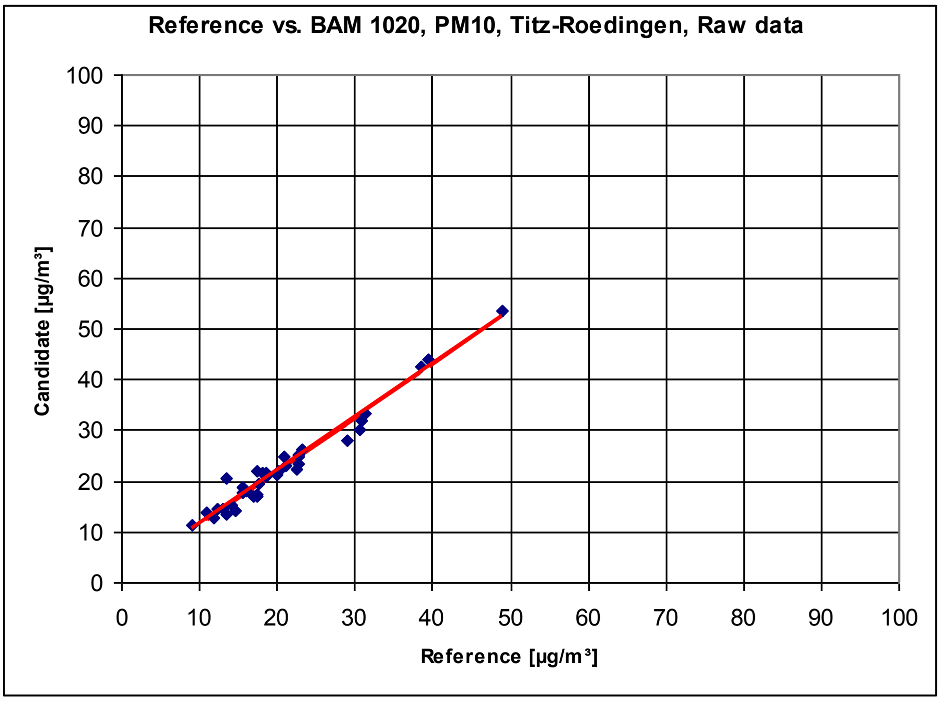

Figure 61: Reference vs. candidate, test site Titz-Roedingen

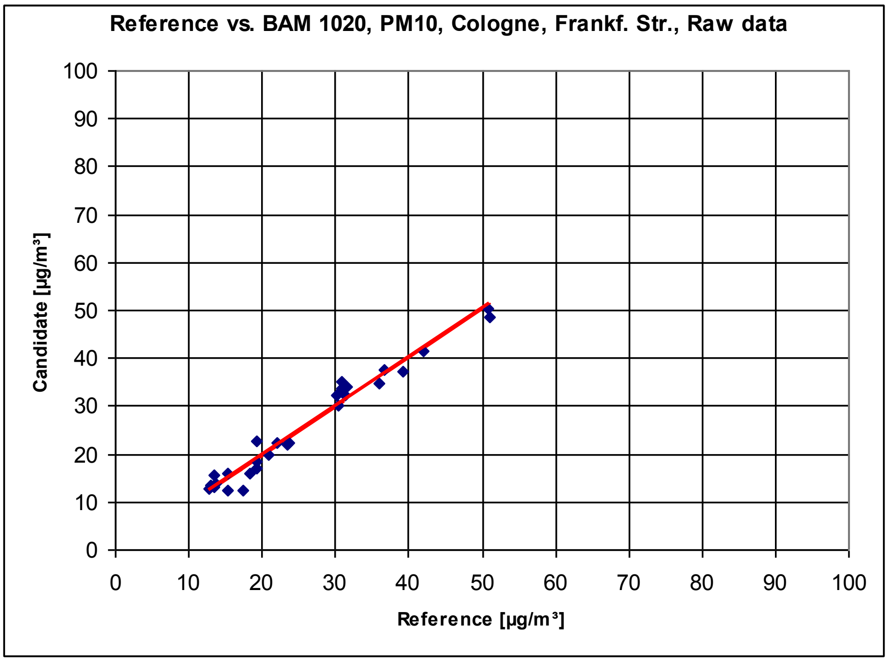

Figure 62: Reference vs. candidate, test site Cologne, Frankfurter Str.

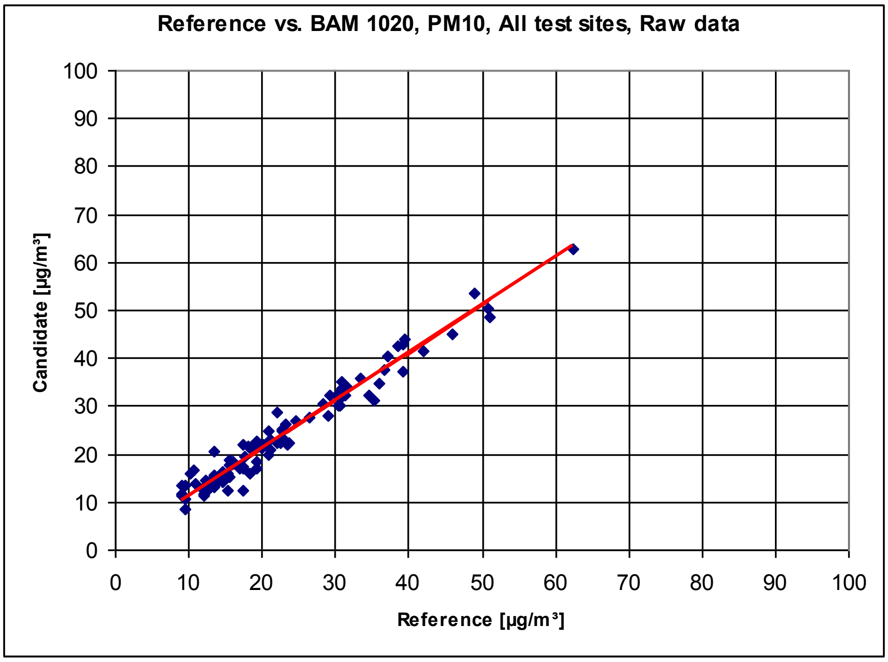

Figure 63: Reference vs. candidate, all test sites

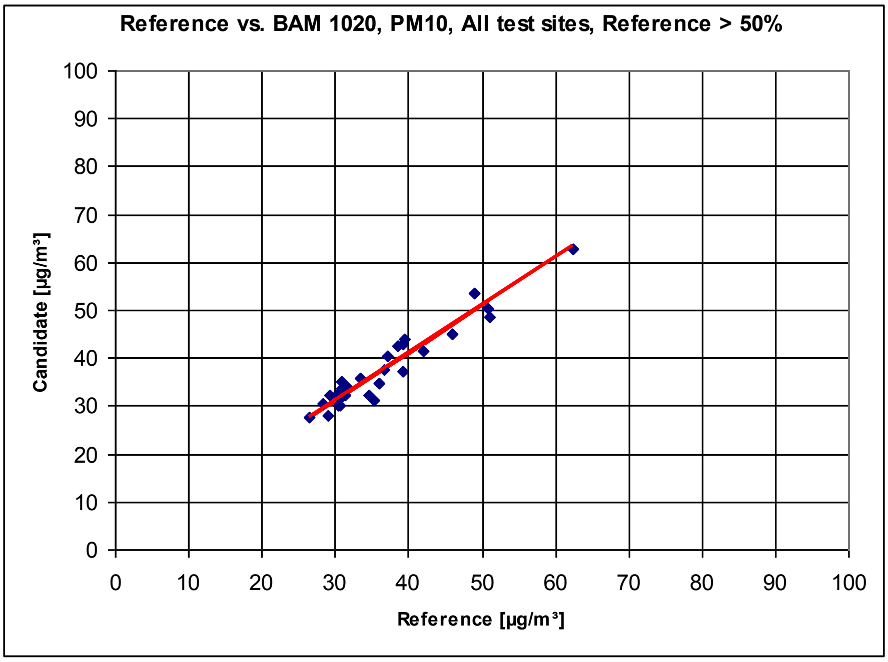

Figure 64: Reference vs. candidate, all test sites, values ≥ 50 % limit value (≥ 25 µg/m³)

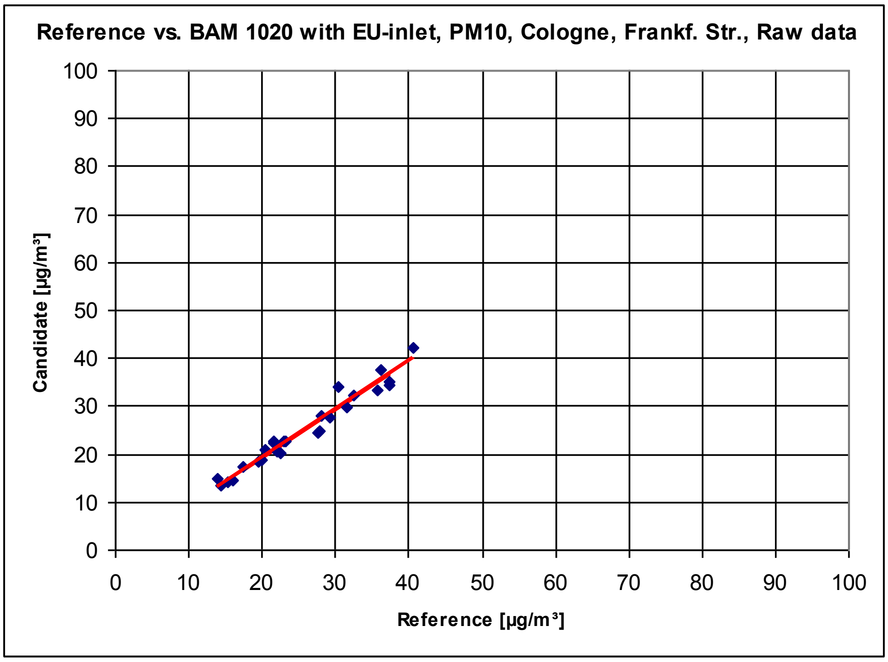

Figure 65: Reference vs. candidate, additional test site Cologne, Frankfurter Str. with EU-sampling inlet

7.1 Application of correction factors or terms [9.7]

If the highest resulting expanded uncertainty of the candidate method is larger than the expanded relative uncertainty, which is defined in the requirements on the data quality of ambient air measurements according to EU-Guideline [7], the application of correction factors or terms is permitted. The corrected values have to fulfill the requirements according to the points 9.5.2.2 et seqq. of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods".

7.2 Equipment

Not required for this minimum requirement.

7.3 Performance of test

Refer to module 9.5.2.2 – 9.5.6.

7.4 Evaluation

If the evaluation of the raw data according to module 9.5.2.2 – 9.5.6 leads to a case $W_{CM} > W_{dqo}$, 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 for the full dataset. The corrected values shall satisfy the requirements for all datasets or subsets (refer to module 9.5.2.2 – 9.5.6).
However, even when it is the case, that $W_{CM} \leq W_{dqo}$, a correction may be applied in order to improve the accuracy of the candidate systems.

Three distinct situations may arise:

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: $|a| > 2u(a)$

Re 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 by linear regression the following new terms:

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

and

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

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 annex B of [9]. RSS is determined analogically to the calculation in module 9.5.2.2 – 9.5.6.

Re 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 by linear regression the following new terms:

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

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 annex B of [9]. RSS is determined analogically to the calculation in module 9.5.2.2 – 9.5.6.

Re 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 by linear regression the following new terms:

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

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 annex B of [9]. RSS is determined analogically to the calculation in module 9.5.2.2 – 9.5.6.

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 dataset the uncertainty at the daily limit value $w_{c,CM,corr}$ is calculated 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 n.

The highest resulting uncertainty $W_{CM,corr}$ is compared and assessed with the requirements on data quality for ambient air quality measurements according to EU-Guideline [7]. Two cases are possible:

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

The defined expanded relative uncertainty W_{dqo} is 25 % for PM [7].

7.5 Findings

The candidate systems fulfill the requirements on the data quality of ambient air quality measurements during the test without the application of correction factors. A correction of the complete data set can be additionally carried out to show possible potential for improvements in the accuracy of the candidate systems. It has been shown, that by the appliance of correction factors and –terms, the accuracy of the candidate systems for the complete dataset can be changed from 9.61 % (raw data) to 8.81 % (correction of intercept), 11.05°% (correction of slope) and 9.69 % (correction of intercept and slope) and thus there are no significant differences in the respective measurement uncertainties after applying of correction factors and terms.

Minimum requirement fulfilled? yes

7.6 Presentation of test results

Table 41 to Table 44 show the results of the evaluations for the complete dataset after applying the possible correction factors/ terms.

Table 41: Comparison candidate with reference, all test sites, raw data

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	All test sites	Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.99**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**1.41**	**significant**		
Uncertainty of a	**0.52**			
Results of the equivalence test				
Deviation at limit value	**1.13**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**2.40**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**4.81**	**%**		
Expanded measurement uncertainty W_{CM}	**9.61**	**%**		
Status equivalence test	**pass**			

Table 42: Comparison candidate with reference, all test sites, correction of ordinate intercept

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	All test sites	Limit value	50	µg/m³
Status of measured values	Correction offset	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.99**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**0.00**	**not significant**		
Uncertainty of a	**0.52**			
Results of the equivalence test				
Deviation at limit value	**-0.29**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**2.20**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**4.41**	**%**		
Expanded measurement uncertainty W_{CM}	**8.81**	**%**		
Status equivalence test	**pass**			

Table 43: Comparison candidate with reference, all test sites, correction of slope

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	All test sites	Limit value	50	µg/m³
Status of measured values	Correction slope	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**1.42**	**significant**		
Uncertainty of a	**0.52**			
Results of the equivalence test				
Deviation at limit value	**1.43**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**2.76**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**5.53**	**%**		
Expanded measurement uncertainty W_{CM}	**11.05**	**%**		
Status equivalence test	**pass**			

Table 44: Comparison candidate with reference, all test sites, correction of ordinate intercept and slope

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	BAM 1020	SN	4924 & 4925	
Test site	All test sites	Limit value	50	µg/m³
Status of measured values	Correction offset & slope	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**0.00**	**not significant**		
Uncertainty of a	**0.52**			
Results of the equivalence test				
Deviation at limit value	**0.00**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**2.42**	**µg/m³**		
Combined measurement uncertainty w_{CM}	**4.84**	**%**		
Expanded measurement uncertainty W_{CM}	**9.69**	**%**		
Status equivalence test	**pass**			

8 Recommendations for the use in practice

Work in the maintenance interval

The following work is required for the tested measuring system in a regular interval:

- Regular visual inspection / telemetric monitoring
- - Device status o.k.
- - No error messages
- - No contaminations
- Check of the instrument functions according to the instructions of the manufacturer
- Check of filter tape stock
- Maintenance of the sampling head according manufacturer's specifications
- At least all 4 weeks: cleaning/lubricating of the impaction plates
- All 4 weeks: plausibility check of temperature, pressure sensors, if necessary re-calibration
- All 4 weeks: check of the flow rate

Furthermore it is to pay attention to the advices of the manufacturer.

The measuring systems carries out by default at each measurement cycle an internal check of the zero point (zero measurement, manually evaluable) as well as of the sensitivity (measurement with reference foil, automatically evaluated). The results of these checks can be used for the continuous check of the stability of the radiometric measurement.

Functional check and calibration

For the performance of the functional check respectively before the calibration, the following procedure is proposed:

- Visual inspection of the device and of the sampling system
- At least once a year: check of the carbon vanes of the pump, followed by check of the flow rate and if necessary re-calibration
- At least once a year: annual base maintenance, incl. check and replacement of the carbon vanes of the pump (only rotary vane), cleaning of sampling tube
- Check of data transmission (e.g. analogue- and status signals) to the evaluation system.

Further details to the functional check and to the calibration can be found in the manual.

Department of Environmental Protection

Karsten Pletscher	Dr. Peter Wilbring

Cologne, December 06, 2006
936/21205333/A

9 Literature

[1] Guideline VDI 4202, Sheet 1, „Minimum requirements for suitability tests of automated ambient air quality measuring systems – Point-related measurement methods of gaseous and particulate pollutants “, June 2002

[2] Guideline VDI 4203, Sheet 3, „Testing of automated measuring systems – Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants “, August 2004

[3] European Standard EN 12341, „Air quality – Determination of the PM10 fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods“, German version DIN EN 12341: 1998

[4] Guideline VDI 2463, Sheet 7, „Particulate measurement – Measurement of mass concentration in ambient air. Filter method. Small filter device GS 050, 1982

[5] Manual for BAM-1020

[6] Manual for SEQ47/50, status 2004

[7] DIRECTIVE 1999/30/EC of the council of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air

[8] Uniform Federal Practice for Ambient Air Quality Monitoring

Guidelines for the execution of construction work and the approval testing for measuring systems for continuous monitoring of ambient air quality. Circular of BMI of 08/19/1981 – U II 8 – 556 134/4

[9] Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods”,
English version of November 2005

10 Appendix

Appendix 1 Measured and calculated values

Annex 1:	Detection limit
Annex 2:	Dependence of zero point / measured value on ambient temperature
Annex 3:	Dependence on mains voltage
Annex 4:	Measured values from the field test sites
Annex 5:	Ambient conditions at the field test sites
Annex 6:	Software-Version BAM-1020

Appendix 2 Manuals

Annex 1 **Detection limit** **Page 1 of 1**

Manufacturer	Met One Instruments				
Meas. Range	0 to 1000	µg/m³		Temperature climate chamber	20 °C
Type	BAM 1020			Rel. Humidity climate chamber	60%
Serial-No.	SN 4924 & SN 4925			Zero point	internal zero measurement on filter tape

No.	Date	24-h-Measured values [µg/m³] SN 4924	SN 4925
1	4/21/06	0.42	0.80
2	4/22/06	-0.10	1.61
3	4/23/06	1.11	1.68
4	4/24/06	0.42	1.35
5	4/25/06	0.16	0.07
6	4/26/06	-0.42	0.69
7	4/27/06	0.25	0.95
8	4/28/06	0.96	-0.05
9	4/29/06	1.28	1.19
10	4/30/06	1.44	0.06
11	5/1/06	0.88	1.01
12	5/2/06	0.37	1.03
13	5/3/06	0.90	0.78
14	5/4/06	0.76	1.05
15	5/5/06	-0.30	0.56
16	5/6/06	1.01	1.20
17	5/7/06	-0.09	0.96
18	5/8/06	0.64	0.76
	No. of values	18	18
	Mean	0.54	0.87
	Standard deviation s_{x0}	0.55	0.49
	Detection limit X	**1.69**	**1.90**

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

Annex 2 **Dependence of zero point / reference point on ambient temperature** **Page 1 of 1**

Manufacturer Met One Instruments

Meas. Range 0 to 1000 µg/m³
Type BAM 1020
Serial-No. SN 4924 & SN 4925

Standards: Zero point — internal zero meas. at filter tape; Reference point — built-in reference foil

			Cycle 1		Cycle 2		Cycle 3			
SN 4924	No.	Temperature [°C]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]		
ZP	1	20	0.0	-	0.5	-	0.2	-		
	2	5	1.5	1.4	-0.7	-1.2	-0.1	-0.3		
	3	20	0.8	0.8	0.2	-0.3	1.4	1.1		
	4	40	0.8	0.8	0.8	0.3	1.2	0.9		
	5	20	0.8	0.8	0.1	-0.4	0.6	0.4		
SN 4925	No.	Temperature [°C]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]		
ZP	1	20	1.2	-	1.1	-	0.2	-		
	2	5	0.8	-0.4	1.6	0.5	1.1	0.9		
	3	20	0.7	-0.5	0.8	-0.3	1.2	1.0		
	4	40	0.8	-0.4	0.6	-0.5	0.9	0.7		
	5	20	0.4	-0.8	1.6	0.5	1.2	1.0		
SN 4924	No.	Temperature [°C]	Meas. value foil [µg/cm²]	Dev. [%]	Meas. value foil [µg/cm²]	Dev. [%]	Meas. value foil [µg/cm²]	Dev. [%]		
RP	1	20	823.6	-	824.9	-	826.9	-		
	2	5	825.9	0.3	825.5	0.1	825.9	-0.1		
	3	20	825.0	0.2	825.7	0.1	826.3	-0.1		
	4	40	825.8	0.3	825.0	0.0	825.5	-0.2		
	5	20	825.4	0.2	824.9	0.0	824.6	-0.3		
SN 4925	No.	Temperature [°C]	Meas. value foil [µg/cm²]	Dev. [%]	Meas. value foil [µg/cm²]	Dev. [%]	Meas. value foil [µg/cm²]	Dev. [%]		
RP	1	20	814.8	-	814.9	-	813.5	-		
	2	5	817.5	0.3	815.7	0.1	815.8	0.3		
	3	20	815.1	0.0	815.0	0.0	813.5	0.0		
	4	40	813.7	-0.1	813.8	-0.1	813.6	0.0		
	5	20	814.6	0.0	815.0	0.0	814.9	0.2		

Annex 3 **Dependence of zero point / reference point on the mains voltage** **Page 1 of 1**

Manufacturer Met One Instruments

Meas. Range 0 to 1000 µg/m³
Type BAM 1020
Serial-No. SN 4924 & SN 4925

Standards
Zero point: internal zero meas. at filter tape
Reference point: built-in reference foil

			Cycle 1		Cycle 2		Cycle 3	
SN 4924	No.	Mains voltage [V]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]
	1	230	-0.2	-	0.0	-	2.1	-
	2	190	0.2	0.5	-0.1	-0.1	2.6	0.5
ZP	3	230	0.0	0.3	-0.6	-0.6	-2.4	-4.5
	4	245	1.3	1.6	-0.8	-0.9	-0.8	-2.9
	5	230	1.8	2.0	1.1	1.1	0.2	-1.9
SN 4925	No.	Mains voltage [V]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]	Meas. value MetOne [µg/m³]	Dev. [µg/m³]
	1	230	0.8	-	0.7	-	1.4	-
	2	190	1.1	0.3	-0.1	-0.8	1.6	0.2
ZP	3	230	0.5	-0.2	0.4	-0.3	0.9	-0.5
	4	245	0.4	-0.3	-0.2	-0.9	1.4	0.0
	5	230	3.3	2.6	0.2	-0.5	1.3	-0.1
SN 4924	No.	Mains voltage [V]	Meas. value foil [µg/cm²]	Dev. [%]	Meas. value foil [µg/cm²]	Dev. [%]	Meas. value foil [µg/cm²]	Dev. [%]
	1	230	822.0	-	823.7	-	823.4	-
	2	190	822.6	0.1	824.7	0.1	824.6	0.1
RP	3	230	824.2	0.3	823.6	0.0	825.5	0.3
	4	245	823.3	0.2	824.7	0.1	821.9	-0.2
	5	230	824.7	0.3	822.7	-0.1	823.9	0.1
SN 4925	No.	Mains voltage [V]	Meas. value foil [µg/cm²]	Dev. [%]	Meas. value foil [µg/cm²]	Dev. [%]	Meas. value foil [µg/cm²]	Dev. [%]
	1	230	812.4	-	812.2	-	810.8	-
	2	190	811.5	-0.1	811.9	0.0	812.8	0.2
RP	3	230	812.6	0.0	811.0	-0.1	809.5	-0.2
	4	245	811.1	-0.2	810.7	-0.2	811.0	0.0
	5	230	811.1	-0.2	812.4	0.0	811.1	0.0

Annex 4 **Measured values from the field test sites, related to standard conditions** **Page 1 of 10**

Manufacturer Met One Instruments

Meas. Range 0 to 1000 µg/m³
Type BAM 1020
Serial-No. SN 4924 & SN 4925

Measured object SPM PM 10, ambient air
Test site Cologne, parking lot
Measured values in µg/m³ std. conditions

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	TSP [µg/m³]	PM10/TSP [%]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
1	2/11/06	35.2	35.6	48.5	73.0	29.7	32.8		Cologne, parking lot
2	2/12/06					25.7	26.0		
3	2/13/06	33.8	35.2	49.9	69.1	31.2	33.7		
4	2/14/06							Flow rate check	
5	2/15/06	13.1	12.3	48.9	26.0	11.4	13.3		
6	2/16/06	10.4	10.0			10.7	12.2		
7	2/17/06	10.1	9.7	32.1	30.8	8.3	8.7		
8	2/18/06					14.6	13.8		
9	2/19/06					10.8	12.0		
10	2/20/06	9.6	10.2	20.0	49.5	12.7	15.1		
11	2/21/06	14.2	14.0	30.5	46.2	14.4	16.5		
12	2/22/06	16.0	16.2	28.3	56.9	17.7	18.9		
13	2/23/06					20.5	20.3		
14	2/24/06					29.7	31.4		
15	2/25/06	28.1	29.1	39.2	73.0	29.2	31.8		
16	2/26/06					30.8	31.9		
17	2/27/06					32.4	34.4		
18	2/28/06					12.0	14.3		
19	3/1/06	15.8	15.9	19.2	82.6	15.8	15.1		
20	3/2/06	19.9	20.5	31.2	64.7	22.5	22.2		
21	3/3/06	47.1	47.0	63.1	74.6	44.8	47.3		
22	3/4/06					46.9	48.7		
23	3/5/06					21.4	23.5		
24	3/6/06	21.4	21.3			19.9	22.3		
25	3/7/06	26.5	27.1	29.3	91.5	27.1	29.0		
26	3/8/06	15.2	14.2	42.6	34.5	14.8	16.8		
27	3/9/06	15.6	15.3	22.0	70.2	17.5	17.0		
28	3/10/06	12.6	12.4	17.9	69.8	11.5	12.0		
29	3/11/06					25.6	27.5		
30	3/12/06					29.0	30.8		

Annex 4 **Measured values from the field test sites, related to standard conditions** **Page 2 of 10**

Manufacturer Met One Instruments

Meas. Range 0 to 1000 µg/m³
Type BAM 1020
Serial-No. SN 4924 & SN 4925

Measured object SPM PM 10, ambient air
Test site Cologne, parking lot / Titz-Roedingen
Measured values in µg/m³ std. conditions

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	TSP [µg/m³]	PM10/TSP [%]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
31	3/13/06	24.4	24.2	36.2	67.1	25.2	27.6		Cologne, parking lot
32	3/14/06	30.3	30.3	92.7	32.7	31.4	33.2		
33	3/15/06	33.7	34.1	49.0	69.2	35.5	37.0		
34	3/16/06	39.6	39.3	44.5	88.7	42.2	43.6		
35	3/17/06					39.6	41.0		
36	3/18/06	37.2	37.5			40.7	40.8		
37	3/19/06					59.8	63.0		
38	3/20/06	64.0	64.0			62.0	66.0		
39	3/21/06					32.5	33.6		
40	3/22/06	29.9	30.0			31.4	34.0		
41	3/23/06	22.0	23.5			29.6	29.6		
42	3/24/06					35.2	37.8		
43	3/25/06	8.7	10.4			12.2	12.9		
44	3/26/06					11.8	12.3		
45	3/27/06					14.2	15.5		
46	3/28/06	9.4	9.8			14.0	14.5		
47	3/29/06	10.8	11.9			16.8	18.0		
48	3/30/06					10.4	11.3		
49	3/31/06	10.2	11.5	15.3	70.9	16.1	17.2		
50	4/1/06					12.0	13.1		
51	4/2/06					10.4	11.0		
52	4/3/06					20.8	23.4		
53	4/4/06					25.2	27.2		
54	7/26/06	54.3	53.8	85.6	63.1	58.5	60.1		Titz-Roedingen
55	7/27/06	42.7	43.6	67.9	63.5	47.6	48.7		
56	7/28/06							Power loss	
57	7/29/06							Power loss	
58	7/30/06	19.3	20.9	26.1	77.0	21.9	23.6		
59	7/31/06	19.0	20.3	25.1	78.4	23.1	23.6		
60	8/1/06	17.2	17.3	22.8	75.6	18.1	21.2		

Annex 4 **Measured values from the field test sites, related to standard conditions** **Page 3 of 10**

Manufacturer Met One Instruments

Meas. Range 0 to 1000 µg/m³
Type BAM 1020
Serial-No. SN 4924 & SN 4925

Measured object SPM PM 10, ambient air
Test site Titz-Roedingen
Measured values in µg/m³ std. conditions

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	TSP [µg/m³]	PM10/TSP [%]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
61	8/2/06	18.7	19.2	22.2	85.3	20.1	21.7		Titz-Roedingen
62	8/3/06	17.7	18.9			17.3	19.0		
63	8/4/06	24.2	24.9	27.1	90.5	26.7	26.9		
64	8/5/06	21.7	23.1			26.1	27.1		
65	8/6/06	20.0	20.1	23.0	87.2	22.5	24.0		
66	8/7/06	23.6	24.7	28.0	86.3	23.2	25.0		
67	8/8/06	15.5	15.7	17.9	87.2	14.6	15.7		
68	8/9/06	31.7	29.8	36.0	85.4	29.5	30.3		
69	8/10/06	23.9	24.4	26.0	92.8	24.5	25.2		
70	8/11/06	19.1	17.6			17.9	18.5		
71	8/12/06	21.8	20.9			21.9	23.3		
72	8/13/06	14.8	13.9	16.9	85.1	14.4	14.1		
73	8/14/06	14.9	13.9	24.4	59.0	21.9	22.5		
74	8/15/06	32.9	32.6	34.1	96.2	32.1	32.7		
75	8/16/06	23.8	25.7	30.9	80.0	26.7	27.3		
76	8/17/06	18.4	19.5	23.1	82.0	18.5	19.3		
77	8/18/06	13.1	12.5	16.6	77.2	14.2	13.8		
78	8/19/06	12.4	14.2			14.9	16.6		
79	8/20/06	10.9	12.4			14.3	15.3		
80	8/21/06	16.3	16.6	18.9	87.1	19.7	20.0		
81	8/22/06	20.7	21.7	23.3	91.0	22.3	23.0		
82	8/23/06	41.0	41.9	55.4	74.8	45.7	45.9		
83	8/24/06	16.1	17.3	21.9	76.3	18.4	19.7		
84	8/25/06	34.2	33.3	56.8	59.5	35.0	36.6		
85	8/26/06	33.3	32.8			34.6	33.7		
86	8/27/06	22.8	22.5	26.7	84.7	24.4	25.1		
87	8/28/06	13.6	14.0	16.4	84.3	15.3	15.6		
88	8/29/06	14.5	15.4			16.7	15.4		
89	8/30/06							Electric meter installed	
90	8/31/06	17.7	19.4			23.7	23.4		

Annex 4 **Measured values from the field test sites, related to standard conditions** **Page 4 of 10**

Manufacturer Met One Instruments

Meas. Range 0 to 1000 µg/m³
Type BAM 1020
Serial-No. SN 4924 & SN 4925

Measured object SPM PM 10, ambient air
Test site Titz-Roedingen / Cologne, Frankf. Str.
Measured values in µg/m³ std. conditions

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	TSP [µg/m³]	PM10/TSP [%]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
91	9/1/06	25.1	25.0	43.9	57.1	28.2	28.2		Titz-Roedingen
92	9/2/06	22.1	21.7			22.2	25.5		
93	9/3/06	10.1	9.7	23.5	42.1	11.1	13.7		
94	9/29/06	35.4	32.8	42.4	80.4	36.0	37.3		Cologne, Frankf. Str.
95	9/30/06	20.2	21.2			17.7	19.1		
96	10/1/06	16.3	16.6	17.2	95.8	12.4	14.0		
97	10/2/06	19.2	18.3	21.0	89.2	12.9	14.1		
98	10/3/06	20.0	19.3			16.4	18.0		
99	10/4/06	24.7	25.0	29.1	85.3	22.6	24.5		
100	10/5/06	14.9	13.4	17.4	81.1	16.0	16.6		
101	10/6/06	15.0	13.7	17.4	82.6	14.0	13.8		
102	10/7/06	21.5	22.3			20.1	21.0		
103	10/8/06	24.7	24.0			22.8	23.0		
104	10/9/06	32.0	32.2	39.6	81.0	32.4	31.3		
105	10/10/06	38.1	37.9			36.7	36.9		
106	10/11/06	42.2	41.6			38.8	40.3		
107	10/12/06	54.0	53.4			52.4	54.4		
108	10/13/06	43.8	43.9			42.1	44.4		
109	10/14/06	53.7	51.6	52.9	99.5	49.3	50.8		
110	10/15/06	38.9	37.0			38.8	38.9		
111	10/16/06	32.2	30.4	38.1	82.1	33.2	34.1		
112	10/17/06	33.3	31.7	40.1	81.0	35.4	35.6		
113	10/18/06	33.9	32.2	51.2	64.5	37.5	38.2		
114	10/19/06	24.3	23.2	31.6	75.3	23.4	24.9		
115	10/20/06	15.3	14.1	18.8	78.1	14.3	15.7		
116	10/21/06	14.6	12.7	18.5	73.7	12.8	14.8		
117	10/22/06	14.3	13.9			12.5	16.4		
118	10/23/06	16.7	16.8	18.6	89.9	16.7	18.1		
119	10/24/06	20.6	20.5	26.4	77.9	19.1	19.7		
120	10/25/06	21.0	19.9	30.9	66.1	23.9	23.9		

Annex 4 **Measured values from the field test sites, related to standard conditions** **Page 5 of 10**

Manufacturer Met One Instruments
Meas. Range 0 to 1000 µg/m³
Type BAM 1020
Serial-No. SN 4924 & SN 4925

Measured object SPM PM 10, ambient air
Test site Cologne, Frankf. Str.
Measured values in µg/m³ std. conditions

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	TSP [µg/m³]	PM10/TSP [%]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
121	10/26/06	31.0	31.4	41.5	75.2	33.5	36.4		Cologne, Frankf. Str.
122	10/27/06	29.8	28.6	41.5	70.3	27.6	29.4	Change to EU-inlet	Cologne, Frankf. Str.
123	10/28/06	23.6	22.4	26.9	85.5	24.0	23.9		
124	10/29/06	23.9	22.4			23.5	23.8		
125	10/30/06	36.3	35.3	50.8	70.4	34.7	34.8		
126	10/31/06	22.1	22.2	33.1	66.9	20.9	22.2		
127	11/1/06	22.3	21.0	34.6	62.6	22.5	23.3		
128	11/2/06	28.7	27.3	32.8	85.4	28.2	28.1		
129	11/3/06	37.4	37.2	43.9	85.0	35.6	35.6		
130	11/4/06	32.3	32.7			34.0	31.7		
131	11/5/06	29.9	31.0	43.2	70.5	35.7	34.0		
132	11/6/06	39.9	41.6	56.4	72.2	43.8	42.7		
133	11/7/06	35.6	36.9			40.0	37.3		
134	11/8/06	31.3	32.0	38.6	82.0	30.7	30.9		
135	11/9/06	27.5	27.8	35.6	77.7	25.3	24.5		
136	11/10/06	38.0	36.6	50.4	74.1	35.1	34.6		
137	11/11/06	17.9	16.7	20.6	84.0	18.2	17.7		
138	11/12/06	19.3	19.8	22.1	88.6	19.6	18.6		
139	11/13/06	14.3	14.7	16.8	86.1	14.3	14.3		
140	11/14/06	16.3	15.6	19.6	81.4	14.4	16.0		
141	11/15/06	28.1	27.8	39.3	71.0	26.1	26.3		
142	11/16/06	21.9	23.3			21.2	22.2		
143	11/17/06	15.2	15.4	22.9	66.7	15.2	14.7		
144	11/18/06	21.7	21.6	30.9	70.1	22.9	23.0		
145	11/19/06	19.9	21.1	22.0	93.2	21.1	21.3		
146	11/20/06	13.7	13.9	19.7	70.2	15.8	15.4		
147	11/21/06	19.5	20.5	24.9	80.3	18.5	20.5		

Annex 4 **Measured values from the field test sites, related to ambient conditions** **Page 6 of 10**

Manufacturer	Met One Instruments		
		Measured object	SPM PM 10, ambient air
Meas. Range	0 to 1000 µg/m³	Test site	Cologne, parking lot
Type	BAM 1020		Measured values in µg/m³ amb. conditions for evaluation according to Guidance "Demonstration of Equivalence of Ambient Air Monitoring Methods"
Serial-No.	SN 4924 & SN 4925		

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
1	2/11/06	35.2	35.5	29.8	32.9		Cologne, parking lot
2	2/12/06			25.7	26.0		
3	2/13/06	33.4	35.7	30.9	33.3		
4	2/14/06					Flow rate check	
5	2/15/06	12.5	11.7	10.9	12.7		
6	2/16/06	9.8	9.4	10.1	11.5		
7	2/17/06	9.6	9.2	8.2	8.7		
8	2/18/06			14.0	13.3		
9	2/19/06			10.4	11.5		
10	2/20/06	9.2	10.0	12.4	14.7		
11	2/21/06	14.0	13.8	14.1	16.1		
12	2/22/06	16.0	16.1	17.7	18.9		
13	2/23/06			20.5	20.3		
14	2/24/06			29.5	31.1		
15	2/25/06	27.9	28.8	29.1	31.6		
16	2/26/06			31.1	32.2		
17	2/27/06			32.1	34.1		
18	2/28/06			11.8	14.0		
19	3/1/06	15.5	15.7	15.6	14.9		
20	3/2/06	19.1	20.0	22.1	21.8		
21	3/3/06	45.8	45.9	43.9	46.3		
22	3/4/06			46.1	47.8		
23	3/5/06			21.0	23.1		
24	3/6/06	21.1	21.0	19.8	22.0		
25	3/7/06	26.2	26.6	26.8	28.7		
26	3/8/06	14.6	13.6	14.3	16.3		
27	3/9/06	14.8	14.6	16.8	16.2		
28	3/10/06	12.1	12.0	11.1	11.6		
29	3/11/06			25.8	27.5		
30	3/12/06			29.9	31.7		

Annex 4 **Measured values from the field test sites, related to ambient conditions** **Page 7 of 10**

Manufacturer Met One Instruments

Meas. Range 0 to 1000 µg/m³
Type BAM 1020
Serial-No. SN 4924 & SN 4925

Measured object: SPM PM 10, ambient air
Test site: Cologne, parking lot / Titz-Roedingen
Measured values in µg/m³ amb. conditions for evaluation according to Guidance "Demonstration of Equivalence of Ambient Air Monitoring Methods"

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
31	3/13/06	24.7	24.5	25.7	28.0		Cologne, parking lot
32	3/14/06	30.2	30.1	31.4	33.2		
33	3/15/06	33.3	33.6	35.2	36.7		
34	3/16/06	39.2	39.1	42.1	43.5		
35	3/17/06			39.5	40.8		
36	3/18/06	37.0	37.2	40.3	40.4		
37	3/19/06			58.8	61.9		
38	3/20/06	62.5	62.5	60.9	64.8		
39	3/21/06			31.8	32.9		
40	3/22/06	29.3	29.4	31.1	33.6		
41	3/23/06	21.3	22.7	28.8	28.7		
42	3/24/06			33.6	36.1		
43	3/25/06	8.1	9.8	11.5	12.2		
44	3/26/06			11.1	11.5		
45	3/27/06			13.4	14.7		
46	3/28/06	8.9	9.3	13.4	13.8		
47	3/29/06	10.3	11.2	16.1	17.3		
48	3/30/06			9.8	10.6		
49	3/31/06	9.6	10.9	15.3	16.3		
50	4/1/06			11.5	12.5		
51	4/2/06			10.0	10.5		
52	4/3/06			20.3	22.8		
53	4/4/06			24.7	26.7		
54	7/26/06	49.1	48.6	52.8	54.2		Titz-Roedingen
55	7/27/06	39.0	39.7	43.4	44.4		
56	7/28/06					Power loss	
57	7/29/06					Power loss	
58	7/30/06	17.8	19.2	20.0	21.6		
59	7/31/06	17.6	18.7	21.3	21.8		
60	8/1/06	15.9	16.0	16.8	19.6		

Annex 4 **Measured values from the field test sites, related to ambient conditions** **Page 8 of 10**

Manufacturer	Met One Instruments		
		Measured object	SPM PM 10, ambient air
Meas. Range	0 to 1000 µg/m³	Test site	Titz-Roedingen
Type	BAM 1020		Measured values in µg/m³ amb. conditions for evaluation according to Guidance "Demonstration of Equivalence of Ambient Air Monitoring Methods"
Serial-No.	SN 4924 & SN 4925		

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
61	8/2/06	17.4	17.8	18.7	20.2		Titz-Roedingen
62	8/3/06	16.5	17.6	16.2	17.8		
63	8/4/06	22.5	23.0	24.8	25.0		
64	8/5/06	20.1	21.4	24.3	25.2		
65	8/6/06	18.7	18.7	21.0	22.4		
66	8/7/06	22.0	22.9	21.6	23.3		
67	8/8/06	14.6	14.8	13.7	14.8		
68	8/9/06	29.8	28.0	27.7	28.5		
69	8/10/06	22.6	22.9	23.0	23.7		
70	8/11/06	18.0	16.6	16.9	17.5		
71	8/12/06	20.4	19.5	20.5	21.8		
72	8/13/06	13.8	12.9	13.5	13.2		
73	8/14/06	13.8	12.9	20.4	20.9		
74	8/15/06	30.7	30.3	29.9	30.5		
75	8/16/06	22.0	23.6	24.8	25.3		
76	8/17/06	16.9	17.8	16.9	17.7		
77	8/18/06	12.1	11.6	13.1	12.7		
78	8/19/06	11.5	13.2	13.8	15.4		
79	8/20/06	10.3	11.6	13.5	14.4		
80	8/21/06	15.4	15.5	18.5	18.8		
81	8/22/06	19.5	20.4	21.0	21.7		
82	8/23/06	38.2	38.9	42.6	42.8		
83	8/24/06	15.0	16.1	17.1	18.4		
84	8/25/06	31.9	31.0	32.5	34.0		
85	8/26/06	31.1	30.6	32.3	31.5		
86	8/27/06	21.3	21.0	22.8	23.5		
87	8/28/06	12.8	13.2	14.4	14.6		
88	8/29/06	13.7	14.5	15.7	14.5		
89	8/30/06					Electric meter installed	
90	8/31/06	16.7	18.2	22.3	22.0		

Annex 4 **Measured values from the field test sites, related to ambient conditions** **Page 9 of 10**

Manufacturer	Met One Instruments	Measured object	SPM PM 10, ambient air
Meas. Range	0 to 1000 µg/m³	Test site	Titz-Roedingen / Cologne, Frankf. Str.
Type	BAM 1020		Measured values in µg/m³ amb. conditions for evaluation according to Guidance "Demonstration of Equivalence of Ambient Air Monitoring Methods"
Serial-No.	SN 4924 & SN 4925		

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
91	9/1/06	23.3	23.1	26.1	26.1		Titz-Roedingen
92	9/2/06	20.4	20.0	20.5	23.5		
93	9/3/06	9.3	8.9	10.3	12.6		
94	9/29/06	32.9	30.4	33.5	34.6		Cologne, Frankf. Str.
95	9/30/06	18.8	19.7	16.5	17.8		
96	10/1/06	15.2	15.4	11.5	13.0		
97	10/2/06	17.9	17.0	12.0	13.1		
98	10/3/06	18.8	18.1	15.4	16.9		
99	10/4/06	23.5	23.7	21.5	23.3		
100	10/5/06	14.1	12.6	15.2	15.7		
101	10/6/06	14.1	12.8	13.1	13.0		
102	10/7/06	20.6	21.3	19.3	20.1		
103	10/8/06	23.7	23.0	21.8	22.0		
104	10/9/06	30.4	30.4	30.8	29.7		
105	10/10/06	36.2	35.9	34.8	35.0		
106	10/11/06	39.7	38.9	36.5	37.9		
107	10/12/06	51.1	50.4	49.5	51.3		
108	10/13/06	42.0	42.0	40.3	42.5		
109	10/14/06	52.1	50.0	47.8	49.3		
110	10/15/06	37.7	35.7	37.5	37.6		
111	10/16/06	31.0	29.2	32.0	32.8		
112	10/17/06	31.8	30.1	33.8	33.9		
113	10/18/06	31.8	30.1	34.8	35.4		
114	10/19/06	22.7	21.6	21.8	23.2		
115	10/20/06	14.2	13.1	13.3	14.5		
116	10/21/06	13.6	11.8	12.0	13.8		
117	10/22/06	13.2	12.9	11.6	15.2		
118	10/23/06	15.4	15.4	15.4	16.7		
119	10/24/06	19.4	19.2	18.1	18.6		
120	10/25/06	19.8	18.7	22.5	22.5		

Annex 4 **Measured values from the field test sites, related to ambient conditions** **Page 10 of 10**

Manufacturer	Met One Instruments		
		Measured object	SPM PM 10, ambient air
Meas. Range	0 to 1000 µg/m³	Test site	Cologne, Frankf. Str.
Type	BAM 1020		Measured values in µg/m³ amb. conditions for evaluation according to Guidance "Demonstration of Equivalence of Ambient Air Monitoring Methods"
Serial-No.	SN 4924 & SN 4925		

No.	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]	SN 4924 [µg/m³]	SN 4925 [µg/m³]	Remark	Test site
121	10/26/06	33.4	29.0	31.1	33.7		Cologne, Frankf. Str.
122	10/27/06	31.1	27.2	27.5	28.1	Change to EU-inlet	Cologne, Frankf. Str.
123	10/28/06	24.8	21.2	22.8	22.7		
124	10/29/06	25.0	21.4	22.5	22.8		
125	10/30/06	37.8	33.7	33.3	33.3		
126	10/31/06	23.2	21.0	19.8	21.0		
127	11/1/06	22.6	20.7	22.2	23.0		
128	11/2/06	28.9	27.0	28.0	27.8		
129	11/3/06	37.8	36.6	35.1	35.1		
130	11/4/06	33.0	31.9	33.3	31.0		
131	11/5/06	30.7	30.1	34.8	33.0		
132	11/6/06	40.9	40.4	42.7	41.6		
133	11/7/06	36.4	35.9	39.0	36.3		
134	11/8/06	32.5	30.8	29.6	29.8		
135	11/9/06	27.9	27.3	25.0	24.2		
136	11/10/06	38.5	36.0	34.6	34.2		
137	11/11/06	18.5	16.1	17.5	17.1		
138	11/12/06	19.9	19.2	19.0	18.0		
139	11/13/06	15.0	13.9	13.6	13.6		
140	11/14/06	17.1	14.8	13.6	15.2		
141	11/15/06	29.6	26.2	24.7	24.9		
142	11/16/06	23.4	21.7	19.8	20.7		
143	11/17/06	15.9	14.6	14.5	14.0		
144	11/18/06	22.3	21.0	22.3	22.4		
145	11/19/06	20.3	20.6	20.7	20.8		
146	11/20/06	14.3	13.4	15.2	14.9		
147	11/21/06	20.4	19.5	17.7	19.6		

Annex 5 — Ambient conditions at the field test sites — Page 1 of 5

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	2/11/06	Cologne,	1.9	102.0	82.9	0.0	187.4	0.7
2	2/12/06	Parking lot	2.5	101.6	65.3	0.7	193	0.0
3	2/13/06		4.1	101.2	61.0	1.0	186	0.0
4	2/14/06		5.4	100.6	79.7	1.4	179	1.5
5	2/15/06		7.1	98.7	84.8	1.4	198	13.3
6	2/16/06		7.2	98.2	75.8	0.9	211	2.2
7	2/17/06		6.6	98.5	66.7	1.1	205	1.1
8	2/18/06		5.4	98.9	80.2	0.2	199	8.5
9	2/19/06		6.9	99.3	69.2	0.8	159	2.2
10	2/20/06		3.2	100.0	82.6	1.0	112	6.7
11	2/21/06		4.0	100.9	72.2	1.0	112	1.5
12	2/22/06		1.8	101.6	60.9	1.4	111	0.0
13	2/23/06		0.5	101.2	50.9	1.1	116	0.0
14	2/24/06		2.6	100.9	49.7	1.9	112	0.0
15	2/25/06		1.0	100.8	50.8	1.3	112	0.0
16	2/26/06		-1.9	101.1	72.8	0.5	105	0.0
17	2/27/06		1.2	100.3	89.1	0.2	185	3.7
18	2/28/06		1.2	99.2	88.9	1.7	234	4.8
19	3/1/06		-0.7	99.4	71.4	1.2	194	1.9
20	3/2/06		0.7	99.4	60.2	0.3	158	0.4
21	3/3/06		0.3	98.9	80.6	0.5	196	1.1
22	3/4/06		0.2	99.2	69.4	0.0	198	0.4
23	3/5/06		2.6	100.0	65.8	1.6	217	1.1
24	3/6/06		2.4	100.8	69.6	2.4	243	1.5
25	3/7/06		2.8	100.8	54.0	0.5	171	0.0
26	3/8/06		4.9	99.1	86.9	0.9	158	15.2
27	3/9/06		7.9	99.1	81.5	1.1	194	3.7
28	3/10/06		4.9	99.3	77.4	0.5	206	13.3
29	3/11/06		-1.2	100.9	68.7	2.3	199	1.1
30	3/12/06		-3.2	102.4	51.9	0.7	126	0.0

Annex 5 **Ambient conditions at the field test sites** **Page 2 of 5**

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	3/13/06	Cologne, Parking lot	-0.1	102.2	42.0	0.5	152	0.0
32	3/14/06		2.2	101.6	39.6	0.8	146	0.0
33	3/15/06		4.4	101.4	42.9	0.9	135	0.0
34	3/16/06		2.6	101.6	46.4	1.0	131	0.0
35	3/17/06		2.8	101.5	52.3	1.9	108	0.0
36	3/18/06		3.8	101.0	57.7	1.2	128	0.0
37	3/19/06		4.5	100.4	55.5	0.7	168	0.0
38	3/20/06		3.9	100.2	62.4	0.5	124	0.0
39	3/21/06		3.6	100.1	43.3	1.0	114	0.0
40	3/22/06		3.3	100.3	42.2	2.0	62	0.0
41	3/23/06		6.6	100.1	33.7	1.8	150	0.0
42	3/24/06		8.7	99.2	72.3	0.3	162	3.3
43	3/25/06		13.4	99.9	66.4	1.7	208	4.4
44	3/26/06		15.6	100.0	66.7	0.5	162	1.1
45	3/27/06		13.4	99.6	60.2	1.4	186	4.8
46	3/28/06		9.8	99.6	58.2	0.7	188	1.9
47	3/29/06		9.1	100.1	70.2	0.9	184	8.5
48	3/30/06		12.8	99.5	68.7	1.3	205	8.9
49	3/31/06		12.2	100.2	61.9	2.6	218	5.6
50	4/1/06		10.7	100.2	65.2	0.8	179	7.8
51	4/2/06		11.5	100.2	46.8	3.0	230	3.7
52	4/3/06		8.3	100.9	59.9	1.2	220	2.6
53	4/4/06		5.5	100.7	54.0	1.4	179	0.0
54	7/26/06	Titz-Roedingen	26.5	100.3	55.8	0.0	197	0.0
55	7/27/06		24.1	100.3	64.7	0.0	256	3.0
56	7/28/06		20.6	99.9	80.1	0.0	237	26.6
57	7/29/06		21.7	99.9	70.5	0.0	267	0.0
58	7/30/06		21.0	100.1	70.5	0.0	207	8.0
59	7/31/06		20.1	100.1	63.0	0.0	223	0.0
60	8/1/06		17.5	99.5	71.6	1.0	229	9.8

Annex 5 **Ambient conditions at the field test sites** **Page 3 of 5**

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	8/2/06	Titz-Roedingen	15.7	99.4	72.8	0.8	224	2.1
62	8/3/06		15.1	99.6	79.8	0.0	280	5.3
63	8/4/06		17.9	100.0	77.2	0.2	176	35.7
64	8/5/06		19.3	100.6	73.3	0.1	254	0.0
65	8/6/06		18.7	100.7	71.0	0.1	277	0.0
66	8/7/06		18.8	100.6	75.0	0.3	241	2.7
67	8/8/06		15.9	100.6	71.7	0.2	236	0.0
68	8/9/06		15.0	100.2	78.3	0.0	234	3.9
69	8/10/06		13.7	100.1	78.1	0.0	246	9.2
70	8/11/06		12.7	99.8	81.0	0.1	231	10.4
71	8/12/06		14.1	99.5	74.4	0.1	163	4.1
72	8/13/06		15.0	99.4	71.8	0.6	169	0.3
73	8/14/06		15.2	99.4	80.4	0.4	246	11.2
74	8/15/06		16.0	99.7	79.4	0.2	164	3.8
75	8/16/06		17.4	99.3	75.3	0.2	120	1.5
76	8/17/06		18.9	99.2	73.9	0.2	122	4.5
77	8/18/06		18.8	99.8	68.8	1.6	203	1.5
78	8/19/06		18.3	100.2	72.4	0.1	175	3.0
79	8/20/06		16.5	100.5	75.0	1.7	233	12.1
80	8/21/06		15.7	100.4	80.3	0.3	200	18.3
81	8/22/06		14.8	100.6	79.5	0.0	221	0.0
82	8/23/06		17.5	100.1	72.0	0.1	183	0.0
83	8/24/06		16.0	99.5	75.1	1.2	203	5.3
84	8/25/06		16.1	99.7	80.5	0.1	269	2.4
85	8/26/06		15.5	99.8	79.9	0.0	210	0.9
86	8/27/06		15.6	100.0	80.5	0.1	242	11.2
87	8/28/06		12.7	99.5	81.7	0.4	200	12.1
88	8/29/06		12.7	99.7	77.8	0.2	198	8.9
89	8/30/06		13.1	100.8	79.6	0.0	170	4.2
90	8/31/06		16.9	101.0	69.9	0.6	255	0.0

Annex 5 **Ambient conditions at the field test sites** **Page 4 of 5**

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	9/1/06	Titz-Roedingen	20.0	100.3	66.1	0.6	225	0.0
92	9/2/06		19.8	100.0	65.5	2.1	224	0.0
93	9/3/06		20.2	100.3	75.9	2.7	172	3.5
94	9/29/06	Cologne,	18.7	100.3	68.5	0.4	175	0.6
95	9/30/06	Frankf. Str.	18.2	100.4	67.3	0.1	199	1.2
96	10/1/06		18.6	100.3	63.8	0.5	207	0.3
97	10/2/06		16.6	99.9	64.2	0.3	201	0.0
98	10/3/06		14.3	99.6	73.4	0.2	286	1.5
99	10/4/06		12.7	100.6	75.6	0.4	227	2.7
100	10/5/06		14.9	100.9	68.1	0.2	199	6.8
101	10/6/06		15.9	100.2	72.1	1.2	214	11.8
102	10/7/06		12.1	101.1	70.4	2.0	243	0.3
103	10/8/06		12.7	101.4	69.6	0.0	184	0.0
104	10/9/06		15.4	101.3	70.2	0.1	170	0.0
105	10/10/06		15.1	101.2	74.7	0.1	139	0.0
106	10/11/06		16.7	100.7	70.6	0.7	173	0.0
107	10/12/06		17.4	101.7	75.3	0.1	231	0.0
108	10/13/06		15.3	102.3	77.8	0.0	155	0.0
109	10/14/06		11.7	102.2	73.8	0.6	111	0.0
110	10/15/06		11.6	102.0	67.7	0.4	119	0.0
111	10/16/06		11.7	101.5	67.3	2.0	168	0.0
112	10/17/06		12.6	100.7	65.8	2.6	172	0.0
113	10/18/06		15.1	99.8	65.3	1.3	174	0.0
114	10/19/06		15.1	99.3	76.0	1.6	166	1.8
115	10/20/06		14.9	99.2	76.7	0.1	183	6.2
116	10/21/06		15.7	99.7	69.1	0.3	188	0.3
117	10/22/06		16.6	99.4	69.3	1.6	186	0.9
118	10/23/06		16.7	98.9	76.9	1.2	192	19.8
119	10/24/06		13.2	99.6	74.5	2.2	250	2.4
120	10/25/06		14.5	100.2	66.3	2.8	168	0.0

Annex 5 **Ambient conditions at the field test sites** **Page 5 of 5**

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
121	10/26/06	Cologne,	19.1	100.3	64.2	0.5	222	0.0
122	10/27/06	Frankf. Str.	14.7	101.7	68.8	0.3	252	0.0
123	10/28/06		15.7	101.4	75.6	0.2	252	0.9
124	10/29/06		13.4	101.6	72.0	2.1	259	0.0
125	10/30/06		11.9	101.0	70.4	0.1	174	0.0
126	10/31/06		11.5	100.1	68.1	3.3	273	2.4
127	11/1/06		5.6	101.7	65.4	3.8	225	1.5
128	11/2/06		5.5	102.2	76.8	1.0	262	2.1
129	11/3/06		7.4	102.4	76.3	0.0	311	0.0
130	11/4/06		9.8	102.4	70.6	1.2	275	0.0
131	11/5/06		10.7	102.1	73.3	1.2	291	0.0
132	11/6/06		9.6	102.0	71.3	0.5	261	0.0
133	11/7/06		7.9	101.4	70.7	0.2	172	0.0
134	11/8/06		11.3	101.4	72.6	0.5	266	7.7
135	11/9/06		8.3	102.4	70.9	2.2	248	0.0
136	11/10/06		7.0	102.2	69.4	1.3	173	2.4
137	11/11/06		9.3	100.7	73.9	3.8	261	9.5
138	11/12/06		7.9	100.9	74.5	2.8	282	4.2
139	11/13/06		10.5	100.1	79.5	0.6	237	2.4
140	11/14/06		12.8	100.5	74.0	0.2	186	1.5
141	11/15/06		13.1	100.3	73.0	2.4	177	0.0
142	11/16/06		15.8	99.8	65.5	2.4	195	3.0
143	11/17/06		11.2	100.3	74.4	1.9	182	0.3
144	11/18/06		8.3	101.2	77.1	0.3	194	1.2
145	11/19/06		6.0	101.1	82.7	1.4	199	10.0
146	11/20/06		9.9	100.0	80.1	0.1	282	13.6
147	11/21/06		7.1	99.2	76.4	0.4	218	2.4

Annex 6: Software version

Remark: During the test work, the software was continuously enhanced and optimized up to the version 3236-02 3.2.1b. There is no influence to expect on the instruments performance due to the performed alterations up to the version 3236-02 3.2.1b.

Appendix 2

Manual BAM-1020-9800 REV E

together with

Software Revision 3.0.0

Software Revision 3.1.0

Software Revision 3.2.0

Software Revision 3.2.1b

Manual temperature sensor BX-592

Manual air pressure sensor BX-594

TÜV RHEINLAND
ENERGIE UND UMWELT GMBH

Deutsche
Akkreditierungsstelle
D-PL-11120-02-00

Addendum

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

luft@de.tuv.com

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

TÜV Rheinland Energie und Umwelt GmbH
is accredited for the following work areas:

- Determination of emissions and ambient airs of air pollution and odor 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 air, and of electronic systems for data evaluation and remote monitoring of emissions

according to EN ISO/IEC 17025.

TÜV Rheinland Energie und Umwelt GmbH
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Summary

The ambient air quality measuring system BAM-1020 with PM_{10} pre-separator of the company Met One Instrument, Inc. has been type-approved and published as follows.

1. BAM-1020 with PM_{10} pre-separator with announcement of the Federal Environment Agency of April 12, 2007 (BAnz. p. 4139, chapter III No. 1.2)

   The last notification on the measuring systems has been:

   BAM-1020 with PM_{10} pre-separator with announcement of the Federal Environment Agency of July 06, 2012 (BAnz AT 20.07.2012 B11, Chapter IV 6th notification), statement of March 21, 2012

The test of the measuring system BAM-1020 with PM_{10} pre-separator in the year 2006 has been designed in the way that the tests have been evaluated and documented according to the minimum requirements of the Standard VDI 4202, Sheet 1 as well as according to the respective European Standard EN 12341. Furthermore an evaluation of the available data sets of the three campaigns according to the Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“ in its version of 2005 has been carried out. However, due to formal reasons, it was not possible to demonstrate equivalence back then, because there has been only three instead of the required four comparisons and the number of valid data pairs for the single comparisons has been below the required minimum number of 40.

Nevertheless - in order to demonstrate equivalence according to the Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“ in its current version of 2010, taking into account the already available data sets, the following approach has been agreed upon together with the English project partner of the UK-GER PM Equivalence Programme:

There will be a new evaluation of the equivalence for the following data sets according to the Guide 2010 for the following test sites:

Test sites Cologne, parking lot, Titz-Rödingen and Cologne, Frankfurter Str. from the existing German type approval

Additionally with BAM-1020 of the same design

2 test sites (Steyregg, Graz) from Austrian equivalence testings of 2007 / 2008, carried out by the Environment Agency Austria,

1 test site (Tusimice) from Czech equivalence testing of 2010, carried out by the Czech Hydrometeorological Institute,

1 test site (Teddington) from English equivalence testing of 2012, carried out by NPL / Bureau Veritas UK.

Therewith 7 comparison campaigns in total are considered for the evaluation and the formal requirements for an equivalence testing according to the Guide 2010 (at least 4 comparisons with each 40 data pairs) is fulfilled. All data from all stations of the used equivalence testing have been used. Furthermore the approach shall demonstrate, that also under these circumstances (different sites in different countries, different candidates of the same design, different operators), the demonstration of equivalence is possible.

In the following Addendum to the type approval test report, the evaluation of the equivalence testing is described in detail. After its publication, this addendum is an inherent part of the TÜV Rheinland test report with the No. 936/212053333/A.

Content

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1. General and methodology of the equivalence check (modules 5.4.9 – 5.4.11)

For the subsequent equivalence check, the following historical comparison campaigns have been used:

Table 1: Overview on comparison campaigns

No.	Country	Test site	Time period	Candidates	Characterisation	Test institute
1	D	Cologne, parking lot	02/2006 – 04/2006	SN4924 / SN 4925	Urban background	TÜV Rheinland
2	D	Titz-Rödingen	07/2006 – 09/2006	SN4924 / SN 4925	Rural	TÜV Rheinland
3	D	Cologne, Frankf. Str.	09/2006 – 11/2006	SN4924 / SN 4925	Traffic-influenced	TÜV Rheinland
4	A	Steyregg	06/2008 – 08/2008	AUSTRIA 1 / AUSTRIA 2	Sub-urban	UBA Austria
5	A	Graz	12/2007 – 03/2008	AUSTRIA 1 / AUSTRIA 2	Urban back-ground + traffic	UBA Austria
6	CZ	Tusimice	01/2010 – 06/2010	J7860 / J7863	Industrial	CHMI
7	UK	Teddington	04/2012 – 05/2012	17011 / 17022	Urban back-ground	NPL / Bureau Veritas

All measured data have been obtained either by accredited test houses or by national reference laboratories. The respective evidence of the accreditation can be found in the appendix in Figure 28 to Figure 31.

The comparison campaigns are characterized by the following conditions:

Table 2: Ambient conditions during the comparison campaigns

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, Frankf. Str.	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

* The Guide in its version of 2010 requires at least 4 comparison campaigns with each at least 40 valid data pairs. This formal requirement is fulfilled by including the test sites Steyregg, Graz, Tusimice and Teddington. The three comparison campaigns from the original type approval tests of 2006 are additionally added and evaluated to the available data sets.

All single values can be found in the appendix of this addendum.

According to the version of the Guide from January 2010, the following 5 criteria must be fulfilled to proof the 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 chapters:

In chapter 2. 5.4.9 Determination of uncertainty between candidates u_{bs} criteria 1 and 2 will be checked.

In chapter 3. 5.4.10 Calculation of the expanded uncertainty of the instruments criteria 3, 4 and 5 will be checked.

In chapter 4. 5.4.11 Application of correction factors and terms, there is evaluation for the case, that criterion 5 cannot be fulfilled without the application of correction factors or terms.

2. 5.4.9 Determination of uncertainty between candidates u_{bs}

For the test of PM2.5 measuring systems the uncertainty between the systems under test shall be determined according to chapter 9.5.3.1 of the guidance document „Demonstration of Equivalence of Ambient Air Monitoring Methods“ in the field test at least at four sampling test sites representative of the future application.

The tests are performed as well for the component PM_{10}

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.

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 (A-Steyregg, A-Graz, CZ-Tusimice, UK-Teddington) each with at least 40 valid data pairs. Additionally the three comparison campaigns (D-Cologne, parking lot, D-Titz-Rödingen, D-Cologne, Frankf. Str.) from the original type approval (test report 936/21205333/A) 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}. The measured concentrations were referred to ambient conditions.

Evaluation

According to **Point 9.5.2.1** of the Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“ applies:

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:

- All test sites respectively comparisons together (complete data set)
- 1 data set with measured values ≥ 30 µg/m³ for PM_{10} (Basis: averages reference measurement)

Furthermore the evaluation of the following data sets is done:

- Each test site respectively comparison individually
- 1 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 = No. 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.

Minimum requirement fulfilled? yes

6.6 Detailed representation of the test results

Table 3 shows the calculated values for the uncertainty between the candidates u_{bs}. The graphical representation is done in Figure 1 to Figure 10

Table 3: Uncertainty between the candidates u_{bs}, 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	D-Cologne, parking lot	52	1.22
4924 / 4925	D-Titz-Rödingen	37	0.86
4924 / 4925	D-Cologne, Frankf. Str.	28	0.99
AUSTRIA 1 / AUSTRIA 2	A-Steyregg	51	0.75
AUSTRIA 1 / AUSTRIA 2	A-Graz	50	1.96
J7860 / J7863	CZ-Tusimice	103	1.18
17011 / 17022	UK-Teddington	42	1.00
Classification via reference value			
Various	**Values ≥ 30 µg/m³**	**105**	**1.49**
Various	Values < 30 µg/m³	215	1.09

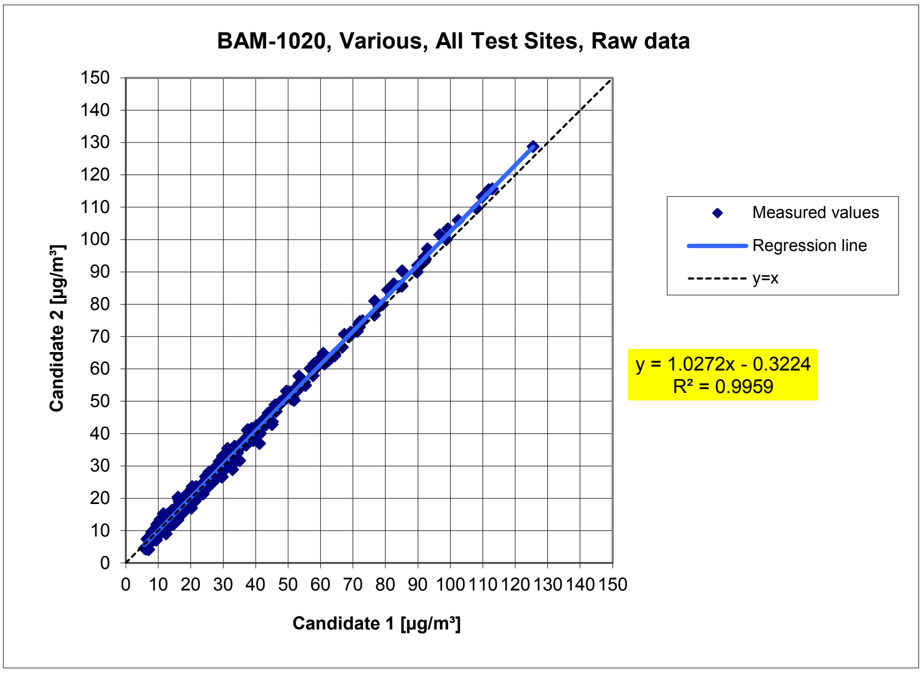

Figure 1: Results of the parallel measurements with the candidates, Measured component PM_{10}, all test sites

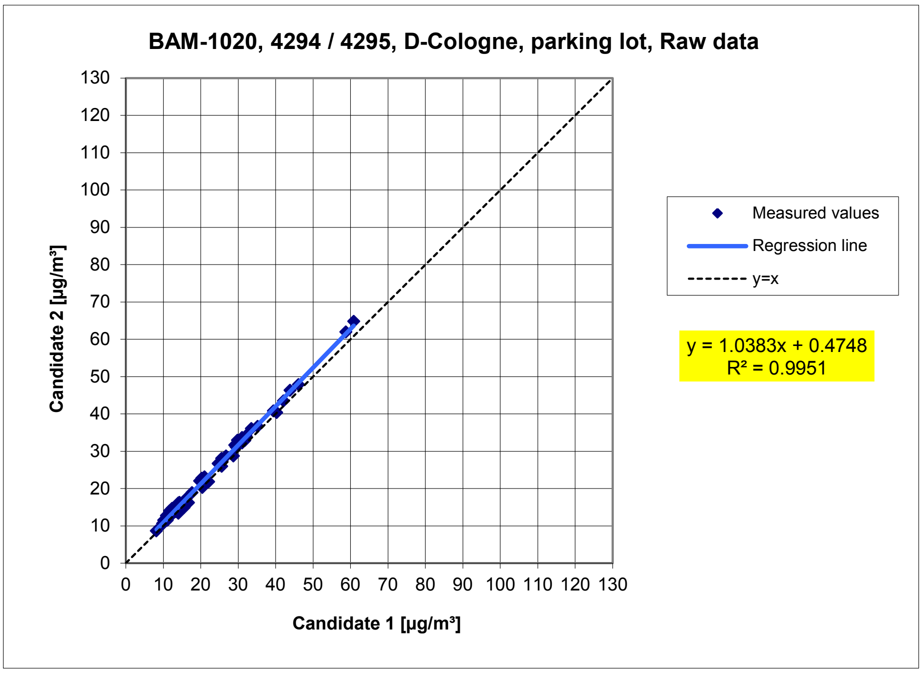

Figure 2: Results of the parallel measurements with the candidates, Measured component PM_{10}, Test site Cologne, parking lot

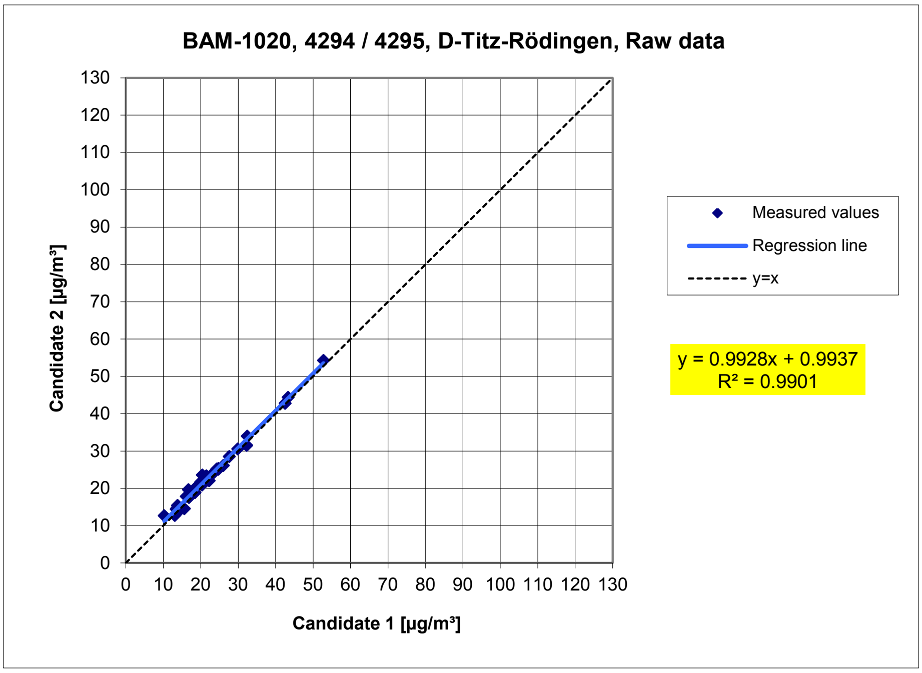

Figure 3: **Results of the parallel measurements with the candidates, Measured component PM_{10}, Test site Titz-Rödingen**

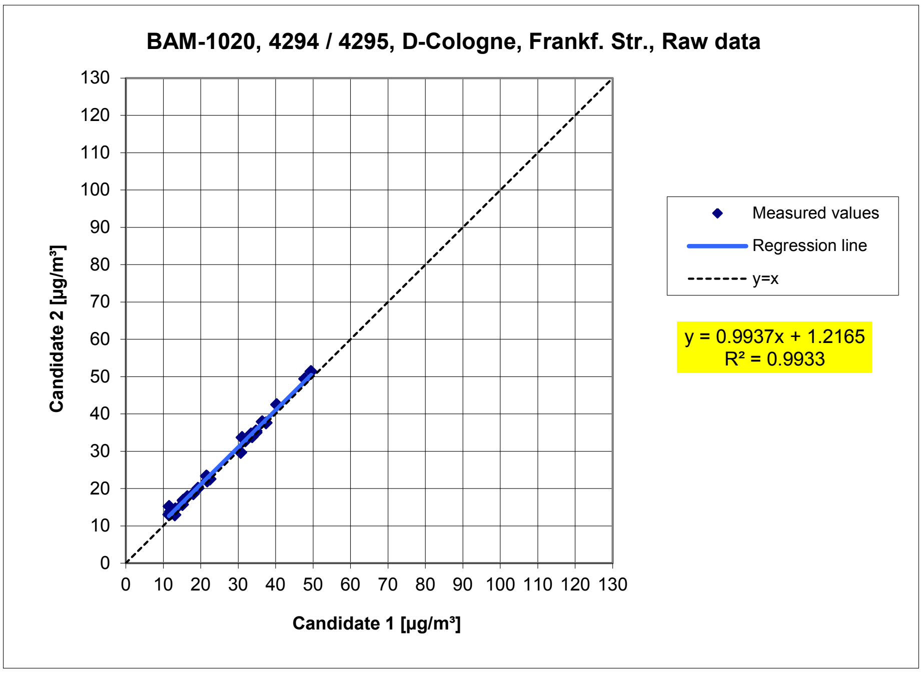

Figure 4: **Results of the parallel measurements with the candidates, Measured component PM_{10}, Test site Cologne, Frankf. Str.**

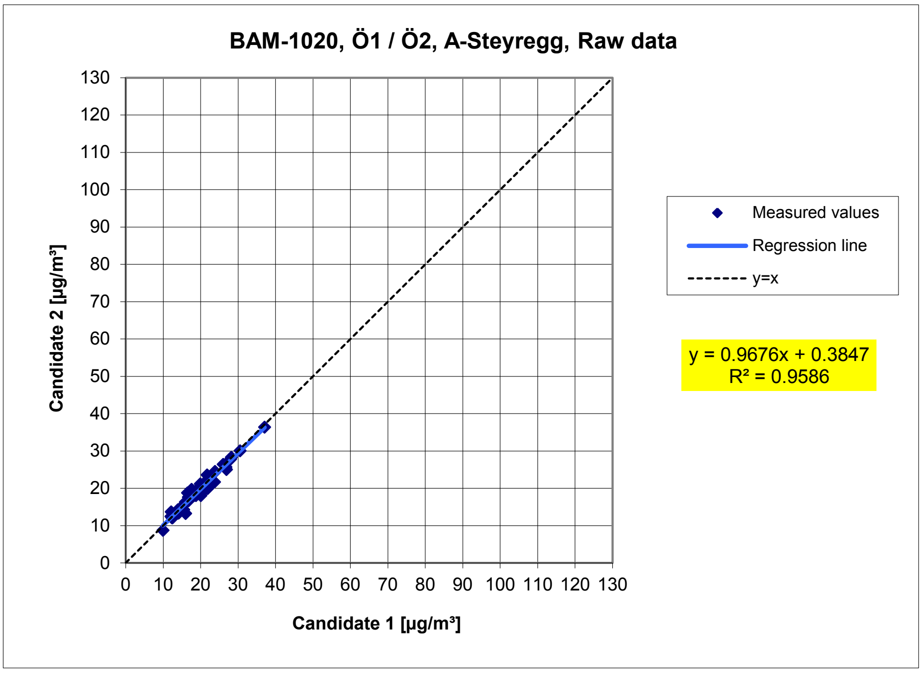

Figure 5: **Results of the parallel measurements with the candidates, Measured component PM_{10}, Test site Steyregg**

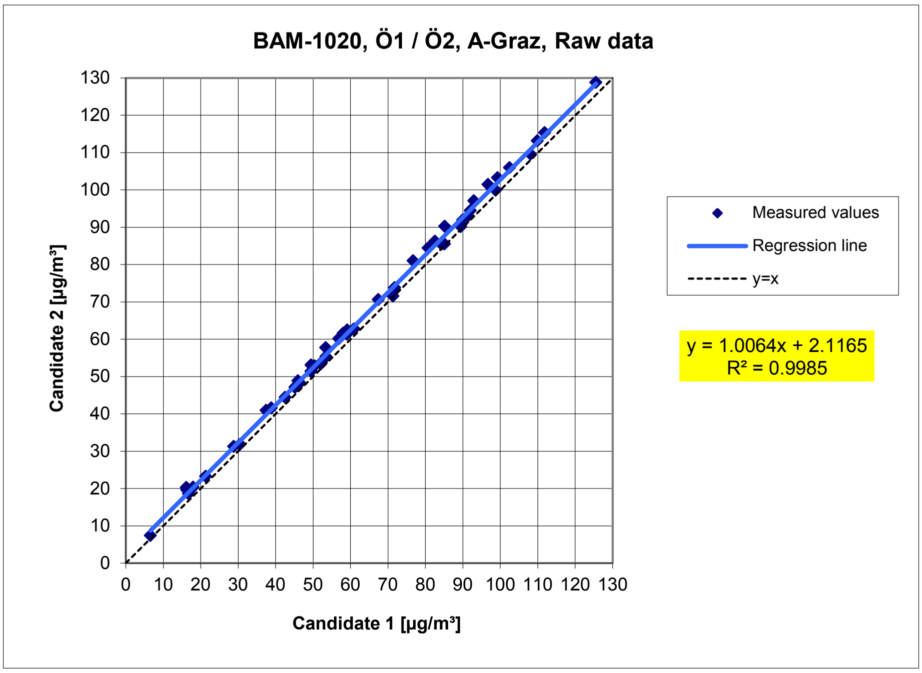

Figure 6: **Results of the parallel measurements with the candidates, Measured component PM_{10}, Test site Graz**

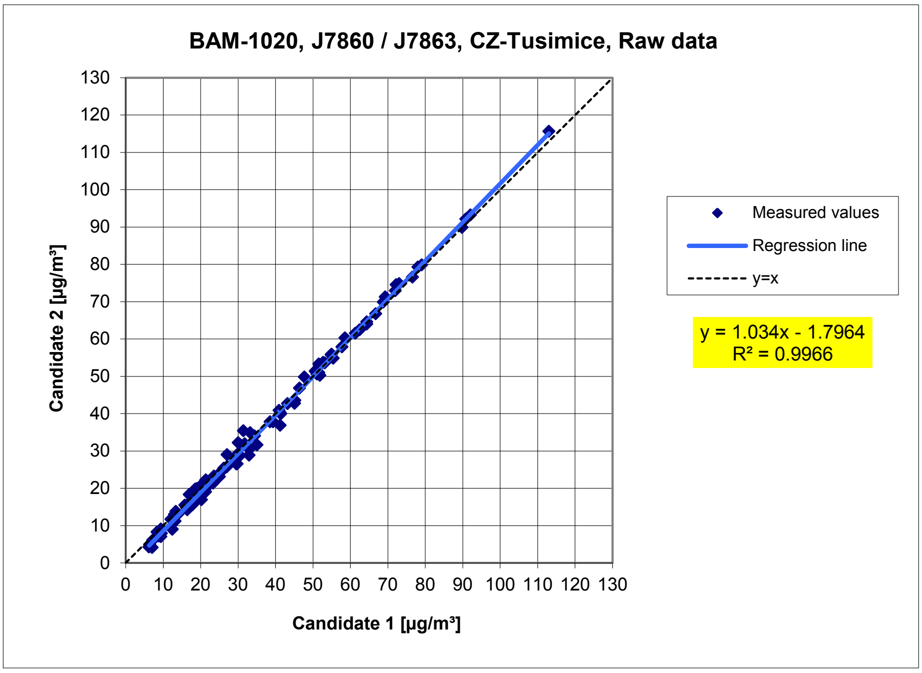

Figure 7: **Results of the parallel measurements with the candidates, Measured component PM_{10}, Test site Tusimice**

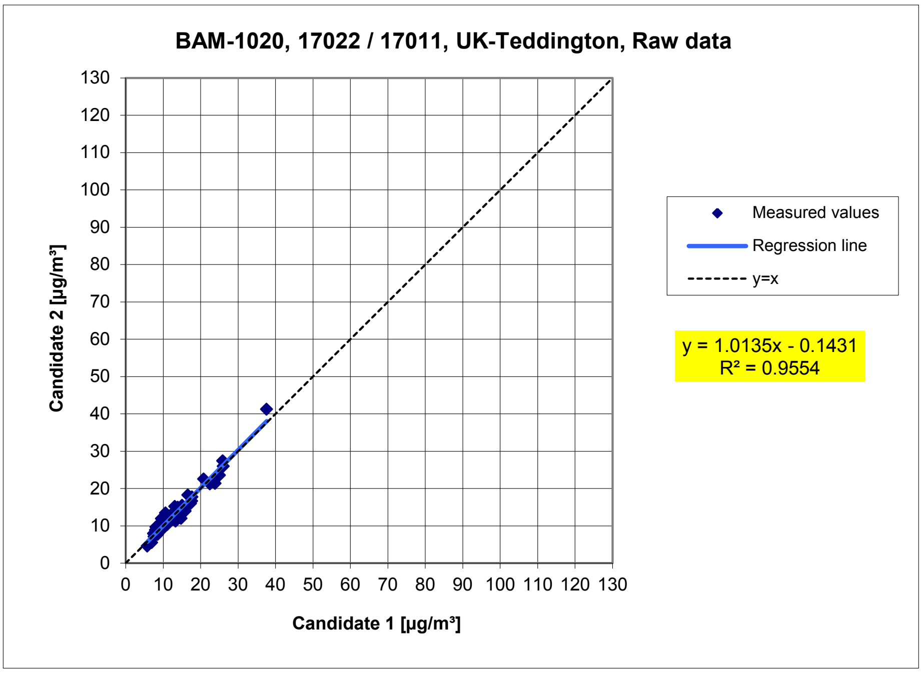

Figure 8: **Results of the parallel measurements with the candidates, Measured component PM_{10}, Test site Teddington**

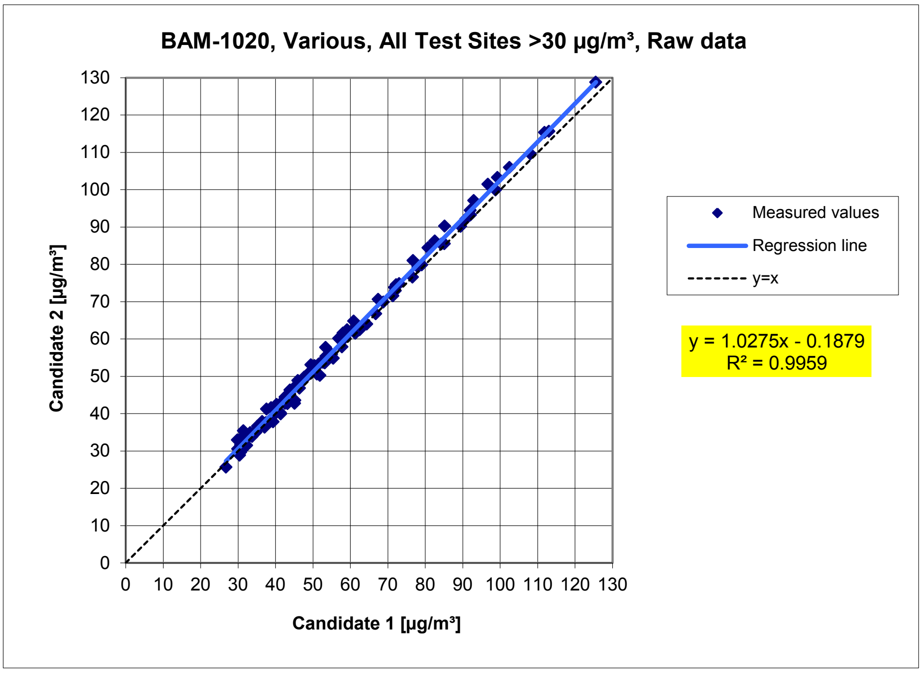

Figure 9: **Results of the parallel measurements with the candidates, Measured component PM_{10}, all test sites, values ≥ 30 µg/m³**

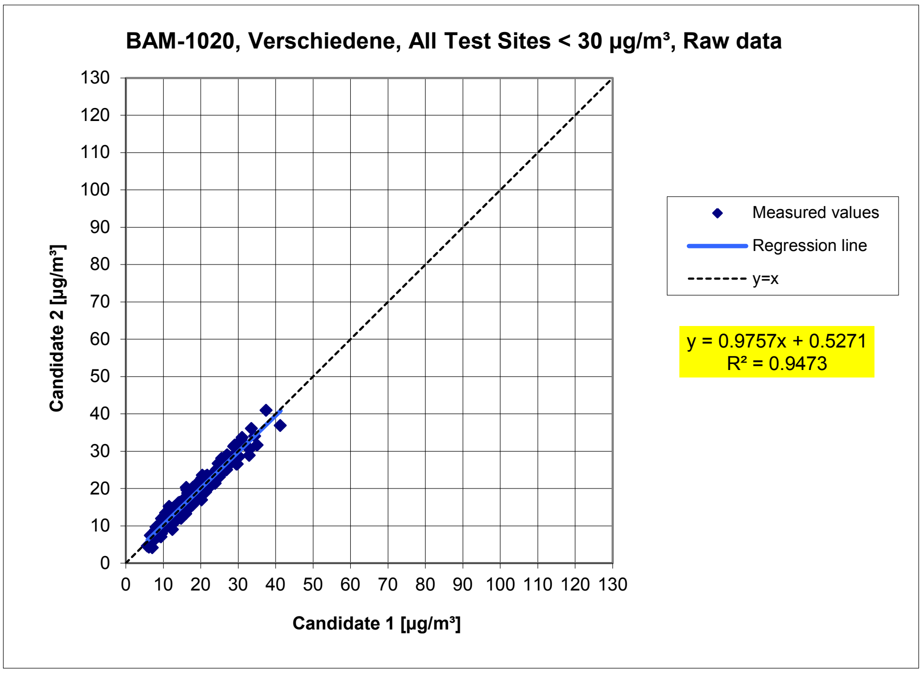

Figure 10: **Results of the parallel measurements with the candidates, Measured component PM_{10}, all test sites, values < 30 µg/m³**

3. 5.4.10 Calculation of the expanded uncertainty of the instruments

For the test of $PM_{2,5}$ measuring systems the equivalency with the reference method shall be demonstrated according to chapter 9.5.3.2 to chapter 9.6 of the guidance document „Demonstration of Equivalence of Ambient Air Monitoring Methods" in the field test at least at four sampling test sites representative of the future application. The maximum expanded uncertainty of the systems under test shall be compared with data quality objectives according to Annex A of Standard VDI 4202 Part 1 (September 2010)

The tests are performed as well for the components PM_{10}.

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.

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 has been 4 comparison campaigns (A-Steyregg, A-Graz, CZ-Tusimice, UK-Teddington) each with at least 40 valid data pairs. Additionally the three comparison campaigns (D-Cologne, parking lot, D-Titz-Rödingen, D-Cologne, Frankf. Str.) from the original type approval (test report 936/21205333/A) 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}. The measured concentrations were referred to ambient conditions.

Evaluation

[Point 9.5.3.2] 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.

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 respectively comparisons
- Each test site respectively comparisons 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 (refer to point 2. 5.4.9 Determination of uncertainty between candidates u_{bs})

Algorithm for the calculation of ordinate intercept a as well as slope b and its variances by orthogonal regression are described in detail in annex B of the Guide.

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 respectively comparisons
- Each test site respectively comparisons 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 significantly 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 point 9.7 of the Guide (refer to 4. 5.4.11 Application of correction factors and terms). The calibration shall only be applied to the full dataset.

[Point 9.5.4] The combined uncertainty of the candidates $w_{c,CM}$ is calculated for each data set by combining the contributions from 9.5.3.1 and 9.5.3.2 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}.

[Point 9.5.5] 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 large n

[Point 9.6] The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality of ambient air measurements according to EU Directive 2008/50/EC.

Two results are possible:

1. $W_{CM} \leq W_{dqo} \rightarrow$ Candidate method is accepted as equivalent to the standard method.
2. $W_{CM} > W_{dqo} \rightarrow$ Candidate method is not accepted as equivalent to the standard method.

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 % [7].

Assessment

The determined uncertainties W_{CM} without application of correction factors are below the defined expanded relative uncertainty W_{dqo} of 25 % for particulate matter for all investigated data sets except for the test site A-Graz (for candidate AUSTRIA 2) as well as for UK-Teddington (for candidate 17011). It is necessary to check, whether all test sites incl. the test sites A-Graz (for candidate AUSTRIA 2) and UK-Teddington (for candidate 17011) will be below the defined expanded relative uncertainty W_{dqo} of 25 % for particulate matter after application of correction factors / terms (refer to chapter 4. 5.4.11 Application of correction factors and terms).

Minimum requirement fulfilled? no

The following Table 4 shows an overview of the results of the equivalence check for the candidate BAM-1020 für PM_{10}. For the case, that a criterion is fulfilled or not, the text is represented in green or red colour. Furthermore the five criteria from chapter 1. General and methodology of the equivalence check (modules 5.4.9 – 5.4.11) are taken into account, the related cells are highlighted in colour.

Table 4: Overview equivalence check BAM-1020 for PM_{10}

PM10 Smart 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

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

The check of the five criteria according to chapter 1. General and methodology of the equivalence check (modules 5.4.9 – 5.4.11) 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: All of the expanded uncertainties are below 25 %.

This requirement is not fulfilled for the raw data set of A-Graz (Austria 2) and UK-Teddington (17011)

Criterion 5: On closer inspection of the slopes and intercepts for the individual candidates, they are several time significantly greater than allowed. Al so the slope and the intercept of the complete data set is 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 at an expended total uncertainty of 16.0 %.

However, since the expanded uncertainty for the raw data sets A-Graz (Austria 2) and UK-Teddington (17011) is 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. These are shaded gold and marked 'other' in the key on the above Table 4.

The 2006 UK Equivalence Report 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“ data set is 1.034.

The intercept for for the „All data“ data set is 0.843.

Thus an additional evaluation after application of the respective correction factors / terms to the data sets has been carried out in chapter 4. 5.4.11 Application of correction factors and terms for the following cases:

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 4 measurement sites (Guide [4], chapter 9.9.2, table 6).

Detailed representation of the test results

Table 5 shows an overview on the uncertainties between the reference devices $u_{ref\ from}$ the field tests. In Table 6 a summarized representation of the results of the equivalence test incl. the determined expanded measuring uncertainties W_{CM} from the field test is shown.

Table 5: Uncertainty between the reference devices u_{ref} 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	D-Cologne, parking lot	29	0.55
1 / 2	D-Titz-Rödingen	37	0.65
1 / 2	D-Cologne, Frankf. Str.	28	1.02
1 / 2	A-Steyregg	45	0.53
1 / 2	A-Graz	45	0.82
1 / 2	CZ-Tusimice	96	-*
1 / 2	UK-Teddington	40	0.25

* only 1 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 u_{ref} is for all test sites < 2 µg/m³.

Table 6: Summary of the results of the equivalence test, Measured component PM_{10}, raw data

PM_{10} Smart 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 m-3	24.7	215	0.826	1.119 +/- 0.032	-0.446 +/- 0.557	0.53	1.09
> 30 µg m-3	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 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	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 m^3	68	0.814	1.040 +/- 0.055	0.162 +/- 0.981	12.58	4.4
	> 30 µg m^3	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 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	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 m^3	68	0.830	1.056 +/- 0.053	0.935 +/- 0.952	17.24	4.4
	> 30 µg m^3	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 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	-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 m^3	50	0.644	1.339 +/- 0.109	-6.789 +/- 2.135	42.75	2.0
	> 30 µg m^3	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 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	1.948 +/- 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 m^3	50	0.557	1.492 +/- 0.130	-9.462 +/- 2.545	62.86	2.0
	> 30 µg m^3	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 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	1.204 +/- 0.839	40.46	6.8
	> 30 µg m^3	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 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	0.159 +/- 0.812	33.73	6.9
	> 30 µg m^3	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 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	0.632 +/- 0.458	11.13	0.0
	> 30 µg m^3	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 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	0.603 +/- 0.477	13.45	0.0
	> 30 µg m^3	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.963	1.110 +/- 0.034	-0.050 +/- 0.488	22.28	2.5

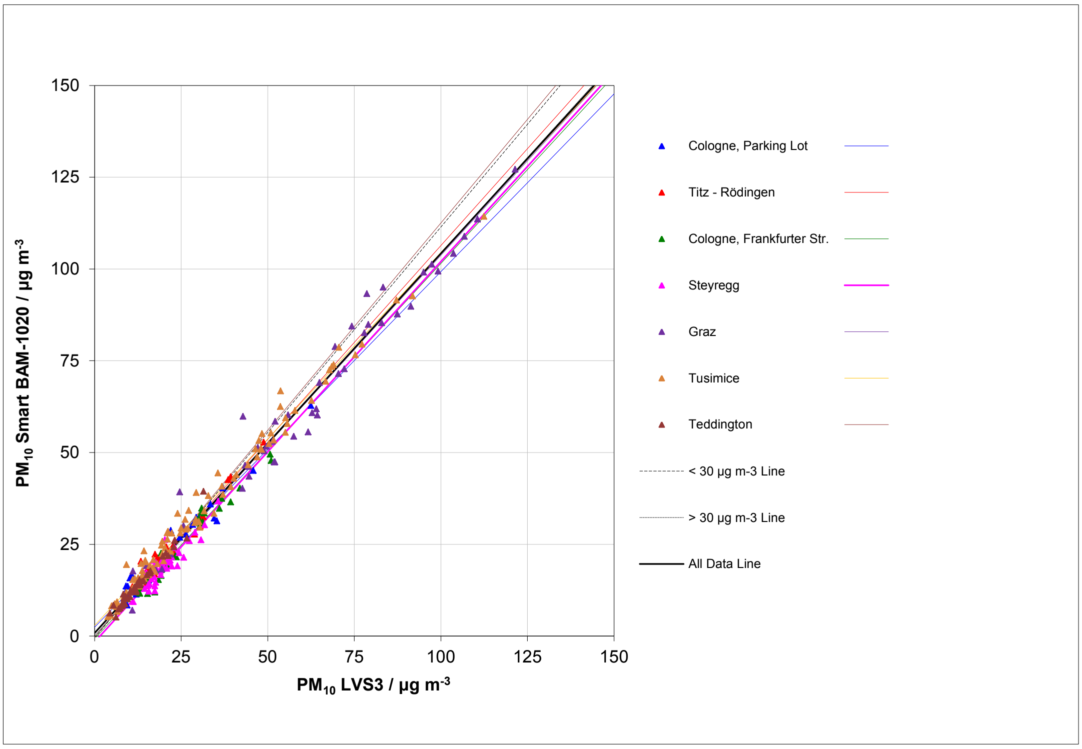

Figure 11: Reference vs. candidate, Measured component PM_{10}, all test sites

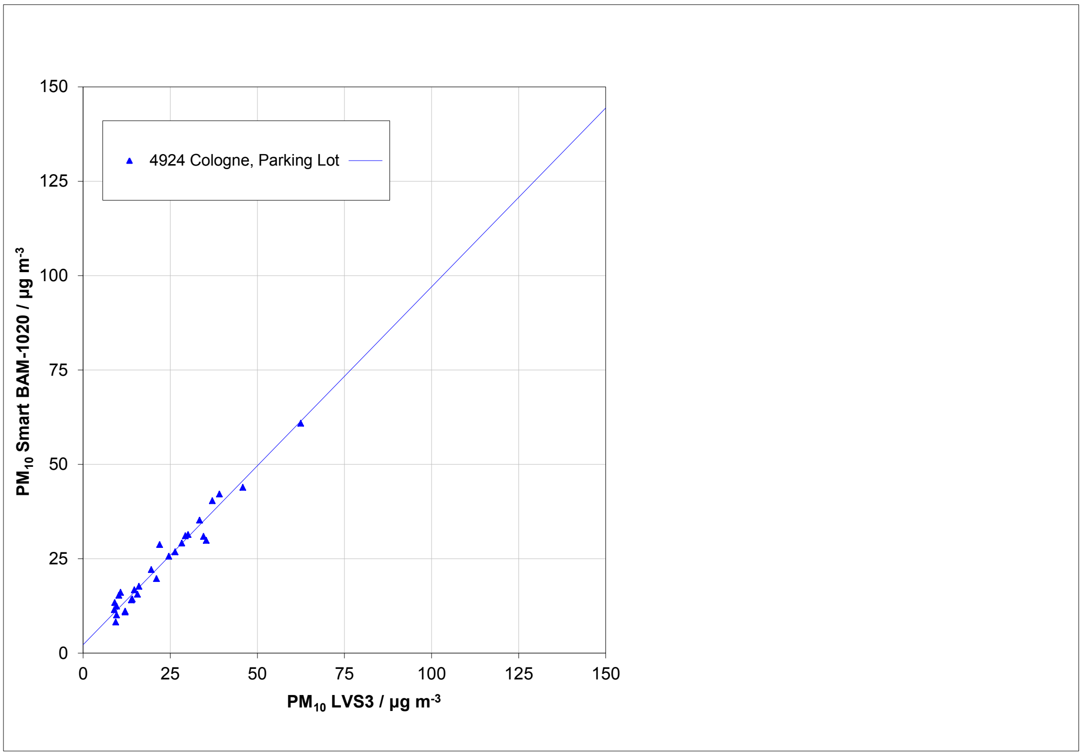

Figure 12: Reference vs. candidate, SN 4924, Measured component PM_{10}, D-Cologne, parking lot

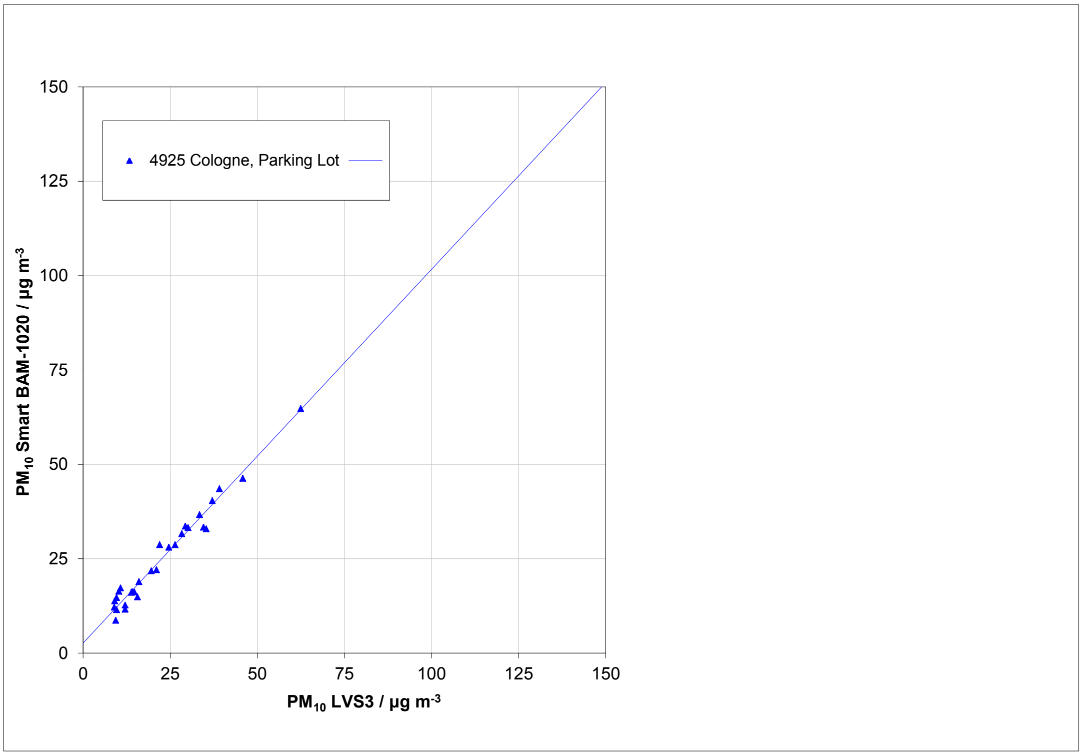

Figure 13: Reference vs. candidate, SN 4925, Measured component PM_{10}, D-Cologne, parking lot

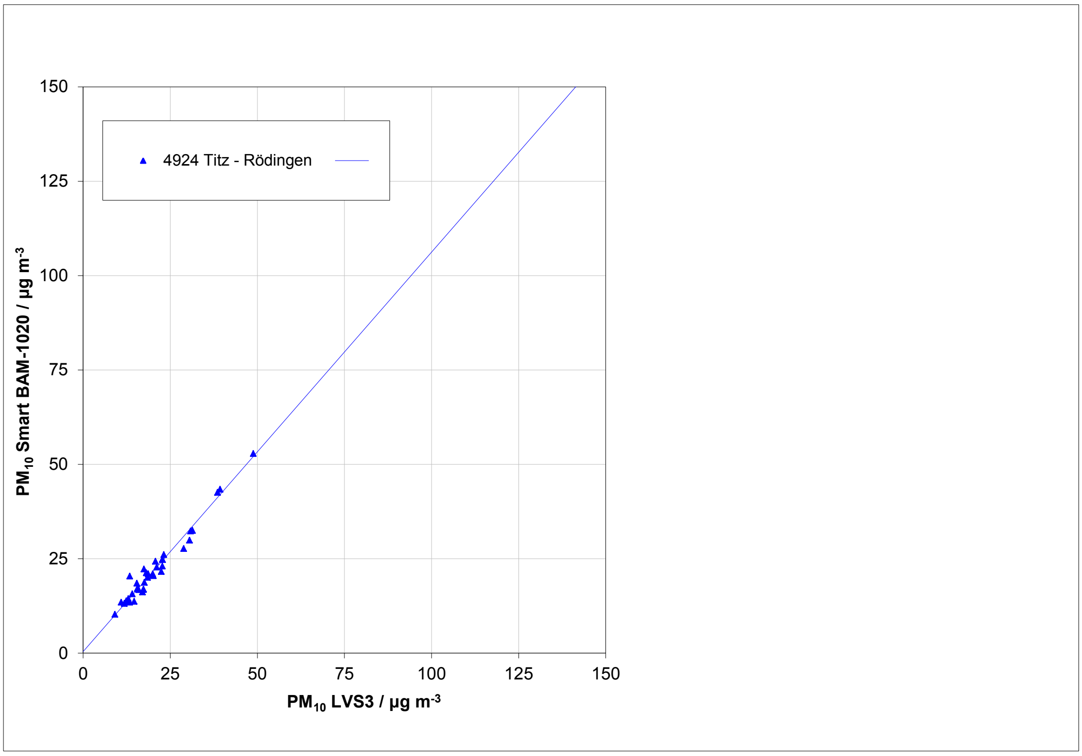

Figure 14: **Reference vs. candidate, SN 4924, Measured component PM_{10}, D-Titz-Rödingen**

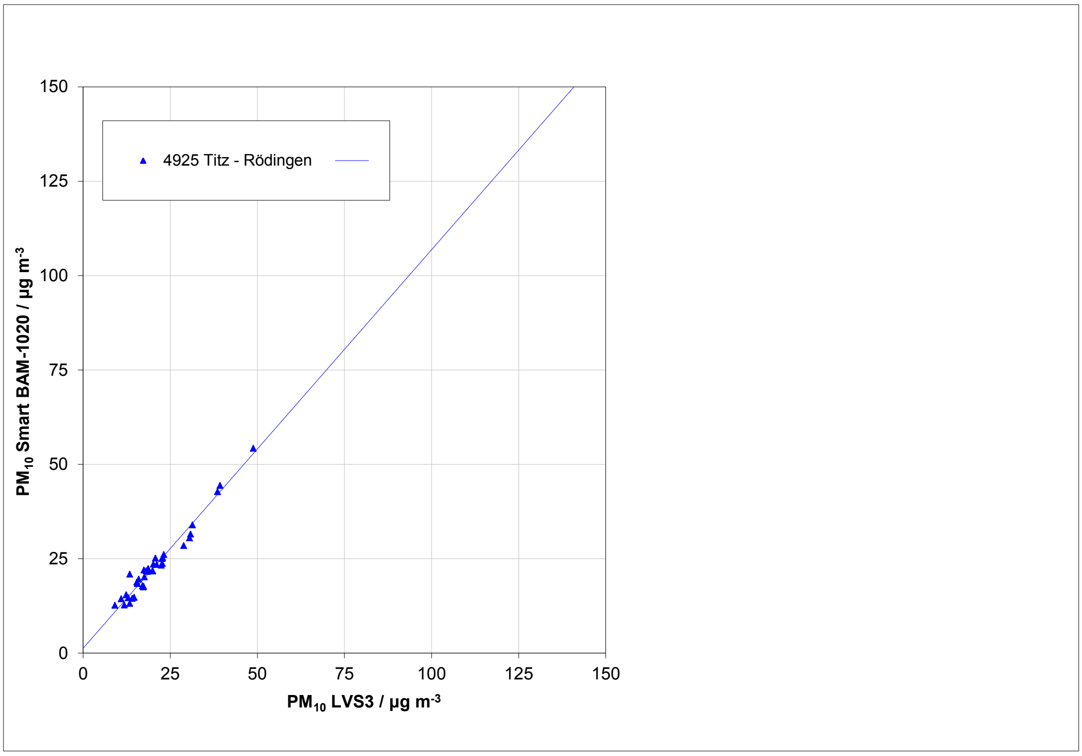

Figure 15: **Reference vs. candidate, SN 4925, Measured component PM_{10}, D-Titz-Rödingen**

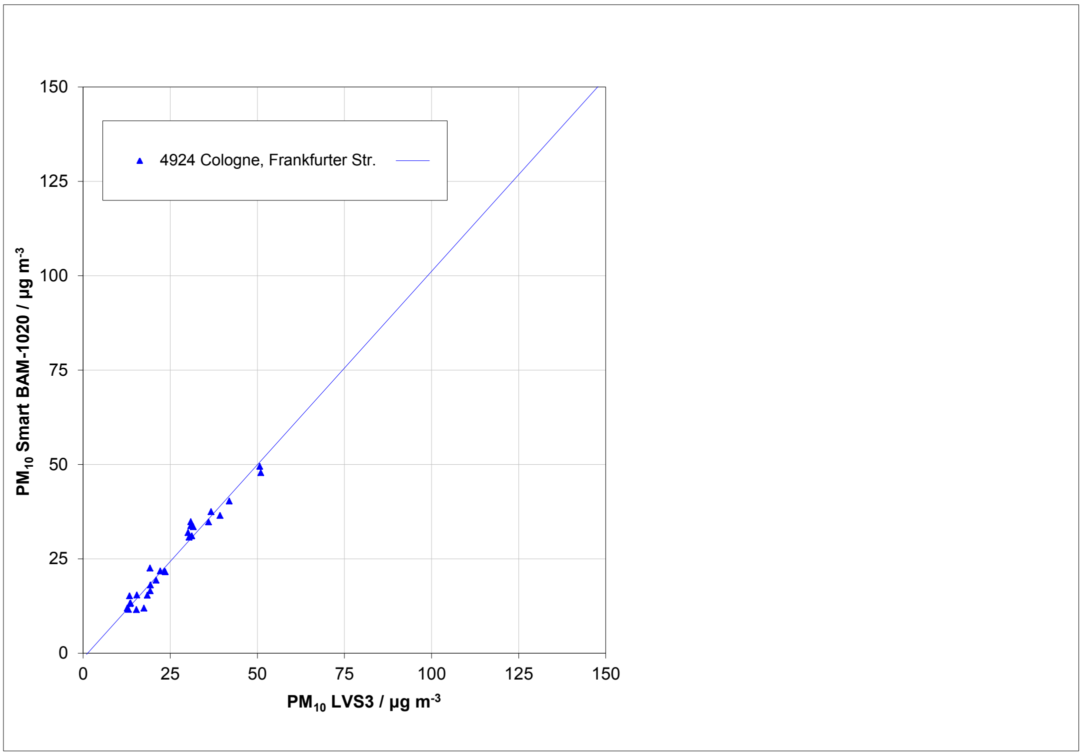

Figure 16: Reference vs. candidate, SN 4924, Measured component PM_{10}, D-Cologne, Frankf. Str.

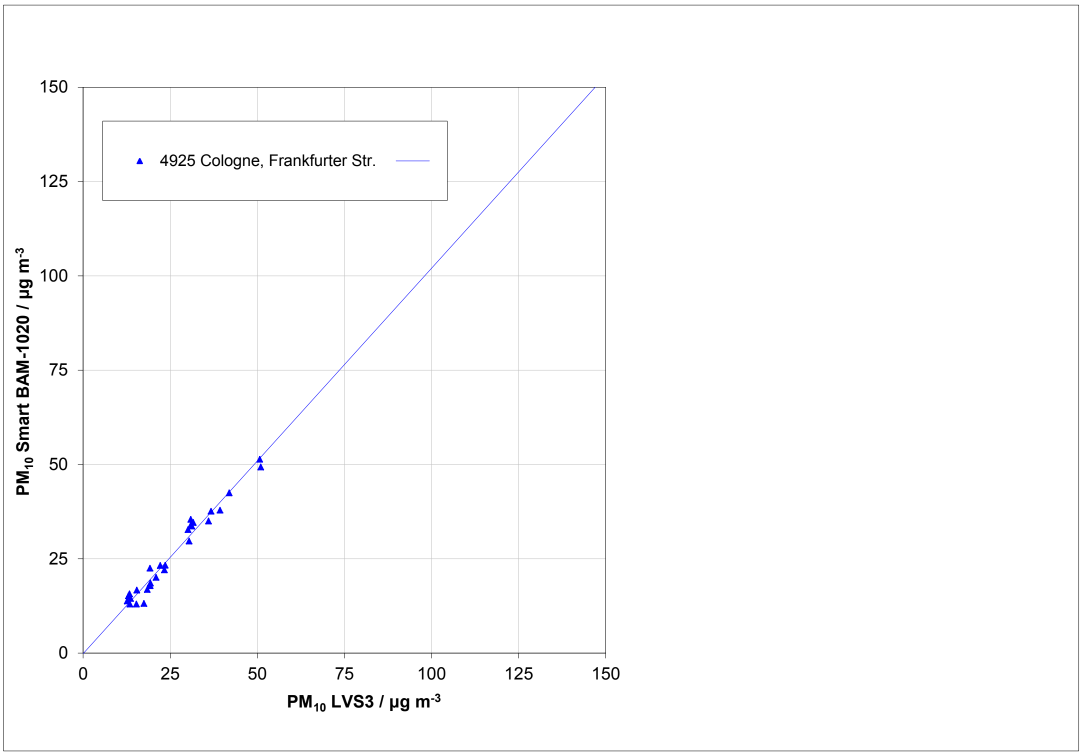

Figure 17: Reference vs. candidate, SN 4925, Measured component PM_{10}, D-Cologne, Frankf. Str.

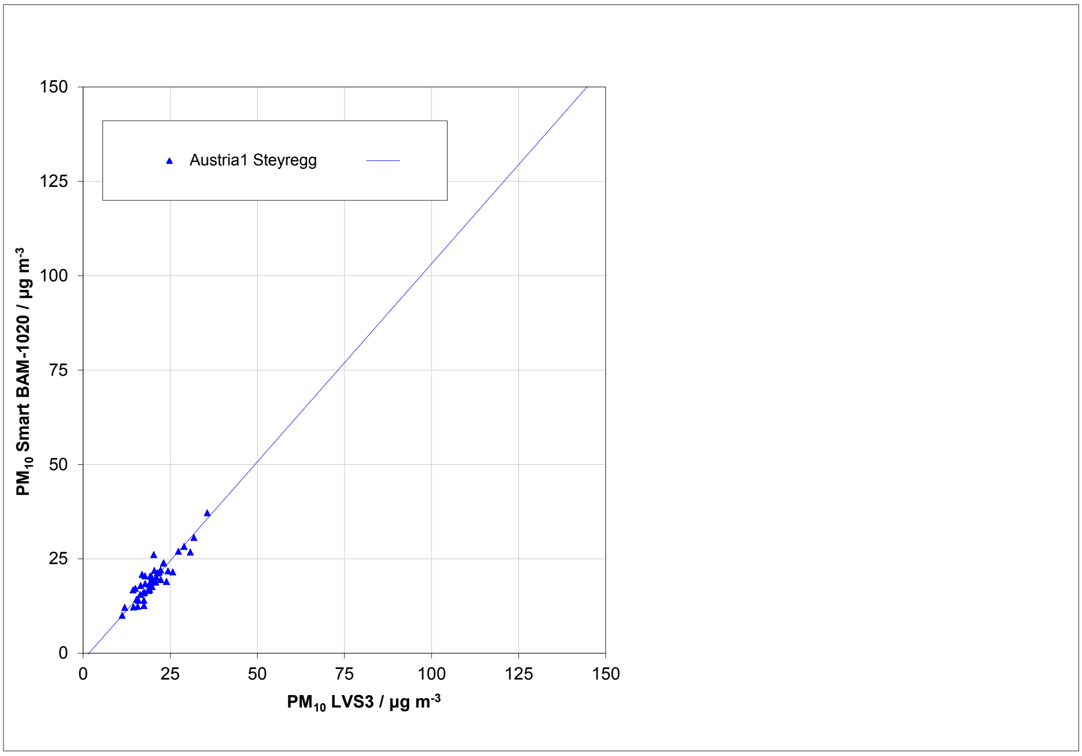

Figure 18: Reference vs. candidate, Austria 1, Measured component PM_{10}, A-Steyregg

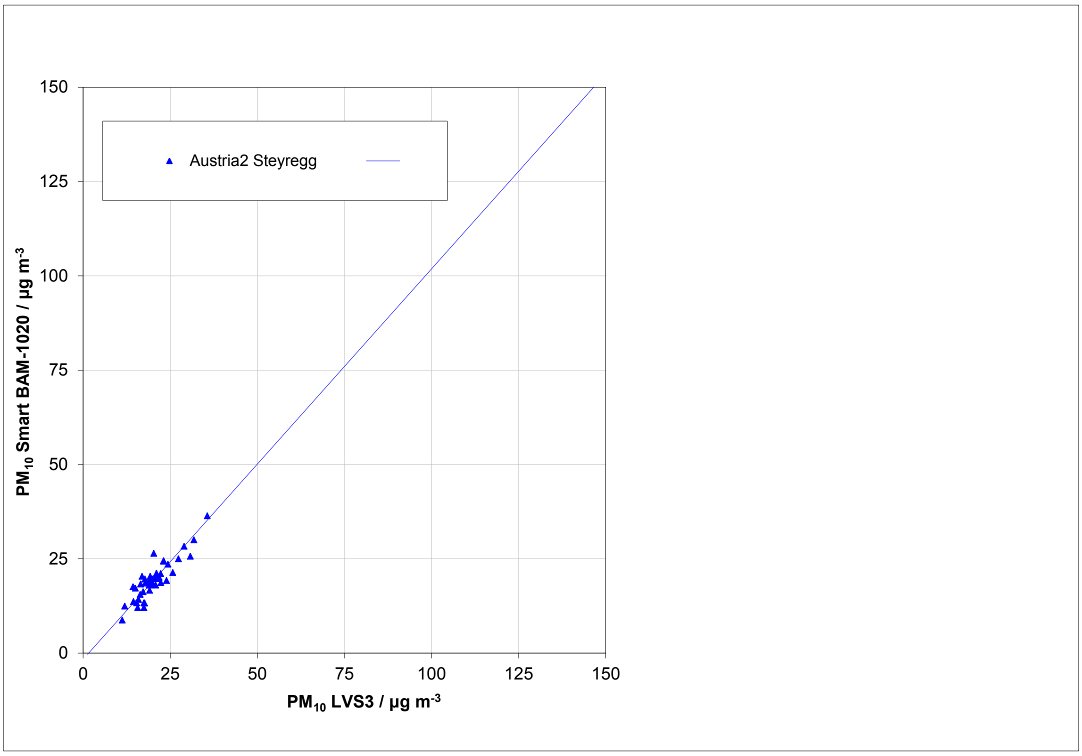

Figure 19: Reference vs. candidate, Austria 2, Measured component PM_{10}, A-Steyregg

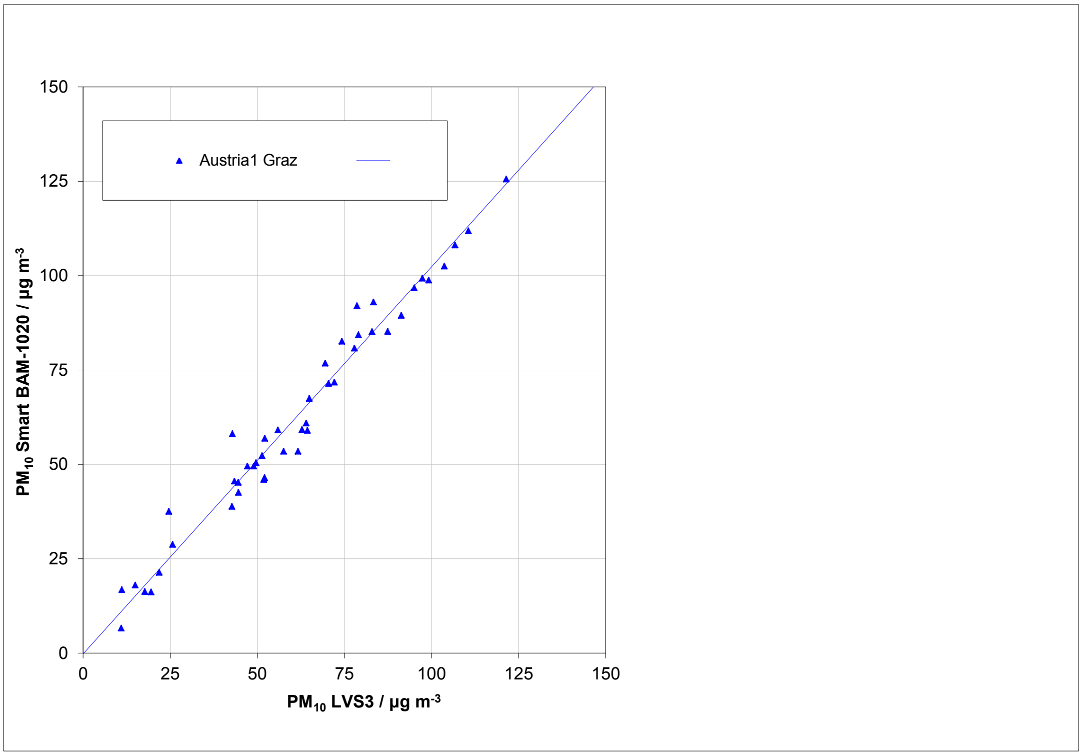

Figure 20: Reference vs. candidate, Austria 1, Measured component PM_{10}, A-Graz

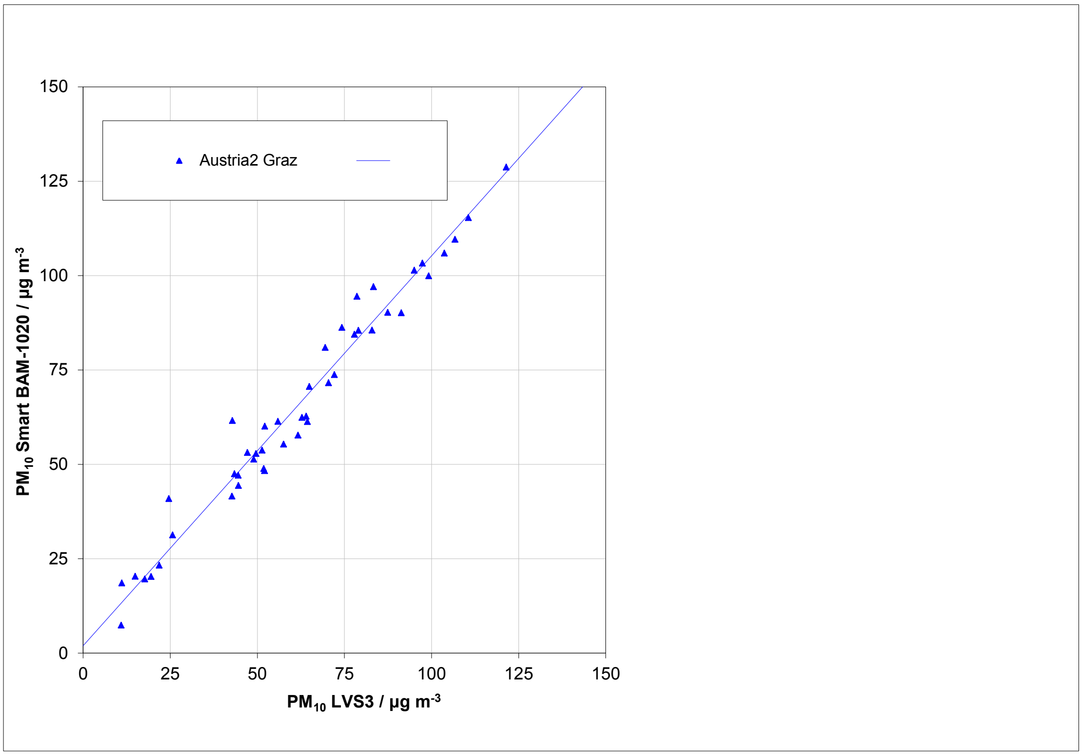

Figure 21: Reference vs. candidate, Austria 2, Measured component PM_{10}, A-Graz

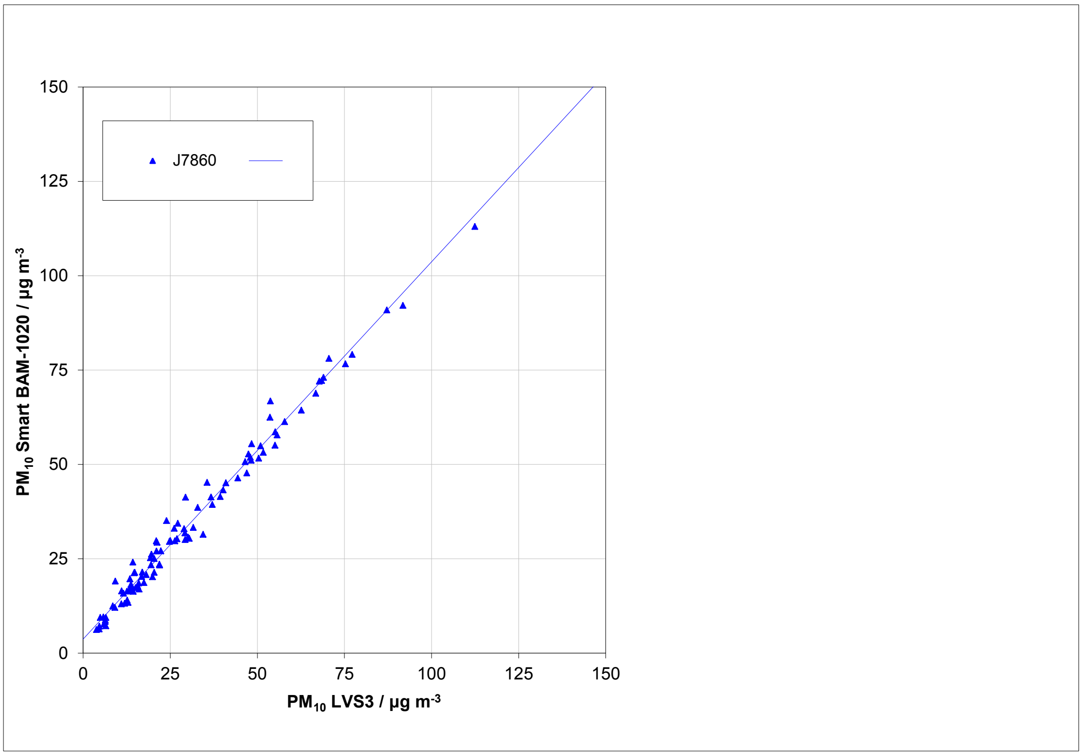

Figure 22: Reference vs. candidate, J7860, Measured component PM_{10}, CZ-Tusimice

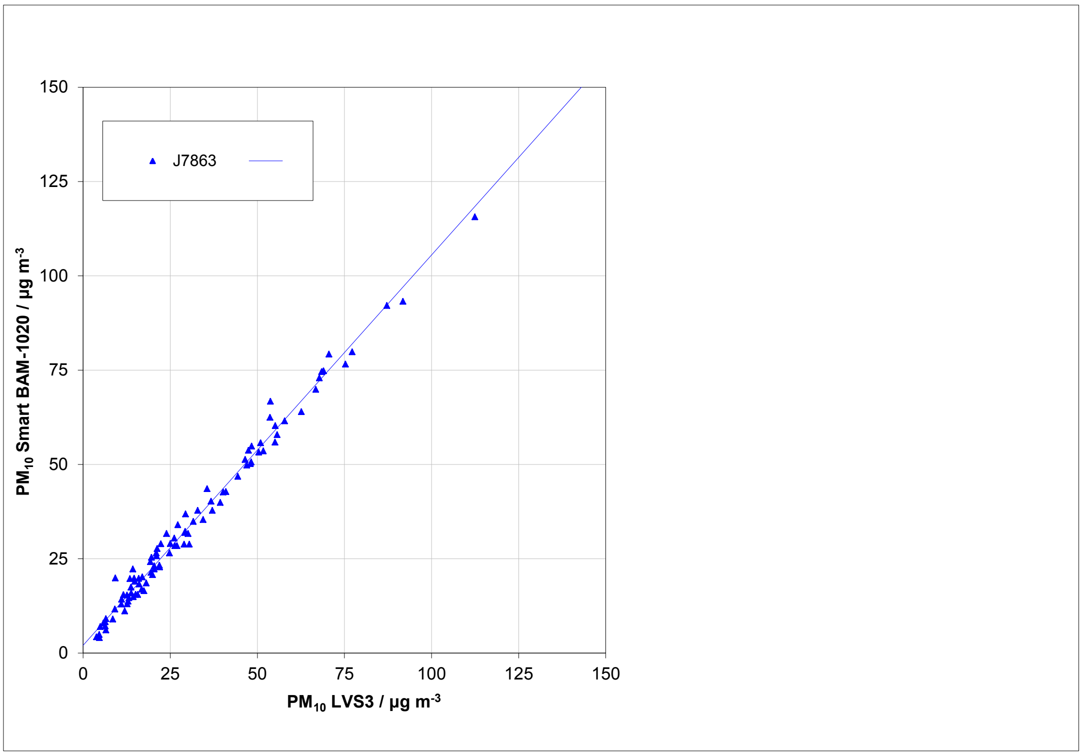

Figure 23: Reference vs. candidate, J7863, Measured component PM_{10}, CZ-Tusimice

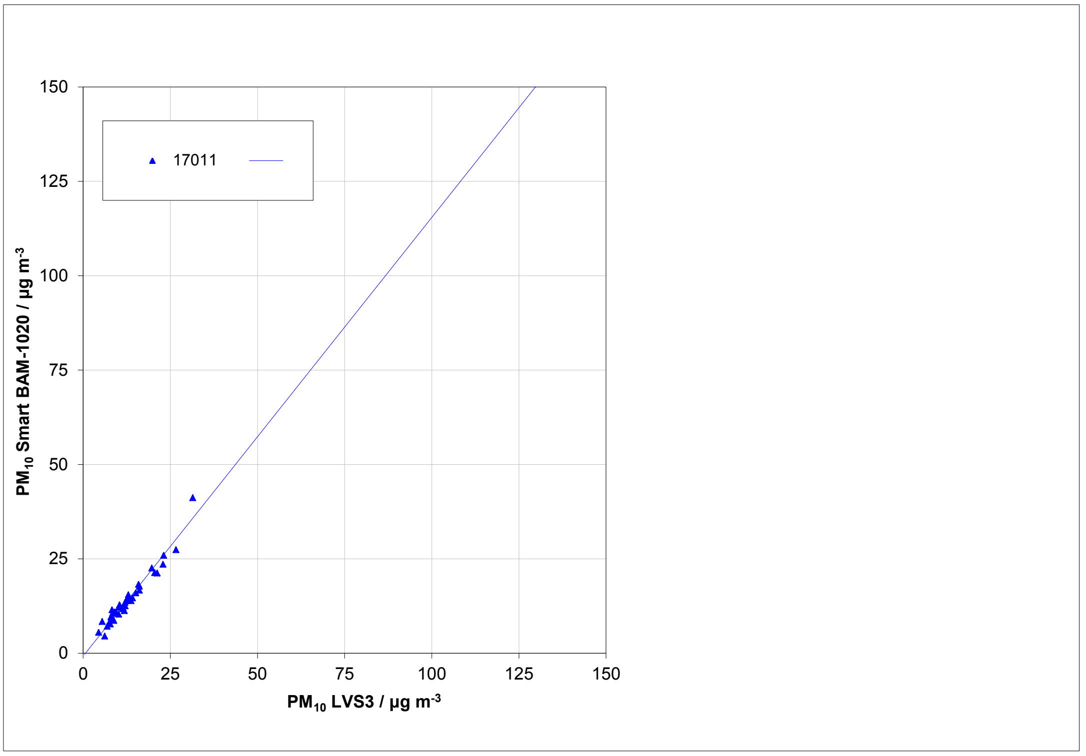

Figure 24: **Reference vs. candidate, SN 17011, Measured component PM_{10}, UK-Teddington**

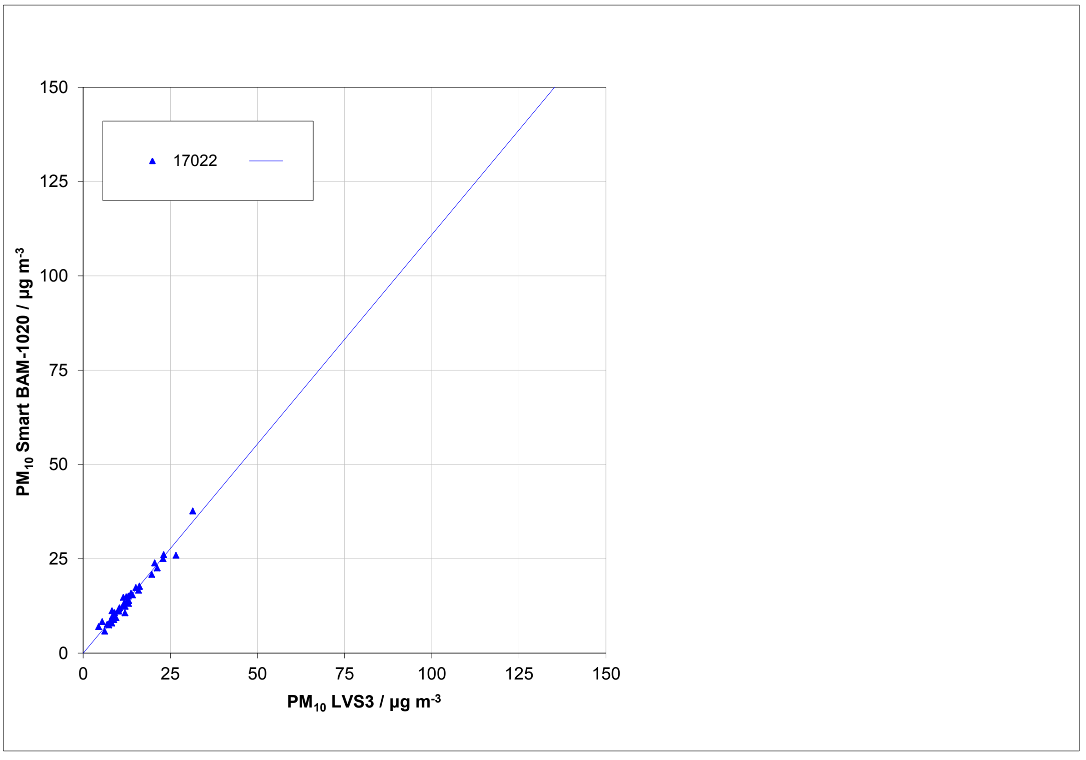

Figure 25: **Reference vs. candidate, SN 17022, Measured component PM_{10}, UK-Teddington**

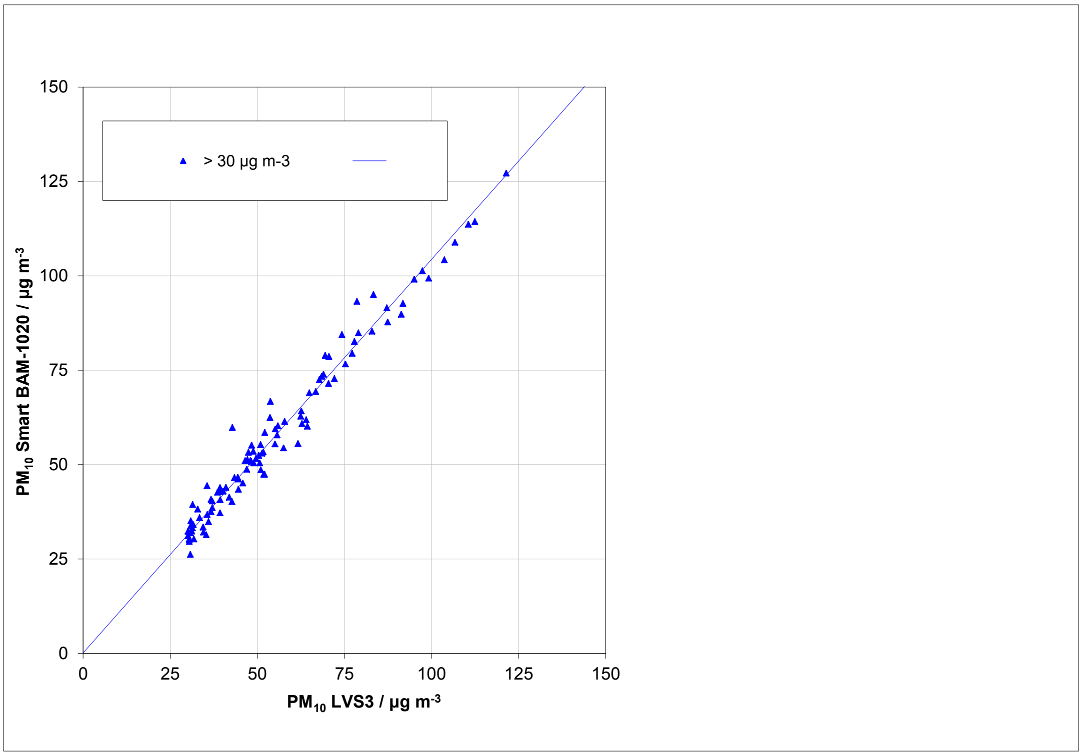

Figure 26: Reference vs. candidate, Measured component PM_{10}, All test sites, Values ≥ 30 µg/m³

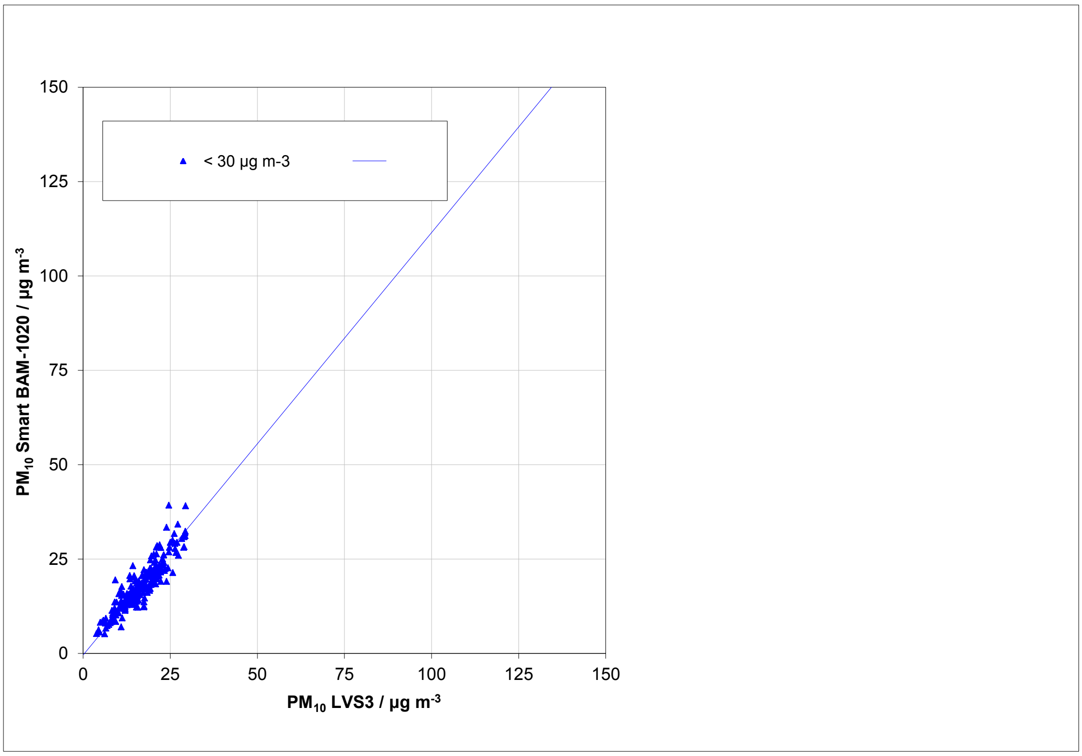

Figure 27: Reference vs. candidate, Measured component PM_{10}, All test sites, Values < 30 µg/m³

4. 5.4.11 Application of correction factors and terms

If the highest resulting expanded uncertainty of the candidate method is larger than the expanded relative uncertainty, which is defined in the requirements on the data quality of ambient air measurements according to EU-Directive, the application of correction factors or terms is permitted. The corrected values have to fulfill the requirements according to point 9.5.3.2 et seqq. of the Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“.

The tests are performed as well for the component PM_{10}

Performance of test

Refer to module 5.4.10

Evaluation

If evaluation of the raw data according to module 5.4.10 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 (refer to module 5.4.10). 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

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

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 annex B of of the Guide. RSS is determined analogue to the calculation in module 5.4.10.

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 annex B of the Guide. RSS is determined analogue to the calculation in module 5.4.10.

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 annex B of the Guide. RSS is determined analogue to the calculation in module 5.4.10.

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 EU Directive.

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 %.

6.5 Assessment

The candidates fulfill 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.

Minimum requirement fulfilled? yes

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 at an expended total uncertainty of 16.0 %.

However, since the expanded uncertainty for the raw data sets A-Graz (Austria 2) and UK-Teddington (17011) is 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 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“ data set is 1.034.

The intercept for for the „All data“ data set 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 7). Thus the correction for the intercept only is not sufficient to demonstrate equivalence.

b) Correction for slope

   The data set is corrected 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 8). Thus equivalence can be demonstrated after slope correction The expanded measurement uncertainty improves from 16.0 % to 12.5 %.

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 9). Thus equivalence can be demonstrated after intercept and slope correction The expanded measurement uncertainty improves from 16.0 % to 12.1 %.

Basically 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 (Guide [4], point 9.9.2, table 6). We have to bear in mind that the highest determined expanded uncertainty after correction for the slope respectively after correction for the intercept and the slope lays in the range 10 % to 15 %.

The respective realization of the above mentioned requirement on ongoing QA/QC in networks 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 % (uncorrected dataset) respectively 12.5 % (dataset after slope correction) respectively 12.1 % (dataset after intercept and slope correction), which again would require an annual test at four respectively three measurement sites.

6.6 Detailed representation of the test results

Table 7 to Table 9 show the results of the evaluations of the equivalence tests after application of correction factors and terms on the complete data set.

Table 7: Summary of the results of the equivalence test, after correction for intercept

PM_{10} Smart 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

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	1.106 +/- 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 m^3	50	0.557	1.492 +/- 0.130	-10.304 +/- 2.545	59.63	2.0
	> 30 µg m^3	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 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	0.361 +/- 0.839	37.23	6.8
	> 30 µg m^3	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 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	-0.684 +/- 0.812	30.54	6.9
	> 30 µg m^3	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 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	-0.210 +/- 0.458	8.21	0.0
	> 30 µg m^3	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 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	-0.240 +/- 0.477	10.40	0.0
	> 30 µg m^3	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.963	1.110 +/- 0.034	-0.893 +/- 0.488	19.05	2.5

Table 8: Summary of the results of the equivalence test, after correction for slope

PM_{10} Smart 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 m-3	17.9	215	0.826	1.079 +/- 0.031	-0.372 +/- 0.538	0.53	1.06
> 30 µg m-3	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 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	0.917 +/- 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 m^3	68	0.814	1.003 +/- 0.053	0.219 +/- 0.949	8.97	4.4
	> 30 µg m^3	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 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	0.957 +/- 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 m^3	68	0.830	1.018 +/- 0.052	0.961 +/- 0.921	11.33	4.4
	> 30 µg m^3	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 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	0.991 +/- 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 m^3	50	0.644	1.285 +/- 0.105	-6.378 +/- 2.065	34.09	2.0
	> 30 µg m^3	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

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	0.998 +/- 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 m^3	50	0.557	1.429 +/- 0.126	-8.879 +/- 2.462	52.84	2.0
	> 30 µg m^3	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 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	1.131 +/- 0.046	1.195 +/- 0.812	32.66	6.8
	> 30 µg m^3	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 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	1.119 +/- 0.044	0.182 +/- 0.786	26.26	6.9
	> 30 µg m^3	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 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	1.004 +/- 0.033	0.620 +/- 0.443	5.53	0.0
	> 30 µg m^3	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 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	1.016 +/- 0.034	0.592 +/- 0.461	7.27	0.0
	> 30 µg m^3	1		+/-	+/-		100.0
	All Data (Teddington)	40	0.963	1.073 +/- 0.033	-0.040 +/- 0.473	15.26	2.5

Table 9: Summary of the results of the equivalence test, after correction for intercept and slope

PM_{10} Smart 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 m-3	15.5	215	0.826	1.079 +/- 0.031	-1.187 +/- 0.538	0.53	1.06
> 30 µg m-3	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

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

5. Appendix (Accreditations)

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 Emissionsfernüberwachung; 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

Siehe Hinweise auf der Rückseite

Figure 28: Accreditation deed of TÜV Rheinland Energie und Umwelt GmbH

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 29: Accreditation deed of Environment Agency Austria

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

Figure 30: Accreditation deed of CHMI, CZ

Schedule of Accreditation

issued by

United Kingdom Accreditation Service

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

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: TSD   Page 1 of 16

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

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Figure 31: Accreditation deed of NPL, UK (excerpts)

6. Appendix (Measured values)

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 1 of 13**

Manufacturer: Net One Instruments

Type of instrument: BAM-1020

Serial-No.: Device 1 / Device 2

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
1	2/11/2006	35.2	35.5	29.8	32.9	Devices 4294 / 4295	D-Cologne, parking lot
2	2/12/2006			25.7	26.0		
3	2/13/2006	33.4	35.7	30.9	33.3		
4	2/14/2006						
5	2/15/2006	12.5	11.7	10.9	12.7		
6	2/16/2006	9.8	9.4	10.1	11.5		
7	2/17/2006	9.6	9.2	8.2	8.7		
8	2/18/2006			14.0	13.3		
9	2/19/2006			10.4	11.5		
10	2/20/2006	9.2	10.0	12.4	14.7		
11	2/21/2006	14.0	13.8	14.1	16.1		
12	2/22/2006	16.0	16.1	17.7	18.9		
13	2/23/2006			20.5	20.3		
14	2/24/2006			29.5	31.1		
15	2/25/2006	27.9	28.8	29.1	31.6		
16	2/26/2006			31.1	32.2		
17	2/27/2006			32.1	34.1		
18	2/28/2006			11.8	14.0		
19	3/1/2006	15.5	15.7	15.6	14.9		
20	3/2/2006	19.1	20.0	22.1	21.8		
21	3/3/2006	45.8	45.9	43.9	46.3		
22	3/4/2006			46.1	47.8		
23	3/5/2006			21.0	23.1		
24	3/6/2006	21.1	21.0	19.8	22.0		
25	3/7/2006	26.2	26.6	26.8	28.7		
26	3/8/2006	14.6	13.6	14.3	16.3		
27	3/9/2006	14.8	14.6	16.8	16.2		
28	3/10/2006	12.1	12.0	11.1	11.6		
29	3/11/2006			25.8	27.5		
30	3/12/2006			29.9	31.7		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 2 of 13**

Manufacturer	Net One Instruments		
Type of instrument	BAM-1020	Suspended particulate matter PM10	Measured values in µg/m³ (ACT)
Serial-No.	Device 1 / Device 2		

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
31	3/13/2006	24.7	24.5	25.7	28.0	Devices 4294 / 4295	D-Cologne, parking lot
32	3/14/2006	30.2	30.1	31.4	33.2		
33	3/15/2006	33.3	33.6	35.2	36.7		
34	3/16/2006	39.2	39.1	42.1	43.5		
35	3/17/2006			39.5	40.8		
36	3/18/2006	37.0	37.2	40.3	40.4		
37	3/19/2006			58.8	61.9		
38	3/20/2006	62.5	62.5	60.9	64.8		
39	3/21/2006			31.8	32.9		
40	3/22/2006	29.3	29.4	31.1	33.6		
41	3/23/2006	21.3	22.7	28.8	28.7		
42	3/24/2006			33.6	36.1		
43	3/25/2006	8.1	9.8	11.5	12.2		
44	3/26/2006			11.1	11.5		
45	3/27/2006			13.4	14.7		
46	3/28/2006	8.9	9.3	13.4	13.8		
47	3/29/2006	10.3	11.2	16.1	17.3		
48	3/30/2006			9.8	10.6		
49	3/31/2006	9.6	10.9	15.3	16.3		
50	4/1/2006			11.5	12.5		
51	4/2/2006			10.0	10.5		
52	4/3/2006			20.3	22.8		
53	4/4/2006			24.7	26.7		
54	7/26/2006	49.1	48.6	52.8	54.2	Devices 4294 / 4295	D-Titz-Rödingen
55	7/27/2006	39.0	39.7	43.4	44.4		
56	7/28/2006						
57	7/29/2006						
58	7/30/2006	17.8	19.2	20.0	21.6		
59	7/31/2006	17.6	18.7	21.3	21.8		
60	8/1/2006	15.9	16.0	16.8	19.6		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 3 of 13**

Manufacturer	Net One Instruments	Suspended particulate matter PM10
Type of instrument	BAM-1020	Measured values in µg/m³ (ACT)
Serial-No.	Device 1 / Device 2	

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
61	8/2/2006	17.4	17.8	18.7	20.2	Devices 4294 / 4295	D-Titz-Rödingen
62	8/3/2006	16.5	17.6	16.2	17.8		
63	8/4/2006	22.5	23.0	24.8	25.0		
64	8/5/2006	20.1	21.4	24.3	25.2		
65	8/6/2006	18.7	18.7	21.0	22.4		
66	8/7/2006	22.0	22.9	21.6	23.3		
67	8/8/2006	14.6	14.8	13.7	14.8		
68	8/9/2006	29.8	28.0	27.7	28.5		
69	8/10/2006	22.6	22.9	23.0	23.7		
70	8/11/2006	18.0	16.6	16.9	17.5		
71	8/12/2006	20.4	19.5	20.5	21.8		
72	8/13/2006	13.8	12.9	13.5	13.2		
73	8/14/2006	13.8	12.9	20.4	20.9		
74	8/15/2006	30.7	30.3	29.9	30.5		
75	8/16/2006	22.0	23.6	24.8	25.3		
76	8/17/2006	16.9	17.8	16.9	17.7		
77	8/18/2006	12.1	11.6	13.1	12.7		
78	8/19/2006	11.5	13.2	13.8	15.4		
79	8/20/2006	10.3	11.6	13.5	14.4		
80	8/21/2006	15.4	15.5	18.5	18.8		
81	8/22/2006	19.5	20.4	21.0	21.7		
82	8/23/2006	38.2	38.9	42.6	42.8		
83	8/24/2006	15.0	16.1	17.1	18.4		
84	8/25/2006	31.9	31.0	32.5	34.0		
85	8/26/2006	31.1	30.6	32.3	31.5		
86	8/27/2006	21.3	21.0	22.8	23.5		
87	8/28/2006	12.8	13.2	14.4	14.6		
88	8/29/2006	13.7	14.5	15.7	14.5		
89	8/30/2006						
90	8/31/2006	16.7	18.2	22.3	22.0		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 4 of 13**

Manufacturer: Net One Instruments

Type of instrument: BAM-1020

Serial-No.: Device 1 / Device 2

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
91	9/1/2006	23.3	23.1	26.1	26.1	Devices 4294 / 4295	D-Titz-Rödingen
92	9/2/2006	20.4	20.0	20.5	23.5		
93	9/3/2006	9.3	8.9	10.3	12.6		
94	9/29/2006	32.9	30.4	33.5	34.6	Devices 4294 / 4295	D-Cologne, Frankf. Str.
95	9/30/2006	18.8	19.7	16.5	17.8		
96	10/1/2006	15.2	15.4	11.5	13.0		
97	10/2/2006	17.9	17.0	12.0	13.1		
98	10/3/2006	18.8	18.1	15.4	16.9		
99	10/4/2006	23.5	23.7	21.5	23.3		
100	10/5/2006	14.1	12.6	15.2	15.7		
101	10/6/2006	14.1	12.8	13.1	13.0		
102	10/7/2006	20.6	21.3	19.3	20.1		
103	10/8/2006	23.7	23.0	21.8	22.0		
104	10/9/2006	30.4	30.4	30.8	29.7		
105	10/10/2006	36.2	35.9	34.8	35.0		
106	10/11/2006	39.7	38.9	36.5	37.9		
107	10/12/2006	51.1	50.4	49.5	51.3		
108	10/13/2006	42.0	42.0	40.3	42.5		
109	10/14/2006	52.1	50.0	47.8	49.3		
110	10/15/2006	37.7	35.7	37.5	37.6		
111	10/16/2006	31.0	29.2	32.0	32.8		
112	10/17/2006	31.8	30.1	33.8	33.9		
113	10/18/2006	31.8	30.1	34.8	35.4		
114	10/19/2006	22.7	21.6	21.8	23.2		
115	10/20/2006	14.2	13.1	13.3	14.5		
116	10/21/2006	13.6	11.8	12.0	13.8		
117	10/22/2006	13.2	12.9	11.6	15.2		
118	10/23/2006	15.4	15.4	15.4	16.7		
119	10/24/2006	19.4	19.2	18.1	18.6		
120	10/25/2006	19.8	18.7	22.5	22.5		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 5 of 13**

Manufacturer Net One Instruments

Type of instrument BAM-1020

Serial-No. Device 1 / Device 2

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
121	10/26/2006	33.4	29.0	31.1	33.7	Devices 4294 / 4295	D-Cologne, Frankf. Str.
122	6/5/2008	20.2	20.4	26.1	26.4	Devices Austria 1 / Austria 2	A-Steyregg
123	6/6/2008	16.6	17.3	20.8	20.3		
124	6/7/2008	13.9	14.9	16.7	17.6		
125	6/8/2008	20.7	21.5	20.0	21.2		
126	6/9/2008	14.7	15.4	17.1	17.2		
127	6/10/2008						
128	6/11/2008	24.1	24.7	21.8	23.5		
129	6/12/2008	21.9	22.7	22.0	21.1		
130	6/13/2008	19.6	20.1	17.6	19.7		
131	6/14/2008	17.6	17.9	20.4	19.6		
132	6/15/2008	16.2	16.6	15.5	15.5		
133	6/16/2008	12.0	11.9	12.1	12.4		
134	6/17/2008						
135	6/18/2008		14.4	15.5	14.3		
136	6/19/2008						
137	6/20/2008		20.4	23.8	21.6		
138	6/21/2008		19.5	18.9	18.6		
139	6/22/2008		27.6	21.2	21.6		
140	6/23/2008		23.1	22.3	22.1		
141	6/24/2008						
142	6/25/2008	28.6	29.4	28.2	28.3		
143	6/26/2008	31.2	32.4	30.6	30.0		
144	6/27/2008	25.4		28.0	27.8		
145	6/28/2008	16.5	16.5	17.9	18.3		
146	6/29/2008	16.7	17.7	15.9	16.2		
147	6/30/2008	19.4	18.6	18.3	18.0		
148	7/1/2008						
149	7/2/2008						
150	7/3/2008	35.6	35.8	37.1	36.4		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 6 of 13**

Manufacturer	Net One Instruments	
Type of instrument	BAM-1020	Suspended particulate matter PM10 Measured values in µg/m³ (ACT)
Serial-No.	Device 1 / Device 2	

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
151	7/4/2008	19.5	19.1	20.4	20.4	Devices Austria 1 / Austria 2	A-Steyregg
152	7/5/2008	18.1	17.6	18.4	18.5		
153	7/6/2008	14.4	14.6	12.2	13.7		
154	7/7/2008	23.6	24.2	19.0	19.2		
155	7/8/2008						
156	7/9/2008	15.6	16.3	14.0	14.2		
157	7/10/2008	19.7	18.3	17.2	18.0		
158	7/11/2008	20.0	18.8	18.7	19.2		
159	7/12/2008	19.0	19.2	16.8	16.6		
160	7/13/2008	15.7	15.7	12.4	12.0		
161	7/14/2008	20.5	21.5	20.2	20.0		
162	7/15/2008						
163	7/16/2008	22.9	23.4	23.8	24.3		
164	7/17/2008	17.3	17.6	12.6	12.1		
165	7/18/2008	20.9	20.8	18.8	18.0		
166	7/19/2008	15.5	15.2	14.2	13.3		
167	7/20/2008	17.3	17.6	14.0	13.3		
168	7/21/2008	18.6	18.9	16.6	18.8		
169	7/22/2008						
170	7/23/2008	22.6	22.0	19.4	18.7		
171	7/24/2008	30.5	31.1	26.8	25.7		
172	7/25/2008	26.8	28.0	27.0	25.0		
173	7/26/2008	20.4	20.5	21.9	19.9		
174	7/27/2008	21.7	22.0	21.4	20.1		
175	7/28/2008	22.5	23.7	23.9	24.5		
176	7/29/2008						
177	7/30/2008	19.5	20.4	19.4	18.5		
178	7/31/2008	19.3	20.1	20.1	18.0		
179	8/1/2008	25.6	25.9	21.5	21.3		
180	8/2/2008	16.8	18.4	16.0	13.2		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 7 of 13**

Manufacturer Net One Instruments

Type of instrument BAM-1020

Serial-No. Device 1 / Device 2

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
181	8/3/2008	10.7	11.7	10.0	8.7	Devices Austria 1 / Austria 2	A-Steyregg
182	8/4/2008	20.5	22.1	21.2	19.7		
183	12/5/2007	121.1	121.8	125.6	128.7	Devices Austria 1 / Austria 2	A-Graz
184	12/6/2007	107.7	105.9	108.1	109.6		
185	12/10/2007	71.4	69.5	71.4	71.6		
186	12/13/2007	11.3	11.0	16.8	18.6		
187	12/16/2007		31.1	30.5	31.9		
188	12/17/2007	53.8		52.1	53.4		
189	12/19/2007		82.5	90.0	91.9		
190	12/20/2007	78.6	79.5	84.3	85.5		
191	1/7/2008		107.4	109.9	113.1		
192	1/8/2008	95.5	94.6	96.8	101.4		
193	1/9/2008		86.5	91.4	93.0		
194	1/10/2008	65.0	64.9	67.4	70.6		
195	1/13/2008	63.7	62.1	59.2	62.4		
196	1/14/2008	50.4	48.8	50.4	52.9		
197	1/15/2008	49.3	48.6	49.5	51.4		
198	1/16/2008	52.9	51.3	46.5	48.3		
199	1/17/2008	57.9	57.1	53.5	55.3		
200	1/20/2008	63.9	64.2	61.0	62.8		
201	1/21/2008	100.5	97.9	98.8	99.9		
202	1/22/2008	44.6	44.6	42.6	44.4		
203	1/23/2008	52.4	50.3	52.3	53.7		
204	1/24/2008	90.6	92.0	89.5	90.1		
205	1/28/2008	20.1	18.9	16.2	20.3		
206	1/30/2008	78.2	77.6	80.8	84.4		
207	1/31/2008	72.8	71.4	71.8	73.8		
208	2/3/2008	22.0	21.7	21.4	23.3		
209	2/4/2008	55.5	56.3	59.1	61.4		
210	2/5/2008	44.7	44.3	45.2	47.1		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 8 of 13**

Manufacturer	Net One Instruments		
Type of instrument	BAM-1020	Suspended particulate matter PM10	Measured values in µg/m³ (ACT)
Serial-No.	Device 1 / Device 2		

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
211	2/6/2008	43.3	43.6	45.6	47.5	Devices Austria 1 / Austria 2	A-Graz
212	2/7/2008	43.2	42.2	38.9	41.5		
213	2/10/2008	64.6	64.1	59.0	61.3		
214	2/11/2008	83.6	82.3	85.1	85.5		
215	2/12/2008	87.9	87.0	85.2	90.2		
216	2/13/2008	111.4	109.8	111.9	115.3		
217	2/14/2008	97.9	96.8	99.3	103.3		
218	2/17/2008	52.6	51.2	46.0	48.9		
219	2/18/2008	47.1	47.2	49.5	53.1		
220	2/19/2008	69.7	69.2	76.8	81.0		
221	2/20/2008	102.8	104.5	102.5	105.9		
222	2/21/2008	84.0	82.7	93.0	97.1		
223	2/24/2008	60.9	62.4	53.4	57.7		
224	2/25/2008	73.8	74.8	82.6	86.2		
225	2/26/2008	79.6	77.7	92.0	94.5		
226	2/27/2008	43.1	42.6	58.1	61.6		
227	2/28/2008	52.7	51.6	56.9	60.1		
228	3/2/2008	10.8	11.1	6.6	7.4		
229	3/3/2008	24.3	24.9	37.5	40.9		
230	3/4/2008	15.2	14.7	18.0	20.4		
231	3/5/2008	17.3	18.2	16.3	19.6		
232	3/6/2008	26.0	25.3	28.8	31.3		
233	1/7/2010	47.0		47.7	49.8	Devices J7860 / J7863	CZ-Tusimice
234	1/8/2010	50.4		51.6	53.3		
235	1/9/2010			50.8	51.6		
236	1/10/2010			17.6	16.7		
237	1/11/2010	40.2		43.2	42.7		
238	1/12/2010	53.7		62.5	62.5		
239	1/13/2010	68.5		72.2	74.6		
240	1/14/2010	31.6		33.3	34.9		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 9 of 13**

Manufacturer	Net One Instruments
Type of instrument	BAM-1020
Serial-No.	Device 1 / Device 2

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
241	1/15/2010	44.4		46.4	46.8	Devices J7860 / J7863	CZ-Tusimice
242	1/16/2010			41.0	40.8		
243	1/17/2010			51.6	51.0		
244	1/18/2010	21.9		23.6	23.3		
245	1/19/2010	29.3		30.1	32.2		
246	1/20/2010	51.7		53.2	53.6		
247	1/21/2010	77.2		79.1	79.8		
248	1/22/2010	91.8		92.1	93.2		
249	1/23/2010			89.9	89.9		
250	1/24/2010			69.4	71.3		
251	1/25/2010			64.4	64.6		
252	1/26/2010	53.8		66.8	66.7		
253	1/27/2010	48.4		55.4	54.8		
254	1/28/2010	5.8		9.6	7.9		
255	1/29/2010	6.0		7.7			
256	1/30/2010			10.4			
257	1/31/2010						
258	2/1/2010	12.7		14.0	13.0		
259	2/2/2010	6.4		8.4	8.3		
260	2/3/2010	9.2		12.1	11.7		
261	2/4/2010	55.7		57.8	57.9		
262	2/5/2010	55.1		55.1	55.9		
263	2/6/2010	66.8		68.9	69.9		
264	2/7/2010	46.5		50.7	51.3		
265	2/8/2010	48.3		51.1	50.6		
266	2/9/2010	62.7		64.4	64.0		
267	2/10/2010	87.2		90.9	92.1		
268	2/11/2010	50.9		54.9	55.7		
269	2/12/2010	16.1		17.0	18.3		
270	2/13/2010	11.0		13.0	13.0		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 10 of 13**

Manufacturer	Net One Instruments		
Type of instrument	BAM-1020	Suspended particulate matter PM10 Measured values in µg/m³ (ACT)	
Serial-No.	Device 1 / Device 2		

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
271	2/14/2010	29.2		31.8	31.9	Devices J7860 / J7863	CZ-Tusimice
272	2/15/2010	47.5		52.8	53.8		
273	2/16/2010	57.9		61.3	61.5		
274	2/17/2010	75.3		76.6	76.6		
275	2/18/2010	69.0		73.0	74.8		
276	2/19/2010	55.2		58.6	60.3		
277	2/20/2010	20.4		21.4	22.3		
278	2/21/2010	19.9		20.2	20.8		
279	2/22/2010	67.8		72.0	72.9		
280	2/23/2010	112.5		113.0	115.6		
281	2/24/2010	70.6		78.1	79.2		
282	2/25/2010	64.6					
283	2/26/2010	37.1		39.4	37.8		
284	2/27/2010	25.0		29.8	29.0		
285	2/28/2010	13.5		19.7	19.7		
286	3/1/2010	6.5		9.5	9.1		
287	3/2/2010	13.8		18.2	17.4		
288	3/3/2010	12.6		16.4	15.3		
289	3/4/2010	14.9		21.4	19.0		
290	3/5/2010	14.3		24.1	22.3		
291	3/6/2010	24.0		35.1	31.7		
292	4/20/2010	41.0		45.1	42.8		
293	4/21/2010	13.8		17.2	15.9		
294	4/22/2010	19.6		26.2	25.4		
295	4/23/2010	32.9		38.6	37.8		
296	4/24/2010	48.0		51.9	50.2		
297	4/25/2010	36.8		41.4	40.2		
298	4/26/2010	20.4		25.1	23.1		
299	4/27/2010	19.5		23.4	21.4		
300	4/28/2010	26.2		33.1	30.5		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 11 of 13**

Manufacturer Net One Instruments

Type of instrument BAM-1020

Serial-No. Device 1 / Device 2

Suspended particulate matter PM10
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
301	4/29/2010	35.6		45.2	43.6	Devices J7860 / J7863	CZ-Tusimice
302	4/30/2010	27.2		34.4	34.0		
303	5/1/2010	13.2		16.6	14.7		
304	5/2/2010	29.0		33.0	28.9		
305	5/3/2010	15.1		17.4	15.5		
306	5/4/2010	21.1		27.0	25.7		
307	5/5/2010	24.8		29.6	26.6		
308	5/6/2010	12.0		13.2	11.2		
309	5/7/2010	8.5		12.5	9.0		
310	5/8/2010	18.1		20.8	18.5		
311	5/9/2010	15.7		17.8	15.6		
312	5/10/2010	39.4		41.5	39.9		
313	5/11/2010	30.5		30.4	28.8		
314	5/12/2010	14.4		16.3	14.9		
315	5/13/2010	17.5		18.7	16.5		
316	5/14/2010	4.7		6.4	4.9		
317	5/15/2010	12.9		13.4	13.8		
318	5/16/2010	16.0		18.6	19.8		
319	5/17/2010	19.4		25.3	24.2		
320	5/18/2010	11.6		15.9	15.5		
321	5/19/2010	6.4		8.8	7.2		
322	5/20/2010	11.0		16.5	14.2		
323	5/21/2010	26.4		29.8	28.5		
324	5/22/2010	27.0		30.3	28.5		
325	5/23/2010	16.8		20.3	16.9		
326	5/24/2010	17.0		21.4	20.2		
327	5/25/2010	21.2		29.3	27.7		
328	5/26/2010	30.2		30.7	31.7		
329	5/27/2010	29.4		41.3	36.9		
330	5/28/2010	22.3		27.1	29.0		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 12 of 13**

Manufacturer	Net One Instruments	
Type of instrument	BAM-1020	Suspended particulate matter PM10 Measured values in µg/m³ (ACT)
Serial-No.	Device 1 / Device 2	

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
331	5/29/2010	34.5		31.5	35.4	Devices J7860 / J7863	CZ-Tusimice
332	5/30/2010	6.6		7.2	6.1		
333	5/31/2010	3.9		6.2	4.3		
334	6/1/2010	4.7		7.1	4.1		
335	6/2/2010	4.9		9.4	7.0		
336	6/3/2010	9.2		19.1	19.9		
337	6/4/2010	14.7		21.3	19.8		
338	6/5/2010	21.0		29.8	26.6		
339	6/6/2010	22.0		23.3	22.9		
340	4/10/2012			8.8	9.8	Devices 17022 / 17011	UK-Teddington
341	4/11/2012			9.6	11.9		
342	4/12/2012	13.8	13.7	15.9	13.9		
343	4/13/2012	21.3	21.2	22.5	21.2		
344	4/14/2012	11.4	11.7	14.8	12.0		
345	4/15/2012	11.5	12.2	13.4	11.3		
346	4/16/2012	10.4	10.0	11.1	10.3		
347	4/17/2012	8.7	8.4	9.8	9.1		
348	4/18/2012	8.3	8.2	7.9	8.9		
349	4/19/2012	12.1	10.9	12.6	11.8		
350	4/20/2012	6.9	6.9	7.6	7.1		
351	4/21/2012	7.9	7.7	8.6	7.7		
352	4/22/2012	9.1	8.5	8.8	8.7		
353	4/23/2012	7.4	7.4	7.4	7.9		
354	4/24/2012	12.1	12.0	12.4	12.5		
355	4/25/2012	9.4	9.5	9.4	10.9		
356	4/26/2012	12.4	12.3	14.9	13.9		
357	4/27/2012	13.9	14.4	15.4	14.6		
358	4/28/2012	4.4	4.5	7.0	5.5		
359	4/29/2012	8.2	8.4	11.2	11.5		
360	4/30/2012	15.1	15.2	17.4	16.0		

Annex 1 **Measured values from field test sites, related to ambient conditions** **Page 13 of 13**

Manufacturer	Net One Instruments	
Type of instrument	BAM-1020	Suspended particulate matter PM10 Measured values in µg/m³ (ACT)
Serial-No.	Device 1 / Device 2	

No.	Date	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Device 1 PM10 [µg/m³]	Device 2 PM10 [µg/m³]	Remark	Test site
361	5/1/2012	20.5	20.6	23.9	21.3	Devices 17022 / 17011	UK-Teddington
362	5/2/2012	22.8	23.1	25.0	23.5		
363	5/3/2012	16.0	16.3	17.7	17.8		
364	5/4/2012	12.8	13.1	15.1	15.5		
365	5/5/2012	10.2	10.2	11.6	12.2		
366	5/6/2012	16.4	15.9	17.6	16.7		
367	5/7/2012	10.3	10.6	12.0	12.8		
368	5/8/2012	12.6	13.0	13.9	13.9		
369	5/9/2012	5.5	5.5	8.3	8.4		
370	5/10/2012	6.1	6.2	5.8	4.5		
371	5/11/2012	8.4	8.6	9.9	10.6		
372	5/12/2012	12.9	13.2	13.9	15.0		
373	5/13/2012	12.1	11.9	10.6	13.4		
374	5/14/2012	8.0	8.0	8.1	9.7		
375	5/15/2012	8.9	9.1	10.7	10.9		
376	5/16/2012	13.0	13.1	13.1	15.2		
377	5/17/2012	26.4	27.0	25.9	27.4		
378	5/18/2012	22.9	23.4	26.1	25.9		
379	5/19/2012	19.4	20.0	20.9	22.5		
380	5/20/2012	15.9	16.0	16.6	18.2		
381	5/21/2012	31.2	31.7	37.7	41.2		

Annex 2 **Ambient conditions at the field test sites** **Page 1 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]		
1	2/11/2006	D-Cologne, parking lot	1.9	82.9	0.0		
2	2/12/2006		2.5	65.3	0.7		
3	2/13/2006		4.1	61.0	1.0		
4	2/14/2006		5.4	79.7	1.4		
5	2/15/2006		7.1	84.8	1.4		
6	2/16/2006		7.2	75.8	0.9		
7	2/17/2006		6.6	66.7	1.1		
8	2/18/2006		5.4	80.2	0.2		
9	2/19/2006		6.9	69.2	0.8		
10	2/20/2006		3.2	82.6	1.0		
11	2/21/2006		4.0	72.2	1.0		
12	2/22/2006		1.8	60.9	1.4		
13	2/23/2006		0.5	50.9	1.1		
14	2/24/2006		2.6	49.7	1.9		
15	2/25/2006		1.0	50.8	1.3		
16	2/26/2006		-1.9	72.8	0.5		
17	2/27/2006		1.2	89.1	0.2		
18	2/28/2006		1.2	88.9	1.7		
19	3/1/2006		-0.7	71.4	1.2		
20	3/2/2006		0.7	60.2	0.3		
21	3/3/2006		0.3	80.6	0.5		
22	3/4/2006		0.2	69.4	0.0		
23	3/5/2006		2.6	65.8	1.6		
24	3/6/2006		2.4	69.6	2.4		
25	3/7/2006		2.8	54.0	0.5		
26	3/8/2006		4.9	86.9	0.9		
27	3/9/2006		7.9	81.5	1.1		
28	3/10/2006		4.9	77.4	0.5		
29	3/11/2006		-1.2	68.7	2.3		
30	3/12/2006		-3.2	51.9	0.7		

Annex 2 **Ambient conditions at the field test sites** **Page 2 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]		
31	3/13/2006	D-Cologne, parking lot	-0.1	42.0	0.5		
32	3/14/2006		2.2	39.6	0.8		
34	3/15/2006		4.4	42.9	0.9		
34	3/16/2006		2.6	46.4	1.0		
35	3/17/2006		2.8	52.3	1.9		
36	3/18/2006		3.8	57.7	1.2		
37	3/19/2006		4.5	55.5	0.7		
38	3/20/2006		3.9	62.4	0.5		
39	3/21/2006		3.6	43.3	1.0		
40	3/22/2006		3.3	42.2	2.0		
41	3/23/2006		6.6	33.7	1.8		
42	3/24/2006		8.7	72.3	0.3		
43	3/25/2006		13.4	66.4	1.7		
44	3/26/2006		15.6	66.7	0.5		
45	3/27/2006		13.4	60.2	1.4		
46	3/28/2006		9.8	58.2	0.7		
47	3/29/2006		9.1	70.2	0.9		
48	3/30/2006		12.8	68.7	1.3		
49	3/31/2006		12.2	61.9	2.6		
50	4/1/2006		10.7	65.2	0.8		
51	4/2/2006		11.5	46.8	3.0		
52	4/3/2006		8.3	59.9	1.2		
53	4/4/2006		5.5	54.0	1.4		
54	7/26/2006	D-Titz-Rödingen	26.5	55.8	0.0		
55	7/27/2006		24.1	64.7	0.0		
56	7/28/2006		20.6	80.1	0.0		
57	7/29/2006		21.7	70.5	0.0		
58	7/30/2006		21.0	70.5	0.0		
59	7/31/2006		20.1	63.0	0.0		
60	8/1/2006		17.5	71.6	1.0		

Annex 2 **Ambient conditions at the field test sites** **Page 3 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]		
61	8/2/2006	D-Titz-Rödingen	15.7	72.8	0.8		
62	8/3/2006		15.1	79.8	0.0		
63	8/4/2006		17.9	77.2	0.2		
64	8/5/2006		19.3	73.3	0.1		
65	8/6/2006		18.7	71.0	0.1		
66	8/7/2006		18.8	75.0	0.3		
67	8/8/2006		15.9	71.7	0.2		
68	8/9/2006		15.0	78.3	0.0		
69	8/10/2006		13.7	78.1	0.0		
70	8/11/2006		12.7	81.0	0.1		
71	8/12/2006		14.1	74.4	0.1		
72	8/13/2006		15.0	71.8	0.6		
73	8/14/2006		15.2	80.4	0.4		
74	8/15/2006		16.0	79.4	0.2		
75	8/16/2006		17.4	75.3	0.2		
76	8/17/2006		18.9	73.9	0.2		
77	8/18/2006		18.8	68.8	1.6		
78	8/19/2006		18.3	72.4	0.1		
79	8/20/2006		16.5	75.0	1.7		
80	8/21/2006		15.7	80.3	0.3		
81	8/22/2006		14.8	79.5	0.0		
82	8/23/2006		17.5	72.0	0.1		
83	8/24/2006		16.0	75.1	1.2		
84	8/25/2006		16.1	80.5	0.1		
85	8/26/2006		15.5	79.9	0.0		
86	8/27/2006		15.6	80.5	0.1		
87	8/28/2006		12.7	81.7	0.4		
88	8/29/2006		12.7	77.8	0.2		
89	8/30/2006		13.1	79.6	0.0		
90	8/31/2006		16.9	69.9	0.6		

Annex 2 **Ambient conditions at the field test sites** **Page 4 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]		
91	9/1/2006	D-Titz-Rödingen	20.0	66.1	0.6		
92	9/2/2006		19.8	65.5	2.1		
93	9/3/2006		20.2	75.9	2.7		
94	9/29/2006	D-Cologne, Frankf. Str.	18.7	68.5	0.4		
95	9/30/2006		18.2	67.3	0.1		
96	10/1/2006		18.6	63.8	0.5		
97	10/2/2006		16.6	64.2	0.3		
98	10/3/2006		14.3	73.4	0.2		
99	10/4/2006		12.7	75.6	0.4		
100	10/5/2006		14.9	68.1	0.2		
101	10/6/2006		15.9	72.1	1.2		
102	10/7/2006		12.1	70.4	2.0		
103	10/8/2006		12.7	69.6	0.0		
104	10/9/2006		15.4	70.2	0.1		
105	10/10/2006		15.1	74.7	0.1		
106	10/11/2006		16.7	70.6	0.7		
107	10/12/2006		17.4	75.3	0.1		
108	10/13/2006		15.3	77.8	0.0		
109	10/14/2006		11.7	73.8	0.6		
110	10/15/2006		11.6	67.7	0.4		
111	10/16/2006		11.7	67.3	2.0		
112	10/17/2006		12.6	65.8	2.6		
113	10/18/2006		15.1	65.3	1.3		
114	10/19/2006		15.1	76.0	1.6		
115	10/20/2006		14.9	76.7	0.1		
116	10/21/2006		15.7	69.1	0.3		
117	10/22/2006		16.6	69.3	1.6		
118	10/23/2006		16.7	76.9	1.2		
119	10/24/2006		13.2	74.5	2.2		
120	10/25/2006		14.5	66.3	2.8		

Annex 2 **Ambient conditions at the field test sites** **Page 5 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]		
121	10/26/2006	D-Cologne, Frankf. Str.	19.1	64.2	0.5		
122	6/5/2008	A-Steyregg	18.1	73.1	2.2		
123	6/6/2008		17.8	77.2	1.9		
124	6/7/2008		17.9	76.6	1.0		
125	6/8/2008		17.4	85.0	0.8		
126	6/9/2008		19.9	71.1	1.3		
127	6/10/2008		22.4	64.9	1.2		
128	6/11/2008		18.5	74.5	1.8		
129	6/12/2008		16.8	65.2	1.5		
130	6/13/2008		10.9	80.0	1.3		
131	6/14/2008		13.3	71.9	0.6		
132	6/15/2008		16.9	58.7	0.8		
134	6/16/2008		16.9	69.1	1.0		
134	6/17/2008		16.6	83.1	1.0		
135	6/18/2008		16.8	84.0	1.0		
136	6/19/2008		20.0	70.9	0.8		
137	6/20/2008		21.2	65.3	1.3		
138	6/21/2008		22.5	63.9	1.0		
139	6/22/2008		26.2	62.6	0.8		
140	6/23/2008		24.8	64.4	1.1		
141	6/24/2008		21.9	75.4	1.0		
142	6/25/2008		25.1	70.1	1.3		
143	6/26/2008		20.5	85.6	0.9		
144	6/27/2008		20.5	71.3	0.8		
145	6/28/2008		20.5	67.6	1.4		
146	6/29/2008		23.7	65.1	1.0		
147	6/30/2008		21.0	73.3	1.3		
148	7/1/2008		22.8	65.0	1.6		
149	7/2/2008		24.2	68.6	1.2		
150	7/3/2008		24.0	69.5	1.9		

Annex 2 **Ambient conditions at the field test sites** **Page 6 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]		
151	7/4/2008	A-Steyregg	18.1	70.5	1.9		
152	7/5/2008		18.9	60.3	1.3		
153	7/6/2008		21.6	76.4	1.2		
154	7/7/2008		14.8	93.0	1.2		
155	7/8/2008		17.6	70.3	1.2		
156	7/9/2008		17.7	73.8	1.1		
157	7/10/2008		20.7	72.0	0.7		
158	7/11/2008		24.6	61.9	1.6		
159	7/12/2008		19.8	80.8	1.4		
160	7/13/2008		17.0	87.1	1.6		
161	7/14/2008		15.8	82.8	1.5		
162	7/15/2008		19.5	61.0	1.9		
163	7/16/2008		21.2	66.8	1.4		
164	7/17/2008		15.6	92.5	0.7		
165	7/18/2008		15.9	86.4	0.9		
166	7/19/2008		21.4	69.7	1.0		
167	7/20/2008		17.8	82.5	1.4		
168	7/21/2008		15.1	68.3	1.7		
169	7/22/2008		13.9	81.5	2.5		
170	7/23/2008		16.1	80.1	1.4		
171	7/24/2008		15.6	93.9	1.3		
172	7/25/2008		18.2	94.6	0.8		
173	7/26/2008		20.9	87.5	0.3		
174	7/27/2008		22.3	72.5	1.4		
175	7/28/2008		23.6	64.4	1.8		
176	7/29/2008		24.3	69.9	0.9		
177	7/30/2008		23.2	74.6	1.2		
178	7/31/2008		22.8	71.3	1.1		
179	8/1/2008		24.3	68.3	1.5		
180	8/2/2008		20.4	84.9	0.7		

Annex 2 **Ambient conditions at the field test sites** **Page 7 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]		
181	8/3/2008	A-Steyregg	22.1	72.7	0.9		
182	8/4/2008		22.2	69.2	2.1		
183	12/5/2007	A-Graz	1.1	83.9	0.1		
184	12/6/2007						
185	12/10/2007		1.1	98.4	0.2		
186	12/13/2007		4.7	41.4	1.8		
187	12/16/2007		-1.3	84.7	0.6		
188	12/17/2007		-2.7	83.5	0.3		
189	12/19/2007		-4.8	84.8	0.8		
190	12/20/2007		-5.9	89.1	0.7		
191	1/7/2008		-1.2	93.9	0.3		
192	1/8/2008						
193	1/9/2008		-1.6	88.0	0.2		
194	1/10/2008		-1.9	90.6	0.3		
195	1/13/2008		3.1	100.0	0.0		
196	1/14/2008		2.2	97.9	0.2		
197	1/15/2008		0.6	98.0	0.4		
198	1/16/2008		3.4	91.6	0.3		
199	1/17/2008		4.5	97.9	0.1		
200	1/20/2008		5.9	90.5	0.1		
201	1/21/2008		3.9	89.2	0.2		
202	1/22/2008		4.4	58.3	1.2		
203	1/23/2008		0.4	61.6	0.7		
204	1/24/2008						
205	1/28/2008		4.6	67.4	0.9		
206	1/30/2008		2.2	80.1	0.3		
207	1/31/2008		2.6	78.2	0.6		
208	2/3/2008		2.7	77.3	0.8		
209	2/4/2008		3.5	89.4	0.3		
210	2/5/2008						

Annex 2 **Ambient conditions at the field test sites** **Page 8 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]	Windrichtung [°]	Niederschlagsmenge [mm]
211	2/6/2008	A-Graz	3.1	93.7	0.4		
212	2/7/2008		2.8	58.1	1.1		
213	2/10/2008		1.4	69.0	0.2		
214	2/11/2008		0.2	73.7	0.4		
215	2/12/2008		-0.7	72.5	0.3		
216	2/13/2008						
217	2/14/2008						
218	2/17/2008		-3.5	46.3	0.4		
219	2/18/2008		4.4	33.9	0.6		
220	2/19/2008		4.5	53.3	0.7		
221	2/20/2008						
222	2/21/2008						
223	2/24/2008		8.1	61.0	0.3		
224	2/25/2008						
225	2/26/2008		8.4	65.5	0.4		
226	2/27/2008		10.2	53.1	0.6		
227	2/28/2008		7.1	68.1	0.6		
228	3/2/2008		13.3	41.7	1.9		
229	3/3/2008		12.2	51.9	1.2		
230	3/4/2008		3.2	77.6	0.8		
231	3/5/2008		1.7	46.5	1.3		
232	3/6/2008		2.0	42.8	0.6		
234	1/7/2010	CZ-Tusimice	-7.0	85.0	0.0		
234	1/8/2010		-7.0	92.0	0.6		
235	1/9/2010		-6.0	93.0	0.6		
236	1/10/2010		-4.0	94.0	1.2		
237	1/11/2010		-7.0	92.0	0.0		
238	1/12/2010		-8.0	92.0	0.0		
239	1/13/2010		-7.0	94.0	0.0		
240	1/14/2010		-3.0	91.0	0.0		

Annex 2 **Ambient conditions at the field test sites** **Page 9 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]	Windrichtung [°]	Niederschlagsmenge [mm]
241	1/15/2010	CZ-Tusimice	-3.0	92.0	0.0		
242	1/16/2010		-2.0	88.0	0.6		
243	1/17/2010		-3.0	93.0	0.0		
244	1/18/2010			94.0	0.0		
245	1/19/2010		-13.0	24.0			
246	1/20/2010		-8.0	53.0			
247	1/21/2010		-5.0	91.0	0.0		
248	1/22/2010		-8.0	88.0	0.0		
249	1/23/2010		-9.0	91.0	0.0		
250	1/24/2010		-8.0	87.0	0.0		
251	1/25/2010		-9.0	87.0	0.6		
252	1/26/2010		-10.0	85.0	0.6		
253	1/27/2010		-13.0	79.0	0.6		
254	1/28/2010		-2.0	85.0	2.5		
255	1/29/2010		-1.0	88.0	1.2		
256	1/30/2010		-2.0	82.0	1.2		
257	1/31/2010		-7.0	85.0	0.0		
258	2/1/2010		-8.0	84.0	0.0		
259	2/2/2010		-2.0	80.0	1.2		
260	2/3/2010		-1.0	82.0	1.2		
261	2/4/2010		-5.0	92.0	0.6		
262	2/5/2010		-2.0	89.0	0.0		
263	2/6/2010		-2.0	96.0	0.0		
264	2/7/2010		-7.0	89.0	0.6		
265	2/8/2010		-9.0	84.0	0.0		
266	2/9/2010		-8.0	85.0	0.0		
267	2/10/2010		-6.0	91.0	0.0		
268	2/11/2010		-6.0	90.0	1.2		
269	2/12/2010		-5.0	90.0	0.0		
270	2/13/2010		-5.0	86.0	0.0		

Annex 2 **Ambient conditions at the field test sites** **Page 10 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]	Windrichtung [°]	Niederschlagsmenge [mm]
271	2/14/2010	CZ-Tusimice	-6.0	85.0	0.0		
272	2/15/2010		-5.0	82.0	0.0		
273	2/16/2010		-7.0	84.0	0.6		
274	2/17/2010		-7.0	91.0	0.0		
275	2/18/2010		-1.0	93.0	0.0		
276	2/19/2010		0.0	96.0	0.0		
277	2/20/2010		1.0	82.0	0.6		
278	2/21/2010		-1.0	84.0	0.6		
279	2/22/2010		-2.0	92.0	0.0		
280	2/23/2010		0.0	89.0	0.0		
281	2/24/2010		3.0	92.0	0.0		
282	2/25/2010		3.0	86.0	0.6		
283	2/26/2010		2.0	90.0	0.6		
284	2/27/2010		4.0	73.0	1.2		
285	2/28/2010		0.0	88.0	0.0		
286	3/1/2010		3.0	71.0	2.5		
287	3/2/2010		0.0	78.0	0.6		
288	3/3/2010		-1.0	75.0	1.2		
289	3/4/2010		-3.0	82.0	0.6		
290	3/5/2010		-5.0	74.0	1.9		
291	3/6/2010		-6.0	82.0	1.2		
292	4/20/2010		9.0	72.0	0.6		
293	4/21/2010		6.0	70.0	1.9		
294	4/22/2010		4.0	63.0	1.2		
295	4/23/2010		5.0	67.0	0.6		
296	4/24/2010		10.0	60.0	0.6		
297	4/25/2010		11.0	64.0	0.6		
298	4/26/2010		11.0	73.0	1.2		
299	4/27/2010		11.0	74.0	1.2		
300	4/28/2010		11.0	70.0	0.6		

Annex 2 **Ambient conditions at the field test sites** **Page 11 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]	Windrichtung [°]	Niederschlagsmenge [mm]
301	4/29/2010	CZ-Tusimice	15.0	60.0	0.6		
302	4/30/2010		17.0	60.0	1.2		
303	5/1/2010		14.0	73.0	0.0		
304	5/2/2010		11.0	93.0	0.6		
305	5/3/2010		11.0	87.0	0.6		
306	5/4/2010		8.0	89.0	0.6		
307	5/5/2010		7.0	85.0	1.2		
308	5/6/2010		8.0	96.0	0.0		
309	5/7/2010		9.0	80.0	0.6		
310	5/8/2010		9.0	74.0	0.6		
311	5/9/2010		9.0	83.0	0.6		
312	5/10/2010		10.0	92.0	0.0		
313	5/11/2010		13.0	90.0	0.6		
314	5/12/2010		13.0	79.0	1.2		
315	5/13/2010		9.0	84.0	0.6		
316	5/14/2010		7.0	91.0	0.6		
317	5/15/2010		6.0	89.0	1.9		
318	5/16/2010		9.0	74.0	2.5		
319	5/17/2010		11.0	71.0	2.5		
320	5/18/2010		9.0	73.0	3.1		
321	5/19/2010		8.0	88.0	1.2		
322	5/20/2010		11.0	92.0	0.6		
323	5/21/2010		13.0	86.0	1.2		
324	5/22/2010		16.0	76.0	0.6		
325	5/23/2010		14.0	80.0	1.2		
326	5/24/2010		15.0	84.0	1.2		
327	5/25/2010		14.0	84.0	1.2		
328	5/26/2010		11.0	90.0	0.0		
329	5/27/2010		14.0	87.0	1.2		
330	5/28/2010		14.0	85.0	0.6		

Annex 2 **Ambient conditions at the field test sites** **Page 12 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]	Windrichtung [°]	Niederschlagsmenge [mm]
331	5/29/2010	CZ-Tusimice	14.0	77.0	0.6		
332	5/30/2010		13.0	87.0	0.6		
333	5/31/2010		10.0	83.0	1.9		
334	6/1/2010		10.0	87.0	2.5		
335	6/2/2010		11.0	91.0	2.5		
336	6/3/2010		12.0	95.0	1.2		
337	6/4/2010		14.0	78.0	1.2		
338	6/5/2010		16.0	73.0	0.6		
339	6/6/2010		19.0	74.0	0.6		
340	4/10/2012	UK-Teddington	8.1	69.5	0.2		
341	4/11/2012		8.6	69.6	0.4		
342	4/12/2012		7.3	81.6	0.2		
343	4/13/2012		9.6	69.1	0.7		
344	4/14/2012		8.1	60.1	2.2		
345	4/15/2012		5.8	63.9	1.5		
346	4/16/2012		8.4	51.9	1.0		
347	4/17/2012		8.5	75.4	0.9		
348	4/18/2012		8.4	85.8	0.9		
349	4/19/2012		8.1	86.1	0.1		
350	4/20/2012		7.8	79.4	0.2		
351	4/21/2012		8.9	70.6	0.2		
352	4/22/2012		9.7	75.8	0.5		
353	4/23/2012		7.9	84.4	2.0		
354	4/24/2012		9.4	70.5	1.5		
355	4/25/2012		10.0	83.6	1.9		
356	4/26/2012		11.4	71.7	1.2		
357	4/27/2012		11.3	77.8	0.7		
358	4/28/2012		7.5	91.8	3.5		
359	4/29/2012		11.3	73.8	2.4		
360	4/30/2012		14.6	69.7	2.4		

Annex 2 **Ambient conditions at the field test sites** **Page 13 of 13**

No.	Date	Test site	Amb. temperature (avg) [°C]	Rel. humidity [%]	Wind velocity [m/s]	Windrichtung [°]	Niederschlagsmenge [mm]
361	5/1/2012	UK-Teddington	14.0	76.2	0.6		
362	5/2/2012		10.8	80.9	1.2		
363	5/3/2012		8.5	86.7	0.6		
364	5/4/2012		8.4	77.4	1.7		
365	5/5/2012		7.8	66.5	1.8		
366	5/6/2012		7.2	72.9	0.7		
367	5/7/2012		11.9	82.2	0.8		
368	5/8/2012		13.9	78.5	0.4		
369	5/9/2012		14.9	91.0	0.8		
370	5/10/2012		14.8	82.0	0.7		
371	5/11/2012		11.5	56.0	1.2		
372	5/12/2012		10.8	58.0	0.8		
373	5/13/2012		12.1	58.7	0.4		
374	5/14/2012		8.7	83.0	0.3		
375	5/15/2012		7.5	76.4	1.0		
376	5/16/2012		11.1	62.7	0.4		
377	5/17/2012		12.6	58.1	1.5		
378	5/18/2012		13.6	79.0	0.6		
379	5/19/2012		13.1	69.8	1.6		
380	5/20/2012		12.2	76.2	1.9		
381	5/21/2012		14.5	75.5	1.5		

Notification as regards the APDA-371 measuring system with PM_{10} pre-separator manufactured by HORIBA Europe GmbH

Notification 1

Notification as regards Federal Environment Agency notice of 12 April 2007 (BAnz. p. 4139, Chapter III Number 1.2) and of ´3 August 2009 (BAnz. p. 2929, Chapter III, 6notificationth notification).

An identical instrument to the BAM-1020 measuring system manufactured by MetOne Instruments, TÜV Report No. 936/21205333A dated 6 December 2006, is distributed by HORIBA Europe GmbH, 61440 Oberursel, under the name APDA-371.

The current software version of the APDA-371 ambient air quality measuring system is:

Version 3236-07 V5.0.5

Announcements published by the Federal Environment Agency on 25 January 2010 (BAnz. p. 552, Chapter IV, 11th notification), statement issued on 9 October 2009

Notification 2

Notification as regards Federal Environment Agency notice of 12 April 2007 (BAnz. p. 4139, Chapter III Number 1.2) and of 25 January 2010 (BAnz. p. 552, Chapter IV, 11th notification).

In future, the APDA-371 measuring system distributed by HORIBA Europe GmbH, 61440 Oberursel, will be exclusively distributed as APDA-371 with PM_{10} pre-separator.

Announcement published by the Federal Environment Agency on 12 July 2010 (BAnz. p. 2597, Chapter III, 8th notification), statement issued on 10 May 2010

Notification 3

Notification as regards Federal Environment Agency notice of 12 April 2007 (BAnz. p. 4139, Chapter III Number 1.2) and of 12 July 2010 (BAnz. p. 2597, Chapter III, 8th notification).

The APDA-371 measuring system with PM_{10} pre-separator manufactured by HORIBA Europe GmbH for suspended particulate matter, PM_{10} fraction, may also be operated with the BX-125 pump.

The measuring system has been fitted with a re-designed back plate, which provides space for additional interfaces such as the BX-965 report processor.

The current software version of the measuring system is:

3236-07 V 5.0.15.

Announcements published by the Federal Environment Agency on 6 July 2012 (BAnz AT 20.07.2012 B11, Chapter IV 3rd notification), statement issued on 22 March 2012

Notification 4

Announcement published by the Federal Environment Agency on 12 July 2010 (BAnz. p. 2597, Chapter II, Number 1.1, 7th note) and Federal Environment Agency notice of 6 July 2012 (BAnz AT 20.07.2012 B11, Chapter IV, 2nd notification).

The APDA-371 measuring system with PM_{10} pre-separator for suspended particulate matter, PM_{10} fraction, manufactured by HORIBA Europe GmbH complies with the requirements of standard EN 12341 and those of guideline "Demonstration of Equivalence of Ambient Air Monitoring Methods", version dated January 2010. Moreover, the manufacturing process and the QMS used for the APDA-371 measuring system with PM_{10} pre-separator meets the requirements specified in standard EN 15267.

Test report No. 936/21221789/A on performance testing is available online at www.qal1.de.

The current software version of the APDA-371 measuring system with PM_{10} pre-separator manufactured by HORIBA Europe GmbH for suspended particulate matter, PM_{10} fraction, is:

3236-07 5.1.1

Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 18 March 2013

TÜV RHEINLAND ENERGY GMBH

Deutsche Akkreditierungsstelle
D-PL-11120-02-00

Addendum to Report No. 936/21221789/A of 19 March 2013 on the performance test of the APDA-371 ambient air quality monitor for suspended particulate matter, PM_{10} manufactured by Horiba Europe GmbH

TÜV Report No.: 936/21246946/A
Cologne, 7 September 2019

www.umwelt-tuv.de

tre-service@de.tuv.com

TÜV Rheinland Energy GmbH and its Ambient Air Quality department in particular
is accredited for the following activities:

- Determination of emissions and ambient air quality affected by air pollutants and odorous substances,
- Inspection of correct installation, function and calibration of continuously operating emission measuring instruments, including data evaluation and remote emission monitoring systems;
- Measurements in combustion chambers;
- Performance testing of measuring systems for continuous monitoring of emissions and ambient air, and of electronic data evaluation and remote emission monitoring systems;
- Determination of the stack height and air quality forecasts for hazardous and odorous substances;
- Determination of emissions and ambient air quality affected by noise and vibration, determination of sound power levels and noise measurements at wind turbines;

according to EN ISO/IEC 17025.

The accreditation will expire on 10-12-2022 and
covers the scope specified in the annex to certificate D-PL-11120-02-00.

TÜV Rheinland Energy GmbH
D - 51105 Köln, Am Grauen Stein,
Tel: + 49 (0) 221 806-5200, fax: +49 (0) 221 806-1349

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Summary Overview

HORIBA Europe GmbH commissioned TÜV Rheinland Energy GmbH to carry out a performance test of the APDA-371 ambient air quality measuring system for suspended particulate matter, PM_{10} in accordance with the following standards and requirements:

- VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated September 2010 or June 2002 respectively.
- VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated September 2010 or August 2004 respectively.
- EN 12341 "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", German version EN 12341:1998 (withdrawn)
- European standard EN 12341, "Ambient air - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2,5}$ mass concentration of suspended particulate matter"; German version EN 12341:2014
- Guideline "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version of January 2010

Regarding standard EN 12341:1998 / 2014, it should be noted that the standard was applicable at the time of the original performance test. This is why the standard is cited here for the sake of completeness. Its successor, standard EN 12341:2014 was added to the list.

The APDA-371 measuring system uses a radiometric principle to determine dust concentrations. A pump sucks in ambient air through a PM_{10} sample inlet. The dust loaded sample air is then sucked onto a filter tape. After having been sampled, the dust mass separated on the filter tape is determined by way of a radiometric method, namely beta ray absorption.

The tested certification range was:

Component	**Certification range**
PM_{10}	0–10,000 µg/m³

Except for a re-designed front plate, the APDA-371 measuring system is identical to the BAM-1020 measuring systems. They have been developed by Met One Instruments Inc. who are also completely responsible for AMS manufacturing of this system. The manufacturer produces the systems simultaneously under the exact same conditions as the BAM-1020 including personnel and materials employed. Inspections of the relevant drawings and audits of the production site in Grants Pass demonstrated that the instrument versions are completely identical.

Given the identical design, the APDA-371 measuring system had not been physically tested before their initial publication as performance tested. All tests were performed with the BAM-1020 measuring system by the original equipment manufacturer Met One. Only a document inspection was carried out and the production site is audited regularly.

The publication history for the APDA-371 measuring system for suspended particulate matter, PM_{10}, distributed by HORIBA Europe GmbH is provided below.

- APDA-371 for suspended particulate matter PM_{10}, Federal Environment Agency notice of 3 July 2013 (BAnz AT 23.07.2013 B4, chapter III number 3.1) – initial announcement of suitability.

- APDA-371 for suspended particulate matter PM_{10}, Federal Environment Agency notice of 25 February 2015 (BAnz AT 02.04.2015 B5, chapter IV notification 9) – notification of new pressure sensor

- APDA-371 for suspended particulate matter PM_{10}, Federal Environment Agency notice of 22 July 2015 (BAnz AT 26.08.2015 B4, chapter V notification 42) – notification of new vacuum pump

- APDA-371 for suspended particulate matter PM_{10}, Federal Environment Agency notice of 13 July 2017 (BAnz AT 31.07.2017 B12, chapter II notification 33) – notification of new software version (3236-7 V 5.5.0)

Standard EN 16450 “Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2,5}$) has been available since July 2017. This standard, for the first time, harmonises requirements for the performance testing of automated measuring systems for the determination of dust concentrations (PM_{10} and $PM_{2.5}$) on a European level and will form the basis for the approval of such AMS in the future.

The present addendum contains an assessment of the APDA-371 measuring system with regard to compliance with the requirements of standard EN 16450 (July 2017). Given the identical design of the APDA-371 and BAM-1020, the APDA-371 measuring system did not undergo physical testing with regard to compliance with the requirements of standard EN 16450. All relevant results (re-assessment and re-testing) are taken from the tests performed with the BAM-1020 measuring system provided by Met One, the original equipment manufacturer. Tests and their results were presented in “Addendum to the report on the performance test of the BAM-1020 measuring system for suspended particulate matter, PM_{10}, with PM_{10} pre-separator manufactured by Met One Instruments Inc., Report No. 936/21243375/A dated 21 September 2018. Alongside the test report, this basic addendum aimed at the initial approval (TÜV Report no. 21221789 dated 19 March 2013) served as appendix to this report.

It was demonstrated that the APDA-371 measuring system meets the requirements of standard EN 16450:2017.

On its publication, this addendum becomes an integral part of TÜV Rheinland test report no. 936/21221789/A dated 13 March 2013 and will be available at www.qal1.de.

Environmental Protection/Air Pollution Control

Cologne, 7 September 2019

F. Hausberg | Guido Baum

Dipl.-Ing. Fritz Hausberg | Dipl.-Ing. Guido Baum

936/21246946/A

3.1 APDA-371 mit PM_{10}-Vorabscheider

Hersteller:
HORIBA Europe GmbH, Oberursel

Eignung:
Zur kontinuierlichen Immissionsmessung der PM_{10}-Fraktion im Schwebstaub im stationären Einsatz

Messbereich in der Eignungsprüfung:

Komponente	Zertifizierungsbereich	Einheit
PM_{10}	0 – 1 000	µg/m^3

Softwareversion: Version 3236-07 5.1.1

Einschränkungen:
Keine

Hinweise:

1. Das Gerät ist zur Erfassung von PM_{10} mindestens mit folgenden Optionen auszustatten: Probenahmeheizung (BX-830), Probenahmekopf (BX-802) und Umgebungstemperatursensor (BX-592) bzw. kombinierter Druck- und Temperatursensor (BX-596).
2. Die Heizung darf nur in der während der Eignungsprüfung verwendeten Betriebsweise eingesetzt werden.
3. Die Volumenstromregelung hat auf Betriebsvolumen in Bezug auf die Umgebungsbedingungen zu erfolgen (Betriebsart ACTUAL).
4. Die Zykluszeit während der Eignungsprüfung betrug 1 h, d. h. jede Stunde wurde ein automatischer Filterwechsel durchgeführt. Jeder Filterfleck wurde nur einmal beprobt.
5. Die Messeinrichtung ist in einem verschließbaren Messcontainer zu betreiben.
6. Die Messeinrichtung ist mit dem gravimetrischen PM_{10}-Referenzverfahren nach DIN EN 12341 regelmäßig am Standort zu kalibrieren.
7. Die Messeinrichtung kann optional mit der Pumpe BX-125 betrieben werden.
8. Die Messeinrichtung wird seit Januar 2012 mit einer neu designten Rückplatte vertrieben, um die erweiterten Schnittstellen, u. a. des optionalen Reportprozessors BX-965, unterzubringen.
9. Die Messeinrichtung erfüllt die Anforderungen der DIN EN 12341 sowie des Leitfadens „Demonstration of Equivalence of Ambient Air Monitoring Methods" in der Version vom Januar 2010. Darüber hinaus erfüllt die Herstellung und das Qualitätsmanagement der Messeinrichtung APDA-371 die Anforderungen der DIN EN 15267.
10. Die Erstbekanntgabe der Messeinrichtung erfolgte mit Bekanntmachung des Umweltbundesamtes vom 25. Januar 2010 (BAnz. S. 552, Kapitel IV 11. Mitteilung). Die letzte Mitteilung zur Messeinrichtung erfolgte mit Bekanntmachung des Umweltbundesamtes vom 6. Juli 2012 (BAnz AT 20.07.2012 B11, Kapitel IV 3. Mitteilung).
11. Der Prüfbericht mit der Berichtsnummer 936/21221789/A ist im Internet unter www.qal1.de einsehbar.

Prüfinstitut: TÜV Rheinland Energie und Umwelt GmbH, Köln
Bericht-Nr.: 936/21221789/A vom 19. März 2013

Figure 1: Initial publication: BAnz AT 23.07.2013 B4, chapter III number 3.1

9 Mitteilung zu der Bekanntmachung des Umweltbundesamtes vom 3. Juli 2013 (BAnz AT 23.07.2013 B4, Kapitel III Nummer 3.1)

Der Drucksensor 970603 (MICROSWITCH #185PC15AT) in der Messeinrichtung APDA-371 mit PM_{10}-Vorabscheider der Fa. HORIBA Europe GmbH wurde abgekündigt und durch den Drucksensor 970595 (HONEYWELL SSCDANN015PAAA5) ersetzt.

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 20. September 2014

Figure 2: Public notification BAnz AT 02.04.2015 B5, chapter IV notification 9

42 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 3. Juli 2013 (BAnz AT 23.07.2013 B4, Kapitel III Nummer 3.1) und vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel IV 9. Mitteilung)

Die Immissionsmesseinrichtung APDA-371 mit PM_{10}-Vorabscheider der Firma HORIBA Europe GmbH kann auch mit der Vakuumpumpe vom Typ BECKER VT 4.4 betrieben werden.

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 23. März 2015.

Figure 3: Public notice BAnz AT 26.08.2015 B4, chapter V notification 42

33 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 3. Juli 2013 (BAnz AT 23.07.2013 B4, Kapitel III Nummer 3.1) und vom 22. Juli 2015 (BAnz AT 26.08.2015 B4, Kapitel V 42. Mitteilung)

Die aktuelle Softwareversion für die Immissionsmesseinrichtung APDA-371 mit PM_{10}-Vorabscheider für Schwebstaub PM_{10} der Firma HORIBA Europe GmbH lautet:

3236-7 V 5.5.0.

Stellungnahme der TÜV Rheinland Energy GmbH vom 8. März 2017

Figure 4: Public notice BAnz AT 31.07.2017 B12, chapter II notification 33

Appendices:

- Report on the performance test of the APDA-371 ambient air monitor for suspended particulate matter PM_{10} manufactured by HORIBA Europe GmbH, TÜV Report no. 936/21221789/A dated 19 March 2013
- Addendum to test report no. 936/21205333/A dated 6 December 2006 on the performance test of the BAM-1020 measuring system for suspended particulate matter, PM_{10} manufactured by Met One Instruments Inc., Report No.: 936/21243375/B dated 21 September 2018

Appendix

APDA-371
PARTICULATE MONITOR
OPERATION MANUAL

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.

Sections and sub-sections marked with an Information Symbol contain critical information which all APDA-371 owners and operators should read and understand. 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.

1.2 *Technical Service*

This manual is structured by customer feedback to provide the required information for setup, operation, testing, maintaining, and troubleshooting your APDA-371 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 expedite customer service.

1.3 *Beta Attenuation Monitor*

The HORIBA model APDA-371 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 ^{14}C (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, an in-depth scientific explanation of the theory of operation and the related equations is included toward the back of the manual.

1.4 *Beta Radiation Safety Statement*

The HORIBA APDA-371 contains a small ^{14}C (Carbon 14) beta radiation-emitting source. The activity of the source is **60 □Ci** ±15¯ Ci (microcurries), which is below the “Exempt Concentration Limit” as defined in 10 CFR Section 30.70 – Schedule A. The owner of a APDA-371 is not required to obtain any license in the United States to own or operate the unit. The owner of a APDA-371 may elect to return the entire unit to HORIBA for recycling of the ^{14}C 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 ^{14}C source nor the beta particle detector are serviceable in the field. Should these components require repair or replacement, the APDA-371 must be returned to the factory for service and recalibration.

1.5 *Model APDA-371 PM_{10} USEPA Equivalent Method*

The HORIBA Europe GmbH Model APDA-371 is designated as an equivalent method for PM10 monitoring by the United States Environmental Protection Agency on August 3, 1998.

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

The EPA designation applies to G, -1, G-1, and later APDA-371 PM10 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 APDA-371 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} inlet head.
- 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 calibration device.
- The SAMPLE TIME parameter must be set for 50 minutes.

1.6 Model APDA-371 $PM_{2.5}$ USEPA Equivalent Method

The HORIBA Europe GmbH Model APDA-371 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 APDA-371 is operated as a $PM_{2.5}$ 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 HORIBA stock number for the VSCC™ is BX-808.
- The inlet must be equipped with a standard EPA PM_{10} inlet head. HORIBA BX-802.
- The unit is operated for hourly average measurements. The $PM_{2.5}$ concentration is calculated (external to the APDA) as a daily average of the hourly concentration measurements made by the APDA-371.
- The unit must be equipped with firmware revision 3.2.4 or later.
- The APDA-371 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 mode.
- The unit must be equipped with a BX-827 (110V) or BX-830 (230V) Smart Inlet Heater, with the heater RH regulation set point set to 35%, and Delta-T control disabled.
- The unit must be equipped with the 8470-1 rev D or later tape control transport assembly with close geometry beta source configuration. All APDA-371 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.
- 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 the 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.

1.7 APDA-371 Specifications

PARAMETER	SPECIFICATION
Measurement Principle:	Particulate Concentration by Beta Attenuation.
US-EPA Existing Designations:	PM_{10}: EPA EQPM-0798-122 $PM_{2.5}$: Class III EPA EQPM-0308-170
Standard Range:	0 - 1.000 mg/m^3 (0 - 1000 ¯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.
Resolution:	± 0.1 µg/m^3
Lower Detection Limit: (2σ) (1 hour)	Less than 4.8 ¯g/m^3 from 0.000 to 0.100 mg/m^3 (less than 4.0 ¯g/m^3 typical)
Lower Detection Limit: (2σ) (24 hour)	Less than 1.0 ¯g/m^3
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.
Beta Source:	^{14}C (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°C
Ambient Temp. Range:	-30° to +60°C
Ambient Humidity Range:	0 to 90% RH, non-condensing.
Humidity Control:	Actively controlled inlet heater module, 10 - 99% RH set point.
Approvals:	US-EPA, CE, NRC, TUV, CARB, ISO-9001
User Interface:	Menu-driven interface with 8x40 character LCD display and dynamic keypad.
Analog Output:	Isolated 0-1 VDC output standard. 0-10V, 4-20mA, 0-16mA switch-selectable.
Serial Interface:	RS-232 2-way serial port 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:	MicroMet Plus®, Comet™, HyperTerminal®, ProComm Plus®.
Error Reporting:	User-configurable. Available through serial port, display, and relay outputs.
Memory:	4369 records (182 days @ 1 record/hr).
Power Supply:	100 - 230 VAC, 50/60 Hz. 0.4 kW 3.4A max.
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 and Inspection

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

Remove the unit and accessories from the shipping boxes and compare the received items to the packing list. Make sure you have all of the required items for the type of installation you plan to perform.

The APDA-371 is shipped with 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. Do not remove the foam rings until the APDA-371 is ready to be installed. These rings must be replaced anytime the unit is being transported in order to avoid damaging the tape control mechanism.

Please keep the special box and foam packing material that the APDA-371 was shipped in, to re-use in the event that you must return the unit to the factory. HORIBA is not responsible for any damages to the unit if returned in non-original packaging, or without the foam rings in place. Contact HORIBA for replacement packing materials if necessary.

2.2 Enclosure Selection

The APDA-371 unit is not weatherproof or water resistant, and is designed to be mounted in a weatherproof, level, vibration free, dust free, and temperature controlled environment where the operating temperature is between 0o C and +50o C, and where the relative humidity is non-condensing and does not exceed 90%. There are two standard configurations described below for providing a weatherproof location in which to install the unit. Please contact HORIBA if you plan to have a non-standard mounting or enclosure configuration.

1. **A walk-in building or mobile shelter with a flat roof:** This is often a pre-fabricated shelter, a trailer shelter, or a room in an existing permanent building. The APDA is mounted on a bench-top or in an equipment rack, often with a variety of other instruments installed in the same shelter. The inlet tube of the APDA must extend up through the roof with appropriate hardware. AC power must be available. Instructions for this type of installation are included in this section of the manual.
2. **BX-902/903 environmentally controlled mini enclosure:** Sometimes nicknamed “dog house” enclosures, these small pre-fabricated enclosure are just big enough for the APDA 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). These enclosures are custom designed by HORIBA to accept the APDA-371, and are supplied with a supplemental setup and installation manual.

NOTE: The air temperature inside any enclosure in which a APDA-371 is installed must be held as constant as possible over the course of the 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. If the air temperature inside the enclosure has changed by more than about 2 degrees C during this time, the concentration measurement can be affected on the order of several micrograms. HORIBA recommends logging the air temperature inside the enclosure to monitor this effect. The exact temperature is not critical as long as it fluctuates as little as possible during any one hour.

2.3 Site Selection

Selection of a proper site for the APDA-371 is critical for accurate measurements. In many cases, 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 methods. Specifications for the site selection can be found in EPA document EPA-450/4-87-007 May 1987 “Ambient Monitoring Guidelines for Prevention of Significant Deterioration”, as well as 40 CFR, Part 58. In any case, the Code of Federal Regulations takes precedence.

Inlet Height:

- The inlet should be located in the “breathing zone”, between 2 and 15 meters above ground level. If the APDA is to be installed in an enclosure at ground level, then the inlet height must two meters or greater above the ground.
- If the inlet is located on (or through) a rooftop, the total height should be no more than 15 meters from the ground level. The inlet height should be two meters above roof surface of the building that the unit is installed in. This matches the specified inlet height of most FRM samplers.
- If the APDA-371 is to be co-located with other particulate instruments, such as FRM filter-based samplers or other APDA units, then the air inlet must be the same height as the inlet of the other samplers.
- The BX-902 and BX-903 environmental shelters are designed to locate the inlet two meters above whatever surface they are placed on.
- Make sure to account for the height of the PM_{10} and/or $PM_{2.5}$ heads when planning the inlet tube length. HORIBA can supply a variety of tube lengths up to 8-feet long.
- The maximum allowable total inlet tube length is 16 feet between the APDA-371 and the bottom of the inlet

head.

- If the APDA inlet is the highest point on a building, then lightning rods must be installed to prevent destruction of the APDA during electrical storms.

Inlet Radius Clearance:

- The APDA-371 inlet must have a one meter radius free of any objects that may influence airflow characteristics, including the inlet of another instrument.
- If a APDA-371 is to be installed at a station with other APDA or FRM sampler, the inlets of each sampler must be no less than one meter apart from each other.
- If the APDA is to be collocated with another APDA instrument or FRM sampler, then the inlets must be spaced between one and two meters apart. Two meters is recommended where possible.
- If installing near a PM_{10} SSI Hi-Volume sampler, then the distance between the inlet of the APDA-371 and the Hi-Vol should be no less than three meters.
- The APDA-371 inlet must be located at least two meters from obstructions such as short walls, fences, and penthouses.
- If located beside a major obstruction (such as a building) then the distance between the unit and the building must be equal to twice the height of the building.
- The inlet must be at least 20 meters from the drip line of any overhanging trees.
- There must be at least a 270 degree arc of unrestricted airflow around the inlet. The predominant direction of concentration movement during the highest concentration season must be included in the 270 degree arc.

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 APDA-371. Even sources of filtered air must not blow across the inlet.

Spacing from Roadways: The APDA-371 should usually not be located directly next to a major highway or arterial roadway, as vehicle exhaust will dominate the concentration measurement. This effect can be difficult to predict accurately as shifting winds may direct the plume toward or away from the APDA inlet.

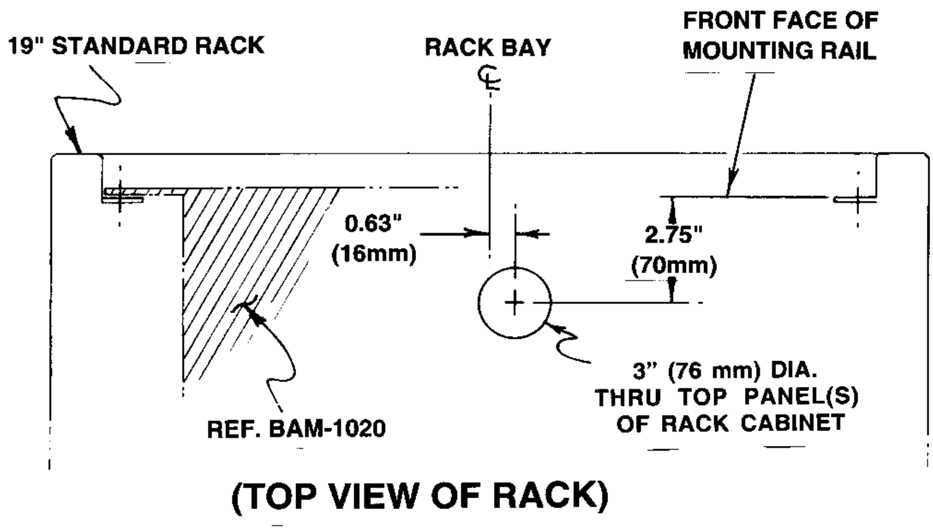
- Roads with a daily traffic volume of less than 3,000 vehicles are generally not considered major sources of pollutants, and in this case the APDA must be located at least five meters from the nearest traffic lane.
- The APDA must be located at least 25 meters from any elevated roadway greater than five meters high.
- 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 affects of re-entrained fugitive dust.

2.4 Mounting Options in a Walk-In Shelter

When the APDA-371 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. HORIBA recommends using an equipment rack when possible, as it does a better job of keeping the unit level and in the correct placement. A rack also tends to be a cleaner installation and is more space-efficient. However, either method may be used as long as the mounting is level and allows the inlet tube to be perfectly vertical. HORIBA supplies brackets standard rack-mount screws with each unit. Take the following into account when planning your mounting:

- **Rear Access:** It is important that your mounting leaves plenty of access to the rear of the APDA-371 unit for wiring connections and maintenance. At least five inches is required. Full access to the back is recommended whenever possible.
- **Top Access:** It is necessary to have a minimum of eight inches clearance between the top of the APDA inlet receiver and the bottom of the shelter ceiling to accommodate the smart inlet heater which mounts on the inlet tube directly above the APDA.
- **Mobile Shelters:** If the APDA-371 is being installed into an equipment rack in a mobile shelter or van, the instrument **must** be supported from the bottom <u>in addition</u> to the rack brackets, due to additional strain. The foam shipping rings must also be inserted any time a mobile shelter is moved with the APDA-371 inside.
- **Rack Modifications:** It is often necessary to modify the top of the equipment rack by cutting a hole to allow the inlet tube to extend through to the ceiling. The drawing below shows the location of the hole. **Note:** The inlet

heater is a cylinder which installs on the inlet tube two inches above the top of the inlet receiver of the APDA-371. If the APDA unit is to be mounted high in the rack, it may be necessary to make the hole in the top of the rack larger in order to clear the heater diameter. The heater is supplied with an insulation tube cover which may be modified as needed. Make sure these parts are going to fit before installing the APDA-371.



Rack top modifications for inlet tube clearance

2.5 Installation Instructions in a Walk-In Shelter

Installation of the APDA-371 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.

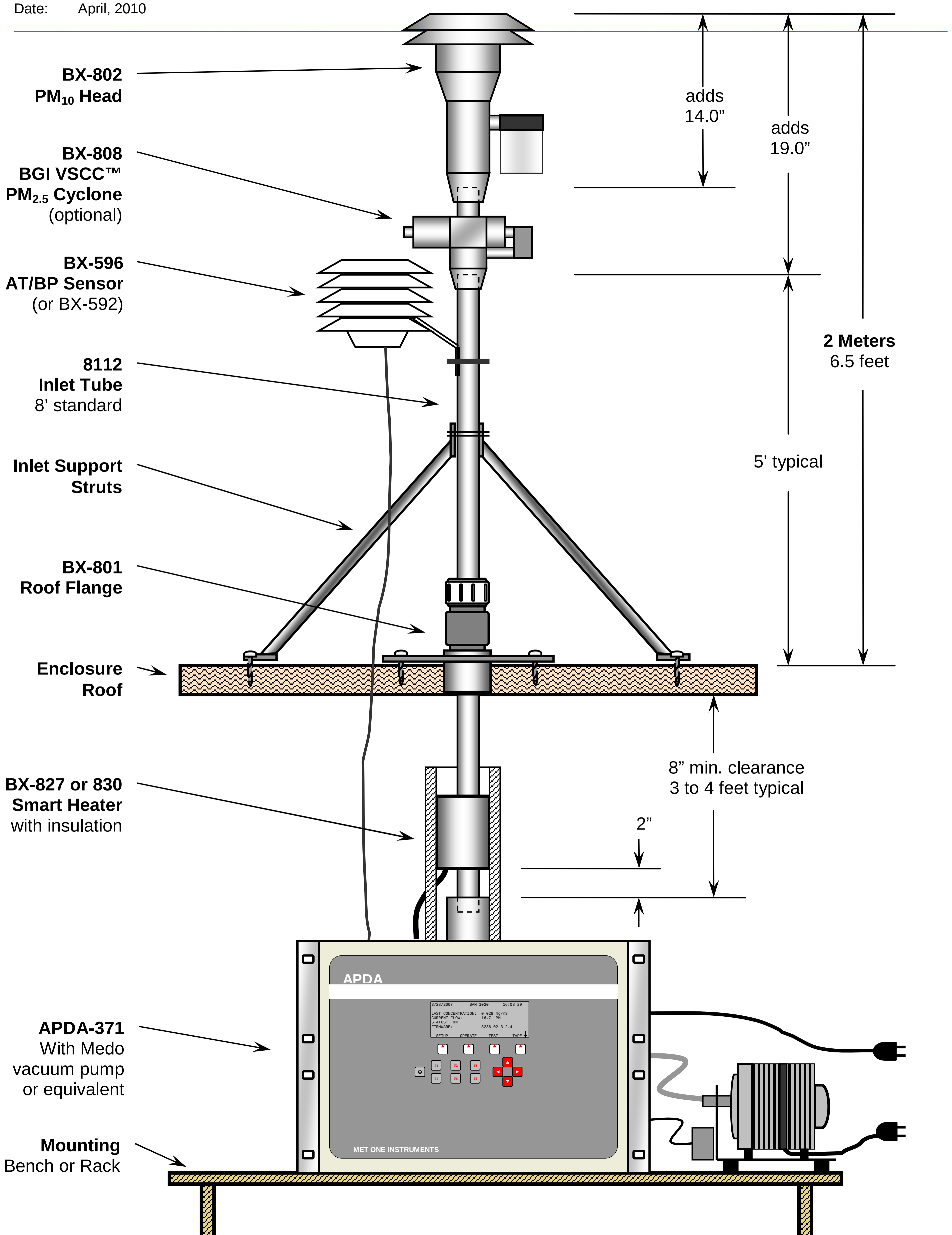
1. **Roof Modifications:** Determine the exact location where the APDA inlet tube will pass through the roof of the enclosure, and drill a 2 ¼" or 2 ½" diameter hole through the roof at that location. Make sure the hole is directly above where the APDA inlet receiver is to be located, as the inlet tube must be perfectly vertical. A plumb-bob is useful for determining where to locate the hole. **Note:** The inlet receiver on the APDA is slightly to the left (0.6 in, 15 mm) of the center line of the unit. See diagrams.
2. **Waterproof Flange:** Apply all-weather caulking around the top of the hole, and install the BX-801 roof flange onto the hole. It is usually best if the threaded barrel of the flange assembly is installed downward, into the hole. 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.
3. **Inlet Tube:** Remove the white cap and rubber seal from the flange assembly. This makes it easier to install the inlet tube, as the rubber seal is a tight fit around the tube. Lower the inlet tube through the flange assembly in the roof and into the inlet receiver on the APDA Make sure the inlet tube is fully seated.
4. **Inlet Alignment:** It is very important for the inlet tube to be perpendicular to the top of the APDA. The nozzle may not close properly if there is binding caused by misalignment. A simple check is to rotate the inlet tube back and forth by hand (before tightening the roof flange seal or the APDA inlet set screws). If the inlet tube is installed straight, then the tube should rotate fairly easily while inserted into the APDA. If it does not rotate, check the inlet tube for vertical alignment or move the APDA slightly.
5. **Smart Heater:** Before tightening the inlet tube in place, the BX-827 or BX-830 smart inlet heater (used on most APDA-371 units) must be installed on the tube. Pull the inlet tube up out of the inlet receiver, 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 APDA. Position the bottom of the heater unit **two inches** above the top of the inlet receiver on the APDA, 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 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.
6. **Inlet Tightening:** 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 or alcohol first. Tighten the white plastic cap.
7. **Support Struts:** The BX-801 inlet kit usually 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). Note: Some installations may require different methods or hardware for supporting the inlet tube. Support the tube in the best manner available.

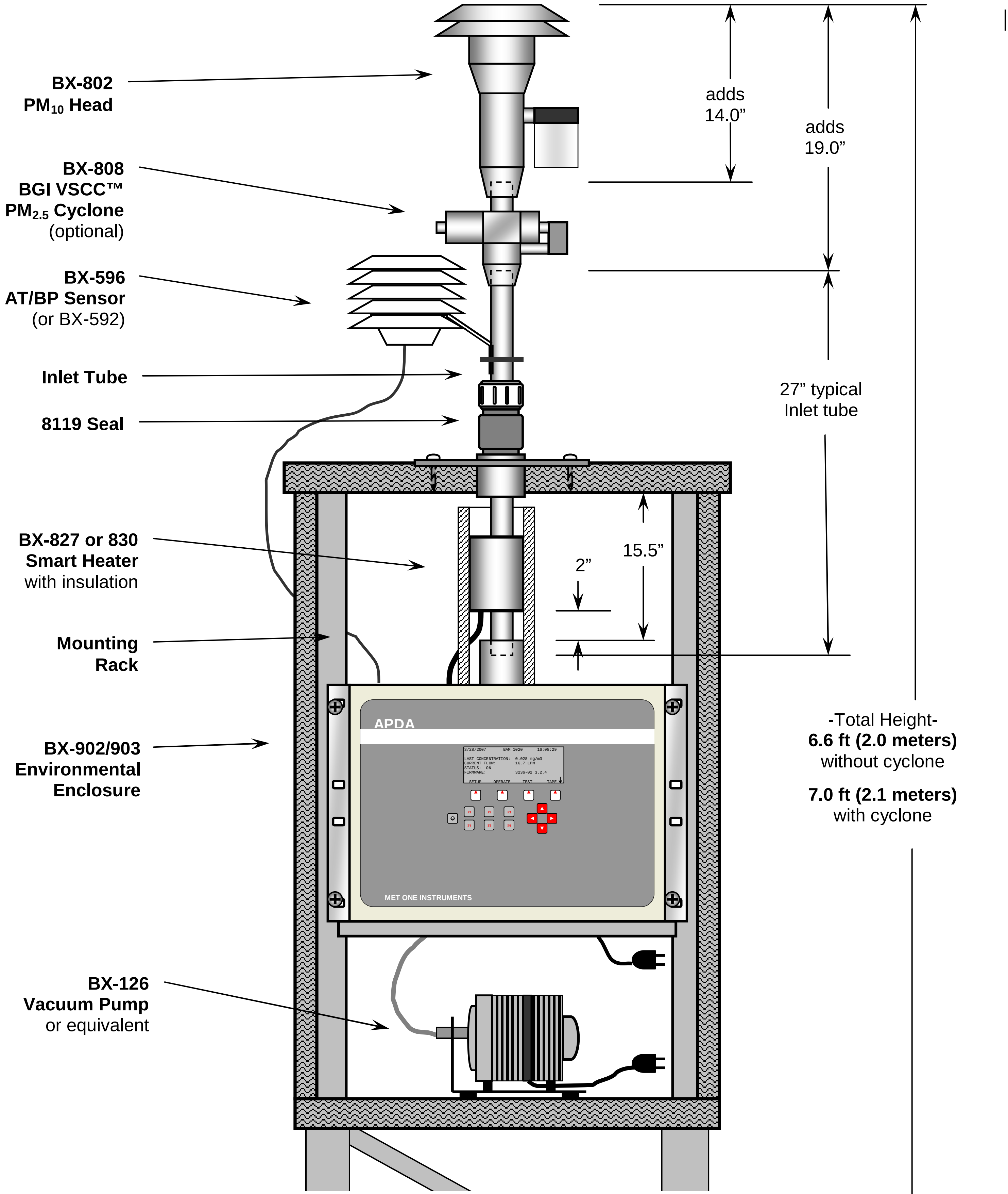
8. **Temperature Sensor:** Most APDA-371 units are supplied with a BX-592 (temperature) or BX-596 (temperature and pressure) sensor, which is attached to the inlet tube above the roof. The sensor cable must feed into the shelter to be attached to the APDA. In some cases it is easiest to simply drill a 3/8" hole through the roof about six inches away from the inlet tube, then feed the cable through the hole and caulk around it to prevent leaks. In some applications there may be a better place to feed the cable into the shelter. Route the cable into the shelter in the best manner. The BX-596 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.

9. **Inlet Separator Heads:** If the APDA-371 is to be configured for FEM $PM_{2.5}$ monitoring, then install the $PM_{2.5}$ Very Sharp Cut Cyclone (BGI VSCC™) onto the top of the inlet tube beneath the BX-802 PM_{10} head. For PM_{10} monitoring, the BX-802 is installed on the inlet tube with no cyclone. Use o-ring lubricant as needed.

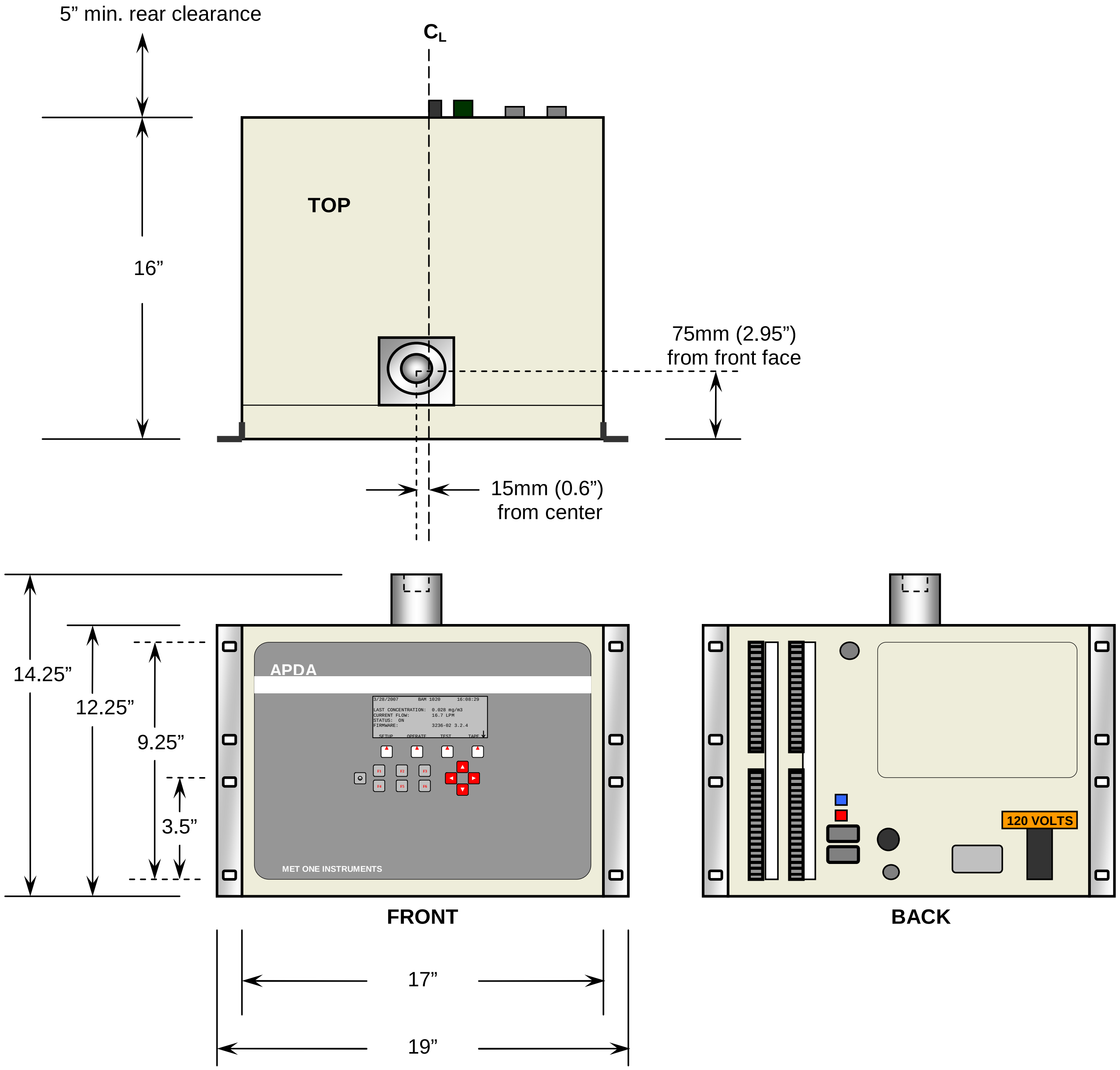
10. **Inlet Tube Grounding:** Tighten the two ¼"-20 set screws located in the inlet receiver of the APDA to secure the inlet tube. This also creates a ground connection for the inlet tube, as static electricity can build up on the inlet under certain atmospheric conditions and cause errors. This is very 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 APDA. It should measure just 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.



Typical APDA-371 Installation in a walk-in shelter



Typical APDA-371 Installation in a BX-902 mini enclosure



APDA-371 mounting dimensions

2.6 Electrical Connections

Each APDA-371 is factory configured to run on either 120 or 230 volt AC power. Your shelter must be wired for power to run the APDA, the pump, and any other AC powered devices such as computers, data loggers, other instruments, etc. A good earth-ground connection point near the APDA unit is highly recommended. Have a qualified electrical contractor provide power according to all local codes. After the APDA unit is installed and power is provided, connect the electrical accessories as follows. Refer to the diagram below.

1. **APDA-371 Power:** Plug the APDA-371 into the AC power mains with the provided power cord. Note: There are two fuses located inside the APDA power switch module, which can be accessed by prying open the small cover surrounding the switch. The power cord <u>must be removed</u> in order to open the cover.

HORIBA recommends plugging the APDA-371 unit into a battery back-up UPS (uninterruptible power supply) since even a momentary power outage will reset the APDA and stop an entire hour's worth of data collection. A small computer-style UPS of 300 Watts or greater is usually sufficient. The vacuum pump usually does not need to be connected to the UPS as the APDA can compensate for short pump power outages. If the pump is to be backed up as well, then a much larger UPS is required.

2. **Chassis Ground:** Connect one of the terminals marked "CHASSIS" on the back of the APDA to a ground point as close as possible to the instrument. Use the green/yellow ground wire supplied with the unit. A ground rod is recommended, but a cold water pipe, or junction box safety ground are other possible connection points. Note: the APDA-371 also uses the standard safety ground line inside the power cord.

3. **Pump Connection:** Decide on a location to place the air pump. The best location is often on the floor under the rack or bench, but it may be up to 25 feet away if desired. Route the air tubing from the pump to the back of the APDA unit, inserting it firmly into the compression fittings on both ends. The tubing should be cut to the proper length and the excess saved for replacements. The pump is supplied with a 2-wire signal cable which the APDA uses to turn the pump on and off. Connect this cable to the terminals on the back of the APDA marked "PUMP CONTROL" The end of the cable with the square black ferrite filter goes to the APDA, but the polarity of the wires is not important. 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.

4. **Temperature/Pressure Sensor:** The BX-596 or BX-592 temperature sensor should already be installed onto the inlet tube, and the sensor cable routed to the APDA-371. Connect the cable to the terminals on the back of the APDA as follows:

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

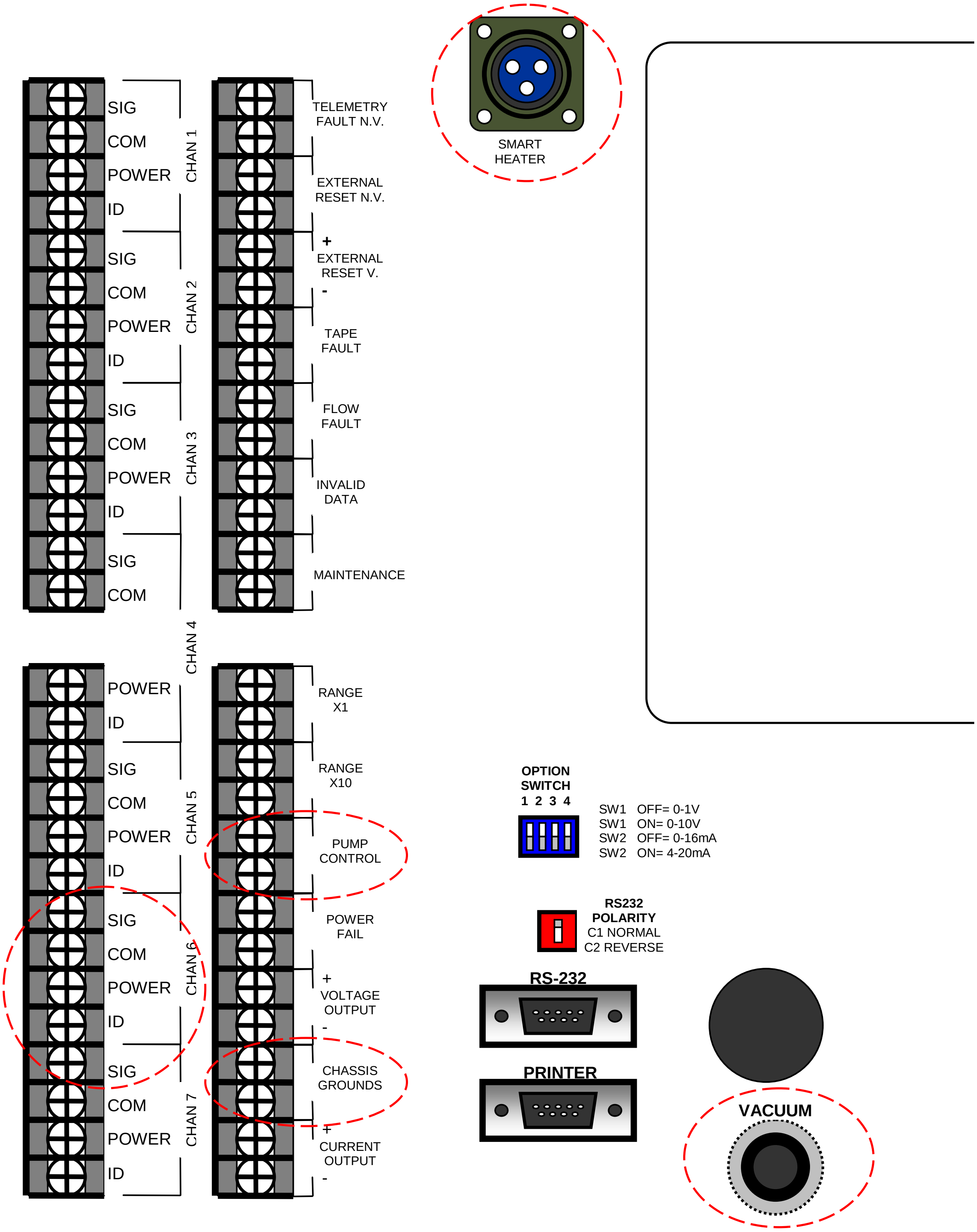
Additional HORIBA BX-500 series sensors may be connected to APDA channels 1 through 5 to log various other meteorological parameters. Details on these sensor connections are given in Section 10.2 of this manual.

5. **Smart Heater:** There are two possible versions of the BX-827/830 Smart Heater electrical connection. If the Smart Heater kit was supplied with a gray relay module (units built after May, 2008 as shown below), then plug the relay module into the mating control connector on the back of the APDA, and connect the Smart Heater to the green connector on the top of the relay module. The relay module has its own power cord to supply power to the heater. **Note:** The connector on the back of the APDA has been changed to prevent connecting the heater directly to the APDA.

On previous versions of the kit, the Smart Heater assembly simply plugs directly into the back of the APDA-371, and power is supplied internally by the APDA. If the APDA is configured like this, then simply plug the heater cable directly into the mating green metal connector on the back of the APDA-371.

6. **Optional Data Logger Connection:** The APDA-371 has an analog output which may be recorded by a separate data logger if required. Connect the terminals on the back of the APDA marked "VOLT OUT +, -" to the data logger with 2-conductor shielded cable (not supplied). Polarity must be observed. Information on configuring this analog output is provided in Section 8 of this manual. A current loop output is also available.

7. **Other Connections:** The APDA-371 has a variety of telemetry I/O relays and error relays located on the back of the unit. There are also RS-232 data connections. These items are described in Section 8 and Section 9 of this manual.



APDA-371 back panel connections

3 INITIAL SETUP OF YOUR APDA-371

This section describes the process for setting up and configuring your APDA-371, 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 APDA-371 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 On

The APDA-371 has a power switch located on the back of the unit directly 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.

```
3/28/2007          BAM 1020       16:08:29
                    APDA-371
LAST CONCENTRATION:    0.028 mg/m3
CURRENT FLOW:          16.7 LPM
STATUS:   FILTER TAPE ERROR!
FIRMWARE:              3236-02 3.2.4

 SETUP      OPERATE      TEST       TAPE
```

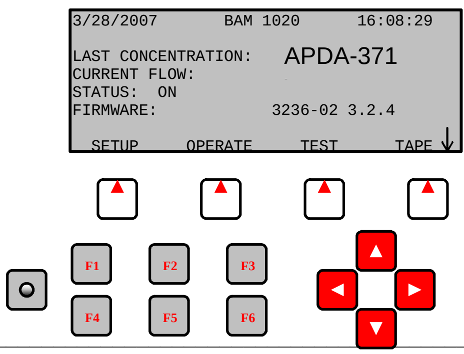
The Main

3.2 Warm-up

The APDA-371 must warm up for **at least one hour** before an operation cycle is started. 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 APDA is powered up.

3.3 Using the Keypad and Display

When the APDA-371 is powered up it will display the main (top level) menu on the LCD display. This menu is the starting point for all functions of the APDA-371 user interface.



The APDA-371 User Interface

Soft Keys:
Directly beneath the display are four white buttons called “soft-keys” or “hot-keys”. These are dynamic keys who’s 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 wide 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 overadjust 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.

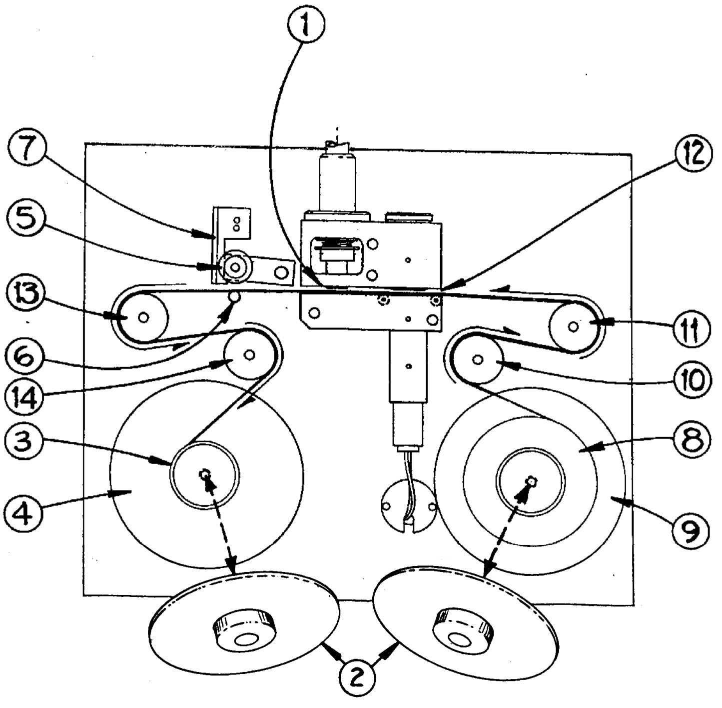
Function Keys F1 to F6:
The function keys serve as shortcuts to commonly used menu screens, and can be safely pressed at almost any time without interrupting the sample cycle. The **F** keys are only functional from the main menu screen or for entering passwords. The factory default password is F1, F2, F3, F4.

F1 **Current:** This key is a shortcut to the OPERATE > INST screen, used to display the instantaneous data values that are being measured by the APDA-371. See section 3.12. The F1 key can be used without interrupting a sample cycle.
F2 **Average:** This key is a shortcut to the OPERATE > AVERAGE screen, used to display the latest average of the data recorded by the APDA-371. See Section 3.13. The F2 key can be used without interrupting a sample cycle.
F3 **Error Recall:** This key allows the user to view the errors logged by the APDA-371. The errors are sorted by date. The last 12 days which contain error records are available, and up to the last 100 errors can be viewed. The F3 key can be used without interrupting a sample cycle.
F4 **Data Recall:** This key allows the user to view the data stored in the APDA-371, 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 in this menu. The F4 key can be used without interrupting a sample cycle.
F5 **Transfer Module:** This key is used to copy the memory contents to an optional transfer storage module to retrieve the digital data without a computer. This function is rarely used. HORIBA recommends downloading the data with a laptop, computer or modem connection.
F6 **(Blank):** This key is not assigned a data function.

3.4 Filter Tape Loading

A roll of filter tape must be loaded into the APDA-371 for sampling. One roll of tape should last more than 60 days under normal operation. It is important to have several spare rolls of tape available to avoid data interruptions. HORIBA recommends wearing lint-free cotton gloves when handling the tape. Some agencies save the used rolls of tape for post-sampling analysis, although there is no guarantee that the sampled spots have not been contaminated. Used filter tape should never be “flipped over” or re-used! This will result in measurement problems. Loading a roll of filter tape is a simple matter using the following steps:

1. Turn the APDA-371 on and enter the TAPE menu (Note: This is not the same as the TEST > TAPE menu). If the nozzle is not in the UP position, press the TENSION soft-key to raise the nozzle.
2. Lift the rubber pinch roller assembly and latch it in the UP position. Unscrew and remove the clear plastic spool covers.
3. An empty core tube **MUST** be installed on the left (take-up) reel hub. This provides a surface for the used tape to spool-up on. HORIBA 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 your last roll to spool-up the new roll. Never fasten the filter tape to the aluminum hub.
4. Load the new roll of filter tape onto the right (supply) reel, and route the tape through the transport assembly as shown in the drawing. Attach the loose end of the filter tape to the empty core tube with cellophane tape or equivalent.
5. Rotate the tape roll by hand to remove excess slack, then install the clear plastic spool covers. The covers will clamp the rolls to the hubs to prevent slipping.
6. 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.
7. Unlatch and lower the pinch roller assembly onto the tape. **The APDA will not function if the pinch rollers are latched up, and it has no way of automatically lowering the roller assembly!**
8. Press the TENSION soft-key in the TAPE menu. The APDA-371 will set the tape to the correct tension and alert you if there was an error with the process. Exit the menu.



1----NOZZLE IN “UP” POSITION
2----CLEAR SPOOL COVER WITH KNOB
3----EMPTY CORE TUBE
4----TAKE-UP SPOOL
5----PINCH ROLLERS
6----CAPSTAN SHAFT
7----LATCH
8----FILTER TAPE
9----SUPPLY SPOOL
10--SUPPLY TENSION ROLLER
11--RIGHT END ROLLER
12--SAMPLING/MEASURING AREA
13--LEFT END ROLLER
14--TAKE-UP TENSION ROLLER

Filter Tape Loading Diagram

3.5 Self-Test

The APDA-371 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 menus are also available in the APDA, and those are described in the troubleshooting section.

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 APDA-371 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 as in normal operation. It will show ON if the roller assembly is latched in the up position. The tape cannot move 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 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 APDA-371 comes pre-programmed with a wide array of default values for the settings which govern the measurement and calibration. Many of these values will not be changed, as the default values are accurate for the majority of 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 APDA-371 clock may drift as much as a couple of 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 APDA 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

Perform a leak check and flow check/calibration as described in Section 5. Become comfortable with these processes, as they will be performed often.

3.8 Starting a Measurement Cycle

When the preceding 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 it is commanded to stop.
The unit will stop if the operator sets the Operation Mode to OFF or enters any of the SETUP or TEST menus. The APDA-371 will also stop itself if a non-correctable error is encountered, such as broken filter tape or failed air flow.

3.9 The Flow Statistics Screen

In the main APDA-371 menu screen a small arrow has been added to the bottom right corner. When the DOWN ARROW button is pressed the APDA will display the FLOW STATISTICS screen as shown below. This screen displays the flow, temperature and pressure statistics for the current measurement cycle. Pressing the ARROW DOWN key while in this screen will further scroll down to the remaining parameters below the viewable area of the display. This screen will not interrupt the sample. 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 Screen

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 stop the measurement cycle, but will not power-down the APDA-371. **NOTE: 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 a 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 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 APDA-371 in the NORMAL screen whenever the unit is operating, instead of the Main menu.

```
11/15/2006         Normal Mode       11:27:54

                             Flow(STD): 16.7 LPM
                          Flow(ACTUAL): 16.7 LPM
LAST C: 0.061 mg/m3              Press: 764 mmHg
LAST m: 0.806 mg/cm2                RH: 37 %
                                Heater: OFF
                               Delta-T: 4.2 C
STATUS: SAMPLING
                                           EXIT
```

The NORMAL 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 value (**ABS**). The other values are instantaneous measurements.

3.12 The INSTANTANEOUS Screen

The INST (Instantaneous) screen displays the instantaneous data values that are being measured by the APDA-371. This screen is useful for monitoring the current reading of any optional sensors that may be connected to the APDA-371. 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.

```
11/15/2006  CAL DATA FLAG: OFF   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

            TOGGLE FLG VOLT/ENG    EXIT
```

The Instantaneous Menu

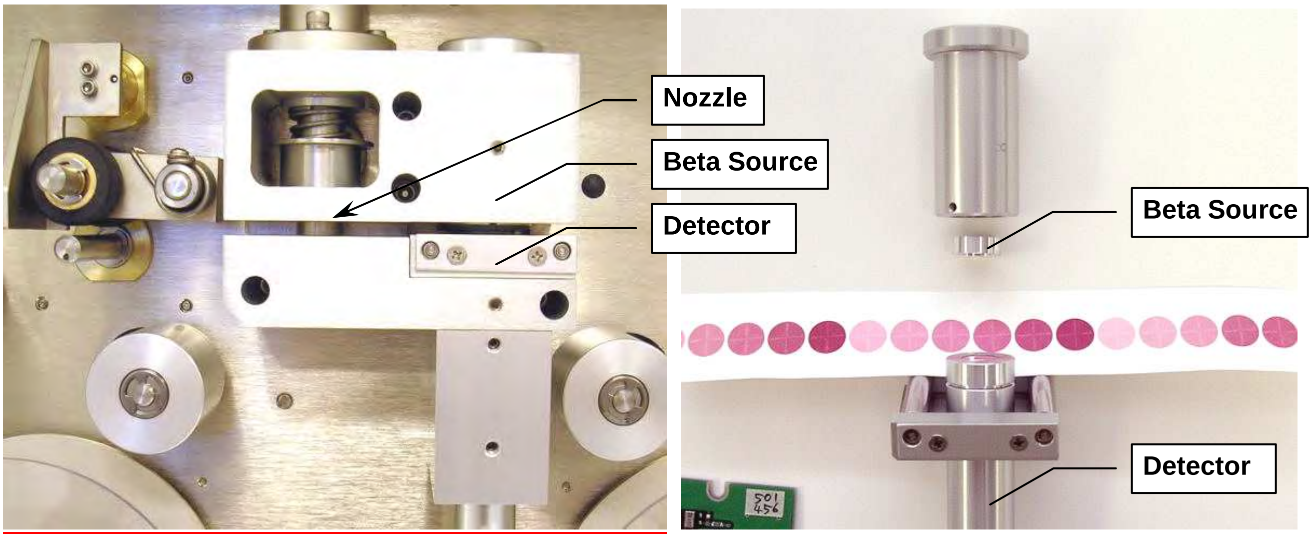
The TOGGLE FLG soft-key in this menu allows the user to set the CAL DATA FLAG value ON or OFF, which marks the data with an **M** flag to indicate a maintenance was performed during that time, such as a flow check. This feature is rarely used, as most maintenance requires stopping the sample anyway. The VOLT / ENG soft-key toggles the displayed values between units and voltages, useful for diagnostic checks on external sensors.

3.13 The AVERAGE Screen

The AVERAGE screen is similar to the INST screen, 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 APDA-371 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.



APDA-371 Sample and Measurement Stations

4.1 The One-Hour Cycle Timeline

The APDA-371 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 two 8-minute beta measurements, and one 42-minute air sample, for a total of 58 minutes. The other two minutes are used for tape and nozzle movements during the cycle.

This example shows the timeline if the unit is set for a COUNT TIME of 8 minutes (required for $PM_{2.5}$). If the unit is set for 4 minutes, then the beta counts at the beginning and end of the hour will be 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 APDA-371 immediately advances the filter tape forward one "window" (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 APDA begins counting beta particles through this clean spot for exactly eight minutes. (I_0)
2. **Minute 08:** The APDA-371 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 (the spot in which I_0 was just measured) for 42 minutes at 16.7 liters per minute.
3. **Minute 50:** The APDA-371 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 APDA begins counting beta particles through this (now dirty) spot of tape for exactly eight minutes (I_3).
4. **Minute 58:** The APDA-371 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 APDA then sits idle and waits a few moments for the remaining time in the hour to expire.
5. **Minute 60:** The beginning of the next hour. The APDA-371 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 Check During The Cycle

While the vacuum pump is on and pulling air through the filter tape, (as described above) the APDA-371 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:** (When the APDA-371 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 APDA begins counting the beta particles through this spot for exactly eight minutes (I_1).
2. **Minute 16:** The APDA-371 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 APDA 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 APDA-371 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 (typical):** (Eight minutes before the pump stops) The APDA-371 counts the beta particles through the same spot again (without 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 APDA in which it is installed. Each hourly measurement of ***m*** must match the ***ABS*** value within ±5%. If not, the unit records an error 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 APDA-371, and can be found on the calibration sheet.

4.3 Sample Period Description

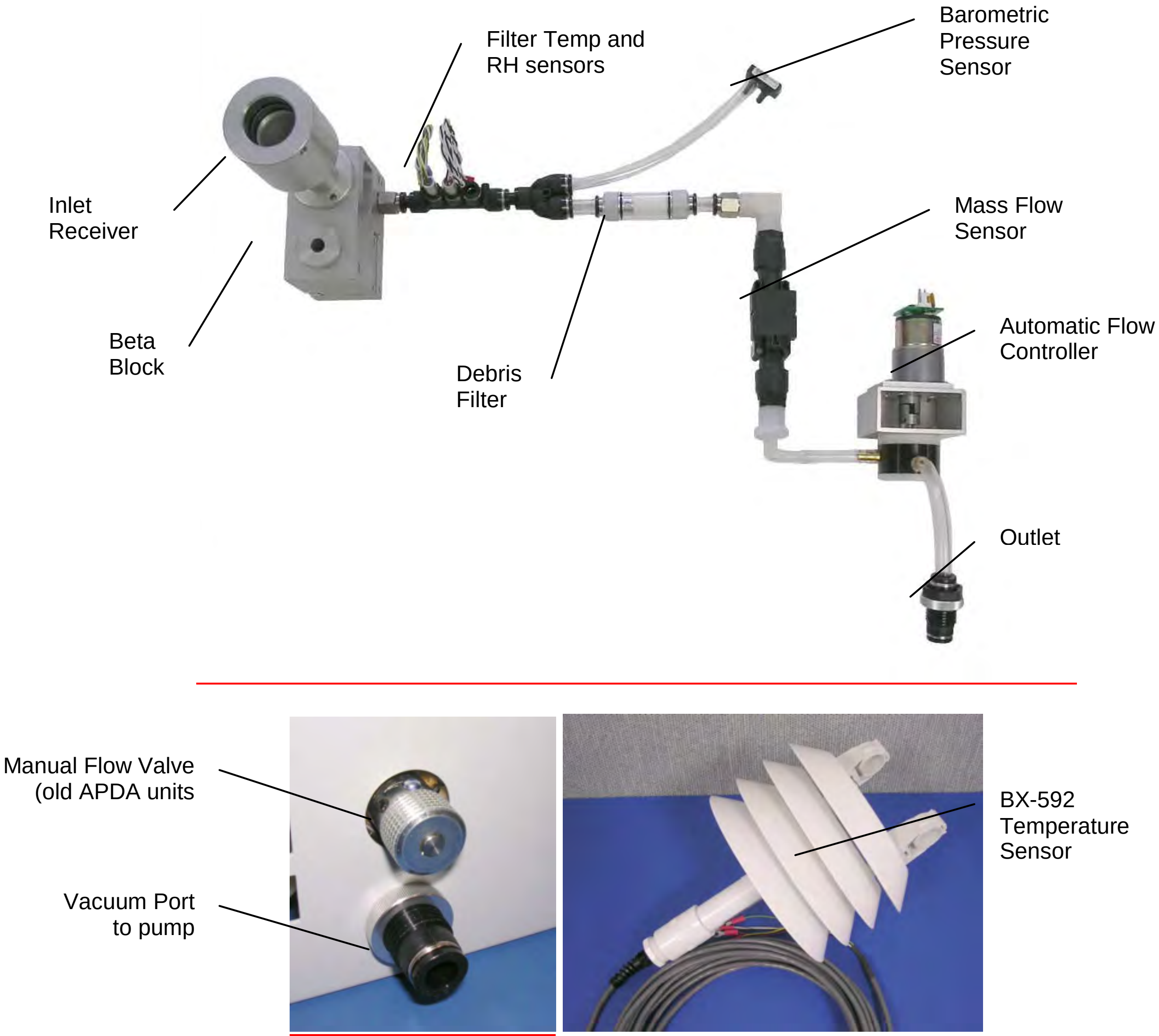
The sample period is the time when the vacuum pump is pulling dust-laden air through the APDA-371. As the air enters the inlet, it first passes through the external PM_{10} head which has a screen to keep out bugs and debris, and uses inertia to separate out and trap particle larger than 10 microns in 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.

The air then goes down the inlet and through the filter tape, where the remaining particles are deposited. Some particles smaller than about 0.2 µm may pass through the filter tape and be exhausted. 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 APDA-371 will put the spots very close together on the tape. At exactly midnight, the APDA 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 APDA-371 airflow control system is very simple and effective, consisting of a few rugged components. Proper operation of the flow system is critical if accurate concentration data is to be obtained from the unit. The key aspects of proper flow system maintenance are **Leak Checks, Flow Checks, and Nozzle Cleaning**. These processes are described in this section. HORIBA recommends performing a leak check and nozzle cleaning before flow calibrations, as a leak can affect the flow. Flow calibrations require a reference flow meter and a reference standard for ambient temperature and barometric pressure. NIST traceable standards are required in many applications. HORIBA suggests the BGI DeltaCal® brand (available from HORIBA as the BX-307 option). It includes flow, temperature and pressure standards in one unit.



APDA-371 Flow System

5.2 *Flow Type Descriptions*

The APDA-371 is designed to operate with an airflow rate of 16.7 liters per minute (lpm). This is important, because the particle separators (PM_{10} inlets, cyclones, and WINS impactors) require this flow rate in order to properly separate the correct sizes of particles from the air stream. All of these separators use the inertia of the particles as they flow through the inlet to sort out the ones above a certain size (cut point) so that they won't be measured by the instrument. If the airflow rate is not maintained within ±5% of the design value flow rate of 16.67 lpm, then particles of the wrong size may be allowed through or sorted out. Periodic APDA-371 airflow calibrations must be performed to ensure the unit maintains the flow within the EPA specified range of **±5% (±0.83 lpm)** of the design value, and **±4% (±0.67 lpm)** of NIST traceable flow standards.

This section describes the different types of flow control and regulation schemes used in the APDA-371. The unit can be set to any of three different flow types: Metered, Standard, or Actual (Volumetric), depending on the hardware available and the desired reporting conditions. All APDA-371 units have a mass airflow sensor and a barometric pressure sensor. The unit also has ***either*** a manual airflow valve on the back of the unit, ***or*** an automatic flow control valve inside the unit. The unit is usually also equipped with an optional BX-592 or BX-596 ambient temperature sensor. Each flow type requires a different process for auditing and calibrating the flow. To verify or set the flow type of the APDA, go to the SETUP > CALIBRATE menu, and check the FLOW TYPE. NOTE: The concentration reporting conditions can now be set independently of the flow type. See section 6.3.

METERED Flow Control:

Neither automatic flow control, nor flow correction for ambient conditions.
Metered flow control is used for APDA units that have a manual (hand-operated) air flow control valve on the back of the unit. These units do not have an automatic flow controller inside, so the unit cannot automatically adjust the flow to compensate for temperature or barometric pressure changes, or for filter loading. The unit does have a mass flow sensor inside. The flow reading from this sensor is stored in EPA conditions, meaning that the volume of air is calculated with the assumption that the ambient temperature is 25 degrees C, and the barometric pressure is 760mmHg (one atmosphere), regardless of the actual temperature and pressure, even if the unit is equipped with a temperature sensor. Due to the lack of automatic flow control, metered units must be frequently flow calibrated and audited, a process which involves a fair amount of math and takes much longer than ACTUAL flow calibrations. Also, metered units must have the flow rate set at a point slightly above the target rate of 16.7 LPM in order to compensate for the fact that the flow rate will drop as the filter becomes loaded with particulate. Note: If a APDA with an automatic flow controller is set to METERED flow control, then the flow will be controlled to EPA STD conditions.

STD (EPA Standard) Flow Control:

Automatic flow control, but usually no flow correction for ambient conditions.
STD (Standard) flow type is often selected when required by specific EPA monitoring regulations, or when no ambient temperature sensor is available. Standard flow control may be selected on any units which have an automatic flow controller instead of the manual valve (almost all APDA-371 units have the automatic controller anyway). The flow rate is automatically controlled using EPA (standard) conditions, meaning that the volume of air (and thus the flow rate) is calculated with the assumption that the ambient temperature is a standard value (default is 25 degrees C), and the barometric pressure is 760mmHg (one atmosphere), regardless of the actual temperature and pressure.

NOTE: At low altitudes and moderate temperature, EPA Standard flow will be very close to the actual volumetric flow rate. However, at high altitudes the difference between Standard and Actual flow will be quite significant, due to lower barometric pressure. Carefully consider this effect when deciding on a flow type to implement.

ACTUAL (Volumetric) Flow Control:

Both automatic flow control, and flow correction for ambient conditions.
Actual (also known as volumetric) flow type is the most accurate flow control mode, and is required for all $PM_{2.5}$ monitoring. The actual flow type is also the easiest and fastest to calibrate and audit. The unit always uses actual ambient air temperature and barometric pressure to correct the flow reading, and the flow rate is continuously and automatically adjusted to correct for changes in ambient conditions and filter loading. The flow values will be stored and displayed in actual volumetric conditions. To operate a APDA in actual flow mode, the unit must have a BX-596 or BX-592 ambient temperature sensor on channel six.

5.3 Leak Check Procedure

Leak checks should be performed at least monthly and whenever the filter tape is changed. Almost all air leaks in the APDA system occur at the nozzle where it contacts the filter tape. **The APDA-371 has no way of automatically detecting a leak at this interface**, because the airflow sensor is located downstream of the filter tape. There will normally be a very small amount of leakage at the tape, but an excessive leak lets an unknown amount of air enter the system through the leak instead of the inlet. This will cause the total air volume calculation (and the concentration) to be incorrect. **Allowing a leak to persist may cause an unknown amount of data to be invalidated!** Perform the following steps to check for leaks:

1. Remove any PM_{10} and $PM_{2.5}$ heads from the inlet tube. Install a BX-305 or BX-302 leak test valve (or equivalent valve for auditing FRM samplers) onto the inlet tube. Turn the valve to the OFF position to prevent any air from entering the inlet tube.
2. In the TEST > TAPE menu, advance the tape to a fresh, unused spot.
3. In the TEST > PUMP menu, turn on the pump. The flow rate should drop below **1.0 lpm**. If the leak flow value is 1.0 lpm or greater, then the nozzle and vane need cleaning, or there may be another small leak in the system.
4. Resolve the leak and perform the check again. A properly functioning APDA with a clean nozzle and vane will usually have a leak value of about **0.5 lpm** or less using this method, depending on the type of pump used.
5. Turn the pump off, remove the leak test valve, and re-install the inlet heads.

NOTES: The reason for the 1.0 lpm leak flow allowance is due to the test conditions. With the inlet shut off the vacuum in the system is very high, about 21 in Hg. This is many times greater than the APDA-371 will encounter during normal sampling. If the leak reading during this test is less than 1.0 lpm, there should not be a significant leak during normal operation.

Some agencies choose to adopt tighter tolerances for the leak test, such as requiring a leak value of 0.5 lpm or less after the nozzle and vane are cleaned. Most agencies perform as-found leak checks (before cleaning the nozzle and vane) for data validation purposes, since it is often necessary to invalidate data from a APDA which is found to have a significant leak, all the way back to the last known good leak test. The typical recommended threshold for invalidating data is an as-found leak value (before cleaning nozzle and vane) of 1.5 lpm or higher. Again, some agencies adopt tighter standards, such as invalidating data if the as-found leak value is greater than 1.0 lpm.

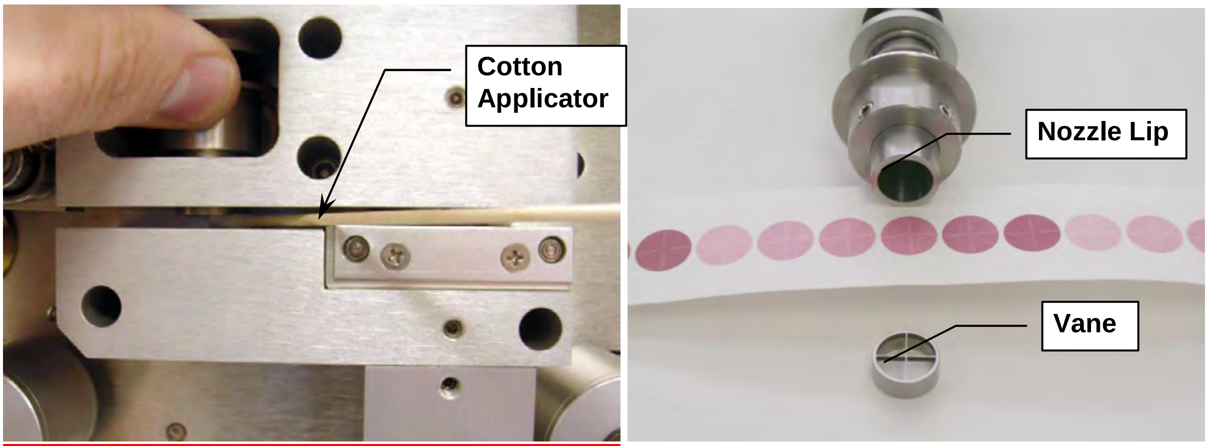
5.4 Leak Isolation and Nozzle Seal Methods

Leaks can be further isolated using a soft rubber sheet with a ¼" hole in it, such as HORIBA part 7440. The filter tape can be removed and the rubber seal inserted with the hole centered under the nozzle. The seal allows the leak check to be performed as usual, but without any leakage through the filter tape. The leak value should drop to 0.2 lpm or less with this method. A leak can be further isolated by using a part of the seal without a hole. This allows a leak test to be performed only on the system below the filter tape junction. If the nozzle and vane are thoroughly clean, but a leak persists, then see Section 7.5 for some troubleshooting steps for leaks in other parts of the flow system.

5.5 Nozzle and Vane Cleaning

The nozzle and vane (located under the nozzle) must be cleaned regularly to prevent leaks and measurement errors. The cleaning must be done at least each time 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 nozzle contamination seems to be hot, humid environments. This is because damp filter tape fibers more easily stick to the nozzle and vane. The fibers can quickly build up and dry out, creating air leaks or even punching small holes in the filter tape. This will cause measurement errors. Use the following steps to clean the parts. Refer to the photos below.

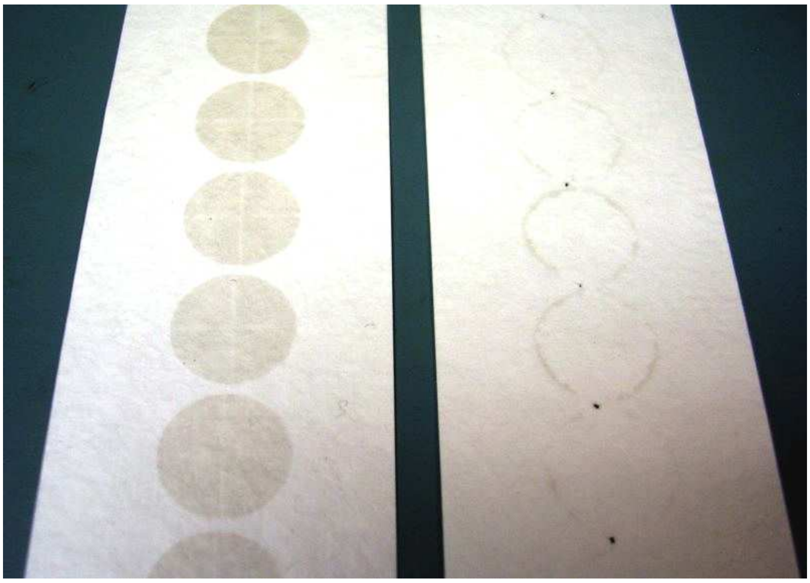
1. Raise the nozzle in the TEST > PUMP menu. Remove the filter tape (if installed) from the nozzle area. It is not necessary to completely remove the tape from the unit.
2. With the nozzle up, use a small flashlight to inspect the cross-hair vane.
3. Clean the vane with a cotton-tipped applicator and isopropyl alcohol. Hardened deposits may have to be carefully scraped off with the wooden end of the applicator or a dental pick or similar tool.
4. Lower the nozzle in the TEST > PUMP menu. Lift the nozzle with your finger and insert another cotton swab with alcohol between the nozzle and the vane. Let the nozzle press down onto the swab with its spring pressure.
5. Use your fingers to rotate the nozzle while keeping the swab in place. A few rotations should clean the nozzle lip.
6. Repeat the nozzle cleaning until the swabs come out clean.
7. Inspect the nozzle lip and vane for any burrs which may cause leaks or tape damage.



Nozzle Cleaning

The figure below shows the difference between good and bad filter tape spots. The tape on the left is from a properly operated APDA-371 with a clean nozzle and vane. Notice the particulate spots have very crisp edges, are perfectly round, and are evenly distributed.

The tape on the right is from a unit which has not been properly maintained. 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 even if the nozzle is not leaking. The spots also show a “halo” effect due to air leaking in around the edged because the debris has built up to the extent that the nozzle no longer seals correctly. These faults are easily corrected and prevented by keeping the nozzle and vane clean.



APDA-371 hourly filter tape spots

5.6 Field Calibration of Flow System – Actual (Volumetric) Flow Mode

Actual (volumetric) flow calibration is very fast and easy. This type of calibration can only be performed on APDA units which have an automatic flow controller and a BX-592 or BX-596 ambient temperature sensor on channel 6. The unit must also have the Flow Type set to ACTUAL in the SETUP > CALIBRATE menu or the flow calibration screen will not be visible.

```
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: 18.3     18.3     18.3 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. The “APDA” column is what the APDA-371 measures for each parameter, and the “STD” column is where you will enter the correct values from your reference standard. The <CAL> symbol will appear next to the parameter selected for calibration. The ambient temperature (AT) and pressure (BP) must be calibrated first, as the APDA uses these to calculate the air flow rate in actual mode.
2. Measure the ambient temperature with your reference standard positioned near the BX-592 or BX-596 ambient temperature probe. Enter the value from your reference standard into the STD field using the arrow keys. Press the CAL hot key to correct the APDA reading. The APDA and STD values should now be the same.
3. Press the NEXT hot key to move the <CAL> indicator to the BP field, and repeat the same steps for barometric pressure.
4. After the temperature and pressure readings are correct, remove the PM_{10} and $PM_{2.5}$ heads from the inlet tube and install your reference flow meter onto the inlet. Press the NEXT hot key to move the <CAL> indicator to the first flow point of 15.0 lpm. The pump will turn on automatically. Allow the unit to regulate the flow until the APDA reading stabilizes at the target flow rate. Enter the flow value from your standard into the STD field using the arrow keys. Press the CAL hot key to correct the APDA reading. **NOTE:** The APDA reading will not change to match the STD until after you have entered all three calibration points.
5. Press the NEXT hot key to move the <CAL> indicator to the second flow point of 18.3 lpm and repeat the process.
6. Press the NEXT hot key to move the <CAL> indicator to the third flow point of 16.7 lpm and repeat the process. Enter the flow value and press <CAL>.
7. **When all of the calibrations are complete, the APDA-371 flow readings should match the traceable flow standard reading at 16.7 lpm, +/- 0.1 lpm. Exit the calibration menu.**

The DEFAULT hot key can be pressed to reset the user calibration from the selected parameter and replace it with a factory setting. If any of the FLOW parameters are selected, the DEFAULT key will reset the calibrations of all three flow points. This feature can be used to start over with a calibration if difficulty is encountered.

Actual flow calibrations in units with older firmware:
APDA-371 units with previous revisions of firmware (prior to Rev 3.0) have a different format in the TEST > FLOW menu, as shown below. These units are flow calibrated in the same way as described above, except that the flow calibration is performed at only a single point of 16.7 lpm, not a multi-point calibration as in new units. The correct values from your traceable reference standard device must be entered into the “REFERENCE” column, then the “ADJUST/SAVE” button is pressed to correct the APDA reading. The “NEXT” key selects the parameter to be calibrated. AT and BP must be calibrated first, then the pump is turned on.

```
      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
```

Previous Format of the Actual Flow Calibration Screen

5.7 Field Calibration of Flow System – EPA Standard Flow Mode

Flow calibration on units operated in EPA STANDARD flow mode can be done a couple of different ways. If the unit has a BX-592 or BX-596 ambient temperature probe installed, 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 an Actual flow calibration as described above. If this method is used, be sure to set the unit back to STD flow when done.

If the unit does not have the temperature sensor then you will not have access to the TEST > FLOW screen. Use the following steps to check the flow instead:

1. Attach your flow standard onto the APDA inlet while the pump cycle is running or turn the pump on in the TEST > PUMP screen. Allow the APDA flow to stabilize.
2. If your reference flow meter has a STANDARD flow reading available, that value can be directly compared to the APDA flow reading. If your flow meter only has a volumetric flow reading, then convert the volumetric flow rate to standard flow $\mathbf{Q_s}$ with the following formula:

$$\mathbf{Q_s = Q_a * (P_a / T_a) * (298 / 760)}$$

T_a = Ambient Temperature (Kelvin) (Kelvin = Celsius + 273)
P_a = Ambient Barometric Pressure (mmHg)
Q_a = Actual Volumetric Flow from Reference Meter

3. Compare the reference flow (converted to STD conditions) to the APDA flow reading (also in STD conditions). The two should match within 1% (about 0.17 LPM). If not, a full flow calibration should be performed. Change the FLOW TYPE to METERED and perform a flow calibration using the $\mathbf{C_v}$ and $\mathbf{Q_0}$ values as described in section 5.8. The sections about the manual flow valve do not apply. Set the flow type back to STD when finished.

5.8 Field Calibration of Flow System – Metered Flow Mode

Metered flow calibration is only performed on APDA-371 units which have a hand-operated manual flow valve on the back (mostly older units). Because these units do not have automatic flow control, the calibration procedure is much more complicated. The flow must also be more frequently checked due to changes in ambient conditions, which these type of units cannot compensate for. Use the following steps for a full Metered flow calibration. The full calibration only needs to be done once in a while, but the flow should be checked and adjusted often. The process is faster if your reference flow meter can provide standard flow.

1. Advance the filter tape to a fresh spot.
2. Enter the SETUP > CALIBRATE menu. Set the $\mathbf{C_v}$ (coefficient of variability) value to **1.000**, and the $\mathbf{Q_0}$ (flow zero correction) value to **0.000.**
3. Disconnect the pump tubing from the back of the APDA, and turn the pump on in the TEST > PUMP menu. There will not be any air flowing through the unit. Record the flow reading from the APDA display. This is the zero flow $\mathbf{Z_f}$ value.
4. Re-enter the SETUP > CALIBRATE menu and set the $\mathbf{Q_0}$ value to equal the negative of the zero flow value $\mathbf{Z_f}$.
5. Go back to the TEST > PUMP menu and turn the pump back on. Verify that the flow reading on the APDA display now reads 0.0 LPM +/-0.1LPM.
6. Reconnect the pump tubing to the back of the APDA. Remove any PM_{10} and $PM_{2.5}$ heads, and connect your reference flow meter to the inlet.
7. Record the ambient temperature $\mathbf{T_a}$ (Kelvin) from your reference standard, and record the barometric pressure $\mathbf{P_a}$ (mmHg) from the OPERATE > NORMAL screen on the APDA.
8. From the TEST > PUMP menu, turn the pump on and allow the flow to stabilize for 5 minutes. Then record the actual flow from your reference flow meter $\mathbf{Q_a}$, and record the standard flow reading from the APDA display $\mathbf{Q_b}$.
8. Convert the volumetric flow rate $\mathbf{Q_a}$ from your reference meter to EPA standard flow $\mathbf{Q_s}$ with the following formula:

$$\mathbf{Q_s = Q_a * (P_a / T_a) * (298 / 760)}$$

T_a = Ambient Temperature (Kelvin) (Kelvin = Celsius + 273)
P_a = Ambient Barometric Pressure (mmHg)
Q_a = Actual Volumetric Flow from Reference Meter

9. Calculate the final value for $\mathbf{C_v}$:

$$\mathbf{C_v = Q_s / Q_b}$$

10. Calculate the final value for $\mathbf{Q_0}$:

$$\mathbf{Q_0 = -C_v * Z_f}$$

11. In the SETUP > CALIBRATE menu, enter the final values for $\mathbf{C_v}$ and $\mathbf{Q_0}$.
12. Turn the pump on in the TEST > PUMP menu again and verify that the flow reading from the APDA display matches $\mathbf{Q_s}$ within 1%. If not, repeat the entire flow calibration.
13. After the flow is calibrated, use the flow adjustment knob on the rear of the APDA-371 and adjust the flow until the display reads **17.3 LPM**. This level is within the specification of the PM_{10} particle separator, and will allow for filter loading in high concentration areas. In lower concentration areas the flow can be set at 16.7 LPM.
14. Exit the TEST menu.

Quick Flow Check and Adjustment for Metered Flow:

These steps can be used to do a quick flow check on a Metered Flow APDA with a manual valve while it is in operation.

4. Insert your volumetric flow standard onto the APDA inlet, and allow the APDA flow to stabilize.
5. Record the ambient temperature, ambient pressure, and the volumetric flow from the reference.

T_a = Ambient Temperature (Kelvin) (Kelvin = Celsius + 273)
P_a = Barometric Pressure (mmHg)
Q_a = Actual Volumetric Flow

6. Convert the volumetric flow from the reference to EPA standard conditions:

$$\mathbf{Q_s = Q_a * (P_a / T_a) * (298 / 760)}$$

7. Compare the reference flow (converted to STD conditions) to the APDA flow reading (also in STD conditions). The two should match within 1%. If not, a full flow calibration should be performed.

8. If the reference flow (converted to STD conditions) and APDA flow reading match, then adjust the flow adjustment knob on the back of the unit until the APDA flow reading equals **17.3 LPM**.

Manual Flow Compensation for Seasonal Weather Changes:
These steps can be used to periodically adjust the flow rate on a Metered flow APDA with a manual valve to compensate for changes in average local atmospheric conditions. Full flow calibrations should still be performed on a regular basis.

1. Measure the ambient temperature $\mathbf{T_a}$ (Kelvin) at approximately 4:00 PM. This usually represents an average daily temperature.
2. Stop the APDA pump and record the barometric pressure $\mathbf{P_a}$ (mmHg) from the OPERATE > NORMAL screen.
3. Calculate a volume correction term by the following:

$$\mathbf{V = (T_a / P_a)*62.4}$$

4. Divide **V** by 24.47 to determine the ratio of EPA flow to Ambient Flow and record as **CALNUM**.
5. Turn the pump on in the TEST > PUMP menu and allow the flow to stabilize for 5 minutes. Then divide the displayed flow by **CALNUM**.
6. Adjust the flow adjustment knob on the back of the APDA-371 until the APDA flow reading equals **17.3 / CALNUM**. Exit the TEST menu.

6 SETUP MENU DESCRIPTIONS

The APDA-371 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. Some of these settings are set at factory default values which are correct for most applications, but 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 cannot be changed without affecting the accuracy and proper operation of the unit.

WARNING: Entering the SETUP menu system will require 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

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	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, ¯sw, K, BKGD) Flow rate, Flow type, Heater 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.

6.1 CLOCK 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 APDA-371 clock may drift as much as a minute or two per month. HORIBA recommends checking the clock monthly to ensure correct sample timing.

6.2 SAMPLE Settings Screen – Critical Information

The SETUP > SAMPLE screen is used to set the APDA-371 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 # 01        MET SAMPLE   60 MIN
RANGE    1.000 mg   OFFSET   -0.015 mg
CONC UNITS mg/m3    COUNT TIME    8 MIN
  SAVE                          EXIT
```

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. Default is 9600. “8N1” means 8 data bits, no parity, 1 stop bit. These handshaking bits cannot be edited.

APDA SAMPLE: This value sets the amount of time that the vacuum pump is on per cycle; the actual sample period (see Section 4.1 for a description of the measurement cycle). The APDA SAMPLE time must be set in response to the COUNT TIME value, since new versions of the APDA-371 allow the option of setting the count time to 4, 6, or 8 minutes. If the unit is used for $PM_{2.5}$ monitoring, the APDA SAMPLE must be set to 42 minutes with 8 minute count time. PM_{10} monitors are almost always set for 50 minutes.

Count Time	APDA Sample	Used for
4 min	**50 min**	PM10 monitoring
6 min	46 min	not used
8 min	**42 min**	PM2.5 monitoring

The APDA SAMPLE value can be set from 0-200 minutes for custom applications. If set for shorter period, such as 15 minutes, the unit will finish the sampling in 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 cycle per hour is allowed, regardless of duration. Setting the value too long may cause the measurement to extend over into the next hour. Contact the Service department before setting this to anything but the values shown in the table.

STATION #: This is a station identification number. This number has a range of 00-99, and will be included in the data reports. When used in a network, every APDA-371 should be given a different station number. Default value is 01.

MET SAMPLE: This value is the averaging period for the data logger. It sets how often data is written to memory, and can be set to 1,5,15, or 60 minutes. For example, if an external wind speed sensor is attached to the APDA, the MET SAMPLE period could be set to 1 minute. This would cause the APDA to store an average of the WS reading every minute. This value applies to all sensors attached to the unit. **Warning: This setting will affect how long the memory will last before getting full.**

There are **4369 records** available in the APDA memory. A MET SAMPLE period of 60 minutes (1 record per hour) will result in over 182 days worth of memory capacity, but a 1 minute average period will fill up these memory records in only 3 days. When the memory gets full the unit over-writes the oldest data. HORIBA recommends leaving the MET SAMPLE period set at the default value of 60 minutes unless otherwise required for a particular application. The dust concentration value will always be an hourly average regardless of this setting.

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 almost never changed from the default setting of **1.000 mg**. This means that the APDA measures a maximum full-scale range of 1000 micrograms above whatever the OFFSET value is set to. The table below shows some examples of the RANGE setting interacting with the OFFSET setting to produce the concentration data outputs of the APDA.

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
0.000 mg	1.000 mg	0.000 to 1.000 mg	0-1V = 0.000 to 1.000 mg
0.000 mg	2.000 mg	0.000 to 2.000 mg	0-1V = 0.000 to 2.000 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. Be sure to account for this value if using a separate data logger to record the APDA-371 analog output.
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 prompt you to clear the memory before letting you change this setting.

OFFSET: The OFFSET value is used to set the lower end of the APDA-371 measurement range, and could more accurately be called a “range offset”. The new factory default value for OFFSET is now -0.015 mg. This causes the entire range of the APDA-371 to shift down slightly so that it can read from -0.015 to 0.985 mg, instead of measuring from 0 to 1.000 mg (assuming the RANGE is set to 1.000 mg). This simply allows the unit to measure slightly negative concentration numbers near zero, which is helpful to differentiate between normal noise and a failure such as punctured filter tape.

The previous default was -0.005 mg, and the value may still be set to -0.005 if needed to work with data logging systems structured around the old setting. Some APDA users choose to set the OFFSET value to 0.000 to avoid confusion, at the expense of not being able to see the true zero noise floor of the unit.

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 APDA-371 analog output voltage. Contact the Service department if you plan to set the OFFSET to any value other than -0.000, -0.005, or -0.015 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 prompt you to clear the memory before letting you change this setting.

CONC UNITS: This setting determines the concentration units which the APDA-371 displays and stores in memory. This can be set to ug/m3 (micrograms) or mg/m3 (milligrams) per cubic meter. This is a new option for the APDA-371. Past versions have always been set for mg/m3. **Note:** 1 mg = 1000 ¯ g.

COUNT TIME: This is the amount of time the unit takes to perform the I_0 and I_3 counts. Past versions of the APDA-371 have always been fixed at 4 minutes. The new options allow the count time to be set for 4, 6 or 8 minutes. When used to monitor $PM_{2.5}$, this must be set to 8 minutes. This increases the sensitivity of the unit in lower concentrations. Increasing the count time will require decreasing the sample time. For example, a count time of 4 minutes allows a sample time of 50 minutes, while a count time of 8 minutes allows a sample time of only 42 minutes. The unit will prompt you to change the sample time if you change the count time to an incompatible value.

6.3 CALIBRATE Screen – Critical Information

The SETUP > CALIBRATE screen is where most of the factory-determined calibration parameters for the APDA-371 are stored. These values are unit-specific, and can also be found on the calibration certificate for the unit in case a setting is accidentally changed. Most of these settings will never be changed without specific information from HORIBA. 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
                    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

FLOW RATE: This sets the air flow rate for the APDA-371 sample period. The APDA will continuously regulate the flow to this value (except manual valve models). The flow rate is almost always set for **16.7 liters per minute**, as this is required for all $PM_{2.5}$ and PM_{10} monitoring. The operator may change this value <u>temporarily</u> in order to test the ability of the pump and flow controller to regulate the flow at different levels. The range of this setting is 10 to 20 LPM.

CONC TYPE: This sets the way that the concentration values are reported. If set to ACTUAL, then the concentration is calculated based on the volume of the air at ambient conditions, and a BX-592 or BX-596 temperature sensor is required. If set to STD, the concentration is calculated based on the standard values for temperature and pressure (usually 25C and 760mmHg), even if a temperature sensor is available. This value is usually set to match the FLOW TYPE setting, and must be set to ACTUAL for $PM_{2.5}$ monitoring. Note: APDA units with firmware prior to rev 3.0 does not have this setting available.

FLOW TYPE: This setting selects the flow control scheme used by the APDA-371. The three possible settings are METERED, STD, and ACTUAL.

- METERED: Usually used for APDA units with a manual flow valve on the back. Flow is reported in EPA conditions.
- STD: EPA Standard flow. The flow is controlled and reported in EPA standard conditions. Used where required by regulations.
- ACTUAL: Actual Volumetric flow is controlled and reported to ambient temperature and pressure conditions. This is required on $PM_{2.5}$ monitors, and is recommended by HORIBA whenever possible. BX-596 or BX-592 sensor is required.

This is an important parameter to understand. At sea-level and moderate temperatures the difference between these settings will be minimal, but at high elevations or varied temperatures the flow rate can be greatly affected by this setting. **NOTE:** Section 5.2 contains a detailed description of each of these flow types, and should be studied to ensure proper operation of the unit.

Cv: This value is the factory-set Coefficient of Variability for the internal flow sensor. The value of Cv is only changed by the user when performing a flow calibration on manual valve (metered) or STD flow units. ACTUAL flow controlled units almost never need to have this value altered.

Qo: This value is the factory-set zero correction factor for the internal flow sensor. The value of Qo is only changed by the user when performing a flow calibration on manual valve (metered) or STD flow units. ACTUAL flow controlled units almost never need to have this value altered.

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

µsw: This is called the Mu-switch value, and is the factory-set mass absorption coefficient used by the APDA-371 in the concentration calculations. Typical values are about 0.285 to 0.310. **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 HORIBA.**

K: The K-factor is the factory-set slope correction (multiplier) for the APDA-371 concentration. The K-factor value is determined by dynamic testing of the APDA-371 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 HORIBA.**

BKGD: The BACKGROUND value is the factory-set zero correction (slope offset) for the APDA-371 concentration. This is determined by running the unit for at least 72 hours with a 0.2 micron 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 correction. The BKGD value is typically between 0.000 and -0.005 mg/m^3. HORIBA does offer a zero filter kit (BX-302) which may be used to audit this value, and comes with complete instructions. **Warning: This is a unit-specific calibration value which may significantly affect the accuracy of the unit.** Note: The BKGD value 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 temperature, used for standard flow or concentration calculations. In the U.S. the value of standard temperature is usually 25 degrees C as mandated by the USEPA. Some other countries use a standard temperature value of 0C or 20C. This setting is not available on units using firmware prior to rev 3.0.

HEATER: This setting selects which mode the Smart Inlet Heater is used in. When set to AUTO, the Smart Heater will use the filter RH and temperature sensors to control the inlet tube heating. When set to MANUAL, the unit will simply turn the heater on all the time regardless of filter conditions. The actual setup parameters for the Smart Heater are located in the SETUP > HEATER menu, which will not appear unless this value is set to AUTO. The operator may safely set this parameter as required. HORIBA recommends using the AUTO setting. This value must be set to AUTO for $PM_{2.5}$ monitoring.

6.4 EXTRA1 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. The lowest concentration value the APDA-371 is allowed to store or display, despite what it measured. Any measurements below this value will be clamped. The range is -0.015mg to +0.010mg, and the default value is -0.015mg. **Note:** This value is not to be confused with the OFFSET value which sets the lower limit of the measurement range, or the BKGD value which is the zero correction.

e2 Not Used.

e3 Membrane OFF Delay. Hysteresis timer, range is 0.000 to 5.000 seconds. Don't change this value unless instructed to do so by HORIBA.

e4 Membrane Time Out. The time the unit allows for the membrane assembly to move before generating an error. Range is 10.00 to 20.00 seconds. Don't change this value unless instructed to do so by HORIBA.

6.5 ERRORS Screen

This screen allows the operator the option of reporting APDA-371 errors with the analog output signal. This type of error indication is used when the operator is limited to a single voltage channel for particulate information, such as when the APDA is connected to certain types of data loggers. In this case, the APDA sets the analog output to **full scale voltage** (usually 1.000 volts) when an error occurs. At the beginning of the next hour, the errors are reset and the output functions normally unless another error occurs. The operator can select which errors, if any, are reported in this manner, by selecting each error from the list below and enabling or disabling it (**1=ON, 0=OFF**) in the error setup screen.

Regardless if a particular error is enabled for the analog output in this manner or not, it will always be reported in the APDA-371 digital memory, and may be viewed with the display or by downloading the data through the serial port. Some of these errors such as P, R, N, and E may be set to cause the analog output to go full scale, even though there may be nothing wrong with that hour's data. In this case, the concentration data can still be downloaded from the APDA. Some (but not all) errors such as M and L cause the digital concentration value to be set to full scale too, usually .985mg.

This scheme is used because it is rare for an actual valid concentration reading to measure full-scale. However, concentrations at or near zero can be common, so leaving the data value at 0.000 during an alarm could be mistaken for valid data.

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

The ERRORS Screen

E EXTERNAL RESET: This error indicates that the system clock time was unable to reset when signaled by an external datalogger. If external reset is successful then no error is logged (see Section 8.2). Sometimes called **INTERFACE RESET**.

U TELEMETRY FAULT: This error indicates that an external datalogger has sent an error to the APDA-371 (on the TELEM FAULT input) indicating that it has encountered a problem. Check the datalogger.

M MAINTENANCE: This is a user-set data flag which indicates that calibration or testing was performed during the flagged hour. The "**M**" flag may also be forced ON in the SETUP > INTERFACE menu by setting "Force Maint" to ON, or in the OPERATE > INST screen by pressing the TOGGLE FLG button. M flags cause the digital concentration to read full-scale for that hour.

I INTERNAL CPU: This indicates an error in the mass concentration calculation by the central processor. Contact the Service department if these errors begin to occur frequently.

L POWER FAIL: This error occurs any time power is cycled or lost, even momentarily. Frequent "**L**" errors usually indicate poor quality AC power. In some cases these errors can be generated by electrical interference (such as large radio antennas or motors) causing an internal reset in the APDA-371. There are also a variety of power supply upgrades available for some older APDAs which experience frequent L errors. If a APDA experiences frequent L failures even when connected to a UPS, contact HORIBA for instructions on possible upgrades. This error also causes the digital concentration value to go full-scale.

R REFERENCE MEMBRANE: This error indicates that the reference membrane assembly is not physically extending and retracting properly. The error is generated if photo sensors S2 and S3 never change state despite drive commands to the membrane motor, and a timeout of the membrane motion occurred after 15 seconds.

N NOZZLE STUCK TIMEOUT (or Delta-T exceeded): This error indicates that the nozzle motor is not operating. The error is triggered if photo sensors S4 and S5 never change state despite drive commands to nozzle motor, and if the sensors do not see the nozzle motor move within 12 seconds of it being turned on. **NOTE:** The nozzle motor lifts the nozzle, but the nozzle is lowered only by its spring. So it is possible for the nozzle to become stuck in the UP position without generating an error! Proper maintenance and inlet alignment prevents this.

The "**N**" error is also used to indicate that the Delta-Temperature set-point was exceeded. This occurs if the sample air temperature (measured below the filter tape) is hotter than the ambient air by at least one degree above the set-point value. This is due to the normal heating of the sample air by the smart heater. In this case, the error is used to simply flag the data. Frequent errors may indicate that the set-point is set too low. In most applications Delta-T control is disabled entirely. See the inlet heater settings instructions in this manual.

F FLOW ERROR: This error occurs if the average air flow over the sample period was out of the limits set by the **FRl** (low limit) and **FRh** (high limit) values. The error will also be generated if the flow during any part of the sample period goes out of regulation by more than 5% for more than 5 minutes, or by more than 10% for more than 1 minute. In the later case, the sample is stopped as well. Momentary changes in airflow do not usually trigger the error. This error may begin to occur if the vacuum pump is wearing out, if the muffler is clogged, or due to a fault with the flow sensor, flow controller, or air tubing.

The **"F"** error is also used to indicate if the ambient temperature or barometric pressure sensor has failed or is incorrectly connected (only if the APDA is set for ACTUAL flow or concentration reporting). This applies to auto ID sensors BX-592 and BX-596, the internal filter pressure sensor, and CARB style temperature sensors. The sensor is considered failed if any 1 minute average reading of the sensor is at or beyond the min or max measurement range of the particular sensor.

P PRESSURE DROP EXCESSIVE: This error indicates that the vacuum beneath the filter tape has exceeded the limit set by the **AP** value. This is almost always caused by high concentrations, or certain types of particulate clogging the filter tape. When this error occurs, the APDA stops the pump to prevent overheating, completes the measurement early, then waits for the top of the next hour. To increase the amount of particulate which can build up on the tape before this occurs, set the **AP** value higher.

D DEVIANT MEMBRANE DENSITY: 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%. If these errors start to occur regularly, it could indicate that the beta detector is beginning to wear out. It can also be caused by a dirty or damaged membrane, or by a membrane assembly that is not extending or retracting fully. Also sometimes called a **APDA CAL** error.

C COUNT 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 per 4 minutes. The beta count rate through clean filter tape is usually more than 800,000 per 4 minutes. This error could occur if the beta detector has failed or if something is blocking the beta particles, such as a stuck membrane assembly or debris.

T TAPE BREAK: This error indicates that the filter tape is broken or has run out. The error is triggered if photo sensor S6 is ON continuously, despite drive commands to motors M3-M5. Tape supply motor (M3) and tape take-up motor (M4) time out after 10 seconds. Capstan motor (M5) times out after 6 seconds. This error is also generated if the pinch roller assembly has been left latched in the UP position when a measurement cycle starts. Photo sensor S9 is ON any time the latch is set. The APDA-371 has no way of unlatching and lowering the pinch rollers. It must be done manually. A tape-break error will cause the measurement cycle will stop, and the APDA to repeat the last good concentration value until the filter tape is fixed or replaced.

AP Pressure-drop limit across the filter tape. The default setting is **150** mmHg, and the range is 0-500 mmHg. See the PRESSURE DROP EXCESSIVE error definition above.

FRl Flow Rate Lower Limit. The default setting is **10** lpm, and the range is 0-30 lpm. See the FLOW OUT OF LIMITS error definition above.

FRh Flow Rate Higher Limit. The default setting is **20** lpm, and the range is 1-38 lpm. See the FLOW OUT OF LIMITS error definition above.

6.6 PASSWORD Screen

The SETUP > PASSWORD screen allows the program administrator to change the password required to enter many of the SETUP menus. The password prevents untrained users from accidentally changing critical settings 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**. HORIBA does not recommend changing the password unless truly necessary. Contact the HORIBA Service department for instructions if the password is lost or forgotten.

6.7 INTERFACE Screen

The SETUP > INTERFACE screen is shown below. These settings are used to configure the APDA-371 for operation with an external data logger recording the analog output. Most of these settings are rarely used, but the Cycle Mode setting must be reviewed if the analog output is being used.

```
                          Interface Setup

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


   SAVE                          EXIT
```

The INTERFACE screen

Force Maint: This can be used to manually toggle the maintenance flag ON or OFF to mark the data when the unit is being worked on, such as during a flow check. This also toggles the Maintenance relay to an external data logger. Rarely used.

Fault Polarity: This sets the polarity of the Telemetry Fault Relay. NORM is normally open, INV is normally closed. Rarely used.

Split DELTAP: Not used.

Reset Polarity: This tells the APDA-371 the incoming polarity of an external clock reset signal, if used. This signal is used to synchronize the APDA clock to an external data logger. NORM is normally open, INV is normally closed.

Cycle Mode: The Cycle Mode can be set to STANDARD or EARLY. If you are not using the analog output voltage of the APDA-371, leave this set to STANDARD. See Section 8.2 for a description of the Cycle Modes.

6.8 SENSOR Screen

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.

HORIBA 500 series meteorological sensors have an Auto ID feature which allows the APDA to automatically recognize the sensor and enter all of the setup parameters for any channel the sensor is attached to. Each channel can also be manually configured by the user for other sensors.

```
                      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: This field selects the channel to be viewed or edited. Use the up/down arrow keys to select the desired channel.

TYPE: This is the channel name. You can enter any desired name here by using the arrow keys to scroll through the alphabet and other 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 the slope multiplier. Any input on the channel is multiplied by this amount. The **M** factor in **Y=MX+B.**

OFFSET: This is the slope offset value. Any input on the channel has this amount added to or subtracted from it, after the multiplier is applied. The **B** factor in **Y=MX+B.**

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 $PM_{2.5}$ monitoring with the ambient temperature sensor BX-596.

6.9 HEATER Screen

The SETUP > HEATER screen is only visible if the HEATER CONTROL value in the SETUP > CALIBRATE menu is set to AUTO. This menu is used to configure the settings used by the APDA-371 to control the Smart Inlet Heater. The APDA 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. Tests have shown that as the relative humidity of the ambient air exceeds 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 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 HEATER Setup Screen

RH Control: 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. When the RH falls back below the set point, the heater turns down to a low power heat mode (about 30 Watts) 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 further RH control will be performed.

RH Setpoint: The RH Setpoint can be a number from 10% to 99%. This is the relative humidity level that will be maintained at the filter. HORIBA recommends setting this value at **35%**, which is the equilibration value for FRM filters and is required when monitoring $PM_{2.5}$.

Datalog RH: If YES is selected, the filter RH values will be logged on channel 4 of the APDA-371. Select YES if you do not have any external sensors attached to channel 4.

Delta-T Control: The APDA-371 can compare the filter temperature to ambient and calculate the difference (Delta-Temperature), if a BX-592 ambient temp sensor is attached to channel 6. If YES is selected, the Smart Heater will be turned down to low power mode whenever the Delta-T Setpoint is exceeded. Volatile organic compounds (VOCs) may be lost if the Delta-T is excessive. However, this is usually not a problem with the APDA-371, because each spot of particulate is sampled for less than an hour before being replaced with a new spot. HORIBA does not recommend using Delta-T control except in special applications, as it overrides the RH control which has a far greater effect on the concentration measurement. **Note:** Delta-T control must be set to NO for $PM_{2.5}$ FEM monitoring.

Delta-T Setpoint: This can be set from 1 to 99 degrees C. If the filter temperature exceeds the ambient temperature by more than this amount, the Smart Heater will turn down to low power mode, **regardless of the RH level**. An **N** error is logged in the data 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 not used.

Datalog Delta-T: If YES is selected, the Delta-T values will be logged on channel 5 of the APDA-371. Select YES if you do not have any external sensors attached to channel 5. **Note:** The measured Delta-T may still be logged even if Delta-T control is set to NO. This is often a useful parameter.

7 MAINTENANCE, DIAGNOSTICS and TROUBLESHOOTING

This section provides information for maintaining your APDA-371, and for performing diagnostic tests if a problem is encountered. If the unit generates errors on the display or in the data array, first check Section 6.5 to identify the error. Many times there is a simple solution. Persistent errors often signify a failure or impending failure which will require investigation.

7.1 HORIBA Suggested Periodic Maintenance

Maintenance Item	Suggested Period
Nozzle and Vane Cleaning*	**Monthly**
Leak Check*	**Monthly**
Flow Rate Verification	**Monthly**
Clean Capstan Shaft and Pinch Roller Tires*	**Monthly**
Clean PM10 Head	**Monthly**
Clean PM2.5 Inlet	**Monthly**
Check Error Log*	**Monthly**
Download Digital Data Log*	**Monthly**
Compare APDA-371 Data to External Datalogger Data (if used)	**Monthly**
Replace Filter Tape	**2 Months**
Run SELF-TEST Function	**2 Months**
Full Flow Audit and Calibration	**2 Months**
Verify APDA-371 Settings	**2 Months**
Set Real-Time Clock	**2 Months**
Replace or Clean Pump Muffler (if used)	**6 months**
Test Pump Capacity	**6 months**
Test Filter RH and Filter Temperature sensors	**6 months**
Test Smart Heater	**6 months**
Perform 72 hour BKGD (BX-302 zero filter) test	**12 months**
Clean Internal Debris Filter	**12 Months**
Check Membrane Span Foil	**12 Months**
Beta Detector Count Rate and Dark Count Test	**12 Months**
Clean Inlet Tube	**12 months**
Test Analog DAC Output (if used)	**12 Months**
Rebuild Vacuum Pump*	**24 months**
Replace Nozzle O-ring (Special tools required)	**24 months**
Replace Pump Tubing	**24 Months**
Factory Recalibration. Not required except for units sent for major repairs.	**---**

*****These items may be performed more often as required.

7.2 Audit Sheet and Test Records

The back of this manual contains a sample of a APDA-371 Audit Sheet. This is a test record which can be filled out as calibrations, checks, or audits are performed on the unit. The operator is encouraged to make copies of this sample sheet to use as needed. HORIBA can also supply the original document in a Microsoft Word® format to be modified as needed. Keeping records of calibrations and maintenance is critical for any monitoring program. Most agencies develop their own SOP for maintenance items and test records.

7.3 Self-Test Feature

A primary method of identifying a hardware malfunction in the APDA-371 is the SELF TEST feature in the TAPE menu. This can identify a large number of the possible mechanical failures in the unit, and is a good place to start if a problem is suspected or if frequent errors are recorded. See Section 3.5 for a description of the self-test process.

7.4 Power-Up Problems

The APDA-371 must at least be able to power on before any further diagnosis can be performed. There are only a few possible reasons that the unit will fail to power up:

- Make sure that the unit is plugged into the correct AC voltage.
- Check or replace 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.
- It is possible for the display contrast to be set so light that it looks like the unit is OFF when it is really ON. Try holding the contrast key for a few seconds. In rare cases the display may fail completely. If the unit "beeps" when you press the keys, it is ON.
- If the above checks are all OK, there could be a failed power supply inside the unit. Contact HORIBA for further instructions. Do not attempt to open or repair the power supply assembly unless qualified.

7.5 Basic Problem and Cause/Solution Table

The following table contains information on some of the more common APDA-371 problems which may be encountered, and some steps to identify and remedy the problems. HORIBA 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 APDA won't start a measurement cycle.**
Cause/Solution:	• The unit is programmed not to start 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, either 4 or 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 not on the main or OPERATE menu. • The unit will usually display an error and "beep" if it cannot start a cycle

Problem:	**The analog output voltage and/or digital concentration reading are full-scale.**
Cause/Solution:	• The unit will force these values full-scale to indicate an error. Download the error log. Whenever the unit is started or interrupted this will happen until the next hour.

Problem:	**The concentration is reading negative values.**
Cause/Solution:	• It is possible for the unit to occasionally read negative numbers if the actual particulate concentration is very low, such as below 3 micrograms. This is because the APDA has a "noise band" of several micrograms. This should not happen often. • If the unit is reading negative numbers hour after hour, it is probably punching holes in the filter tape. These holes can be very small and hard to see. This is almost always caused by debris on the nozzle or vane. Clean the parts. • Make sure the SETUP > CALIBRATE values match the calibration sheet, especially the BKGD value. • The BKGD value may need to be field-audited. HORIBA supplies the BX-302 zero filter kit for auditing the zero reading of the unit.

Problem:	**The airflow rate is too low and won't adjust up to 16.7 lpm.**
Cause/Solution:	• The gray plastic pump mufflers clog up after several months. Replace it or drill a hole in the end of it for a temporary fix. The brass mufflers 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 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 connected to a APDA. • 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. • Set the flow rate in the SETUP > SAMPLE screen to 14.0 and 17.5 lpm, and turn the pump on in the TEST > PUMP screen. The APDA should try to regulate to these values. If the flow does not change, the flow controller is probably stuck. If the flow regulates lower, but not higher than 16.7 lpm, the pump is probably worn out, or there is a leak. Be sure to set the flow back to 16.7 lpm when done.

Problem:	**The nozzle gets stuck in the UP position, or won't press down onto the tape fully.**
Cause/Solution:	• This is often caused by a misaligned inlet tube. Make sure it is straight up and perpendicular to the top of the unit. • The nozzle o-ring eventually breaks down and needs to be replaced. Contact HORIBA for detailed instructions. Special shims are required to reinstall the nozzle. • The brass nozzle bushings may have grit in them. Remove the nozzle and clean the parts. Contact HORIBA for detailed instructions. BX-308 tool kit required. • Lift the nozzle with your fingers and determine if it feels sticky or gritty.

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. Contact HORIBA for instructions for removing the nozzle and replacing the internal o-ring. • Check the o-rings on the sharp-cut cyclone (if used). These frequently leak. • Check the zero of the flow sensor in the APDA: Perform another leak check, but disconnect the tubing between the pump and the APDA, so there can be no air flow through the unit. Verify that the flow reading on the APDA reads less than 0.2 lpm. If not, the flow sensor $\mathbf{C_v}$ and $\mathbf{Q_0}$ settings may need to be recalibrated as described in Section 5.8 of the APDA manual. • Check for bad o-rings on the APDA inlet receiver. • Remove the APDA case cover and inspect all air fittings inside the APDA. 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 over-measures or under-measures concentrations compared to a collocated FRM filter sampler.**
Cause/Solution:	• The most common cause is moisture getting on the filter tape or being absorbed by the particulate. Review the Smart Heater settings for proper operation. • Test the filter RH sensor calibration, and log the filter RH on channel 4 if possible. RH should be controlled to 35%. • Verify the flow rate and temperature and pressure calibrations. • Make sure that the K-factor setting has not been changed on the APDA. This would appear as a slope error in the APDA concentration data. • Verify the BKGD (background) value is correct, and perform a 72-hour BX-302 zero filter test to verify. If the BKGD value is not correct, it will offset the APDA data by up to several micrograms. • Check for leaks at the nozzle. A leak can cause either a positive or a negative measurement bias depending if the air leaking around the nozzle is cleaner or dirtier than ambient air.

	• Verify the collocation setup requirements, especially making sure the inlets are spaced correctly and the same height. • If the analog output of the APDA is being logged by an external datalogger, make SURE the logger's scaling of the APDA output is correct! In most cases, a 0.000 volt analog output on the APDA does NOT equal 0.000mg, but rather -0.015 or -0.005mg. See Section 6.2 and Section 8. Periodically verify that the digital data log from the APDA matches the external logger data. • Single event FRM samplers often perform better than multi-channel FRM samplers. If a multi-channel unit is used, then filter collection must still be performed on a daily basis. If the FRM filters are not properly collected and retained every day, then correlation results with the APDA can suffer. • The daily 24-hour average of the APDA hourly values is calculated externally from the APDA. It is important that the 24 hours worth of APDA data used for correlation to the FRM is the same 24 hour period in which the sampler schedule is run. For example, if the FRM is scheduled to stop for filter changes at 9:00 am each day, but APDA data used for that same day is from midnight to midnight, then a bias can result.

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 APDA 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 APDA can be prone to oxidization which can cause the unit to reset frequently. Upgrade parts may be available for certain units. Contact the Service department. • Rarely, some older 220 volt units can experience resets caused by the Smart Heater control wiring inside the APDA. Contact the Service department.

Problem:	**The APDA data shows repeated concentration values hour after hour.**
Cause/Solution:	• Certain error flags, such as the "T" (tape broken) flag will cause the APDA to repeat the last known good concentration value until the error is resolved. Check the error log to identify any errors for those hours. • If the RANGE setting on the APDA is set higher than 1.000mg, 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 APDA 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.

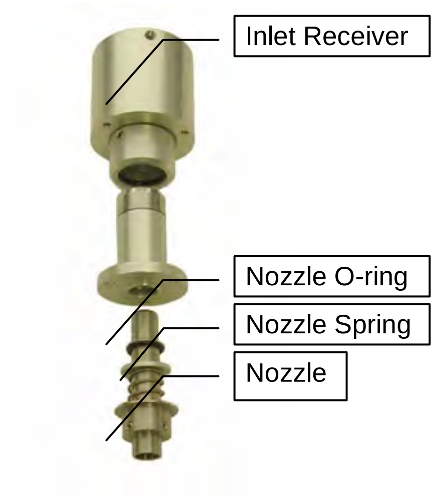
Problem:	**The clock settings are lost when the unit is powered down.**
Cause/Solution:	• The lithium battery on the 3230 circuit board may need to be replaced after about 10 years. It is normal for the clock to drift as much as 1 minute per month.

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 APDA.

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 APDA, this message will appear. • If the Auto ID line from the temperature sensor is not working, the APDA will not ID the sensor, causing the alarm.

7.6 Nozzle Component Replacement

The nozzle components need periodic inspection, cleaning, and replacement. The nozzle o-ring will need to be replaced every couple of years to prevent the nozzle from starting to stick. The nozzle itself may need to be replaced if it becomes worn or damaged, and should be removed and thoroughly cleaned annually or bi-annually. Complete instructions are available from HORIBA. A set of shim tools are required for nozzle re-assembly.

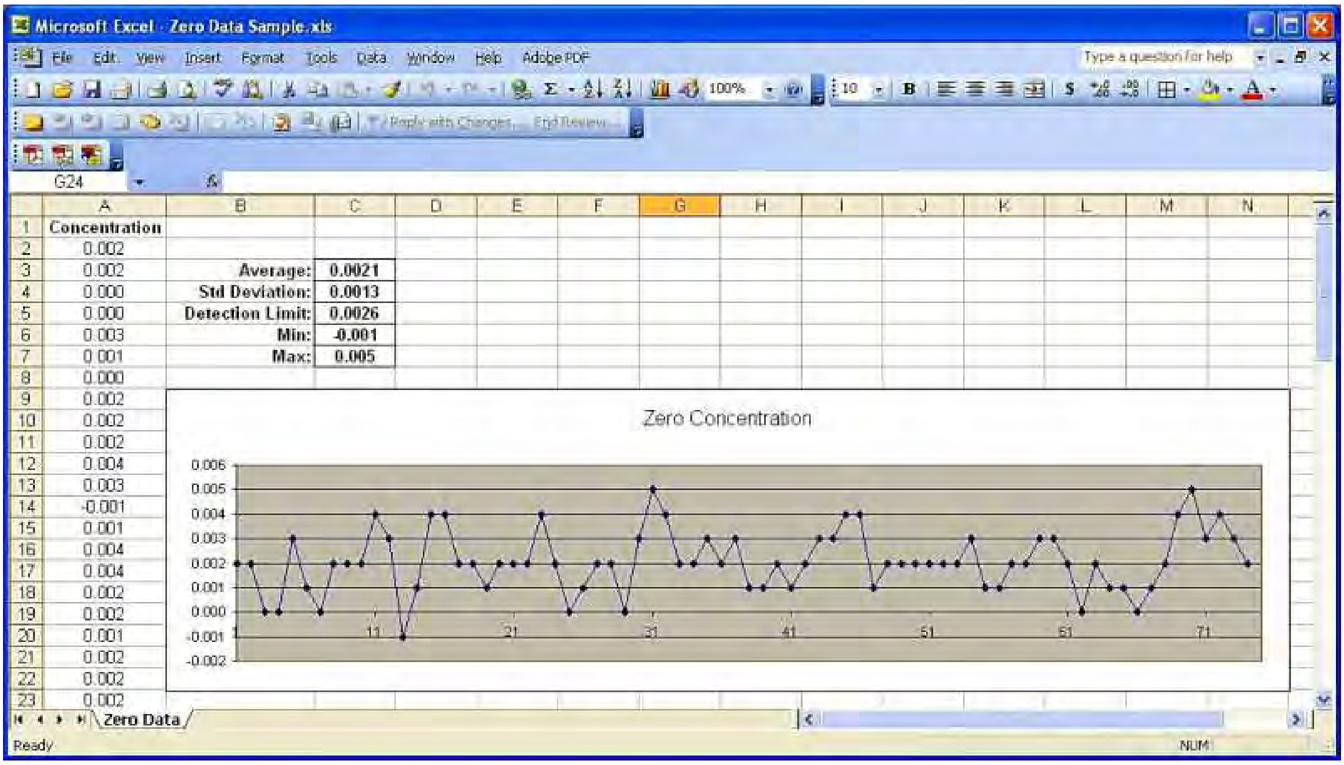


7.7 Field BKGD Zero Background Tests

The Background value is a correction offset for the concentration data collected by the APDA-371 (see section 6.3 for a description of the BKGD value). This value is factory calibrated for each unit under laboratory conditions, and is typically never changed for PM_{10} monitoring.

APDA-371 units set up to monitor $PM_{2.5}$ must to have this value field verified (and adjusted if necessary) upon deployment, and at least once per year afterwards using the BX-302 Zero Filter Calibration Kit. The test corrects the BKGD value to compensate for minor variations caused by local conditions such as grounding and shelter characteristics. This results in optimum accuracy at lower concentrations typical of $PM_{2.5}$ levels. The test also provides information about the zero noise levels of the unit being tested.

The test involves running the APDA in its normal operating environment with a zero filter on the inlet for at least 72 hours. The new BKGD will then be calculated and entered into the APDA. The test should not be performed during a period of rapidly changing weather. A complete set of instructions for the test are included with the BX-302 kit.



Typical zero background test results

7.8 Test Menu System

The following sub-sections provide information for performing diagnostic checks on the APDA-371 sub-systems using the TEST menus. Most of these tests will be 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 MODE

COUNT       PUMP        TAPE      DAC
CALIBRATE   INTERFACE   FLOW      ALIGN
HEATER      FILTER-T    RH


 SELECT                            EXIT
```

The TEST Menu

7.9 COUNT test Screen

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 value 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 test also allows the membrane to be extended between the source and detector as well, if desired.

TIME: This shows the time that the count test is started.

COUNT: This is the total number of beta particles counted during the four-minute test. You will see this count rapidly accruing during the test. Typical four-minute count values are between 600,000 and 1,000,000 counts through clean filter tape. The count total will be lower if the membrane is extended, which simulated adding particulate to the tape. If the count total is less than 500,000 then the beta detector is possibly wearing out.

M: Indicates if the membrane is extended (Y), or not extended (N).

MEMBRN: Press this soft-key to extend the membrane between the source and detector.

NO MEMBRN: This soft-key withdraws the membrane.

GO: This soft-key starts the four minute count test. The counting will immediately begin. After four minutes the counting will stop and wait for the operator to initiate another cycle or EXIT.

7.10 PUMP Test Menu

The TEST > PUMP screen is very useful to test the pump and nozzle, and to perform leak checks and nozzle cleaning. See section 5.3 for the leak check procedure. Note: The APDA nozzle motor drives the nozzle UP, but the nozzle is lowered by only its spring tension. It is possible for the nozzle to become stuck in the UP position even if the motor is working and no errors are generated. It is also possible for the nozzle to not fully seat against the filter tape as well. These faults are usually caused by an inlet tube alignment problem, a disintegrated nozzle o-ring, or grime in the nozzle bearings. A good indication of this problem is an irregularly shaped dust spot on the tape, often with a “halo” around it.

```
            NOZZLE/PUMP TEST MODE

NOZZLE:  ▾

Flow (STD):  16.7 LPM    PUMP:  ON


MOVE NOZZLE    PUMP ON    PUMP OFF    EXIT
```

The PUMP Test screen

NOZZLE: Nozzle status. UP (¯) or DOWN (¯).

PUMP: Pump status. ON or OFF.

Flow (STD): The air flow rate, displayed in EPA Standard liters/minute.

MOVE NOZZLE: This soft-key will move the nozzle up or down. The test allows for checking proper nozzle movement. Total elapsed time is about 5 seconds. If the pump is ON this operation is disabled.

PUMP ON: This soft-key will turn ON the vacuum pump. The nozzle will automatically be lowered if necessary.

PUMP OFF: This soft-key will turn the pump OFF.

7.11 TAPE Test Menu

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 to test the tape transport mechanism or to move fresh spots of tape for other tests, such as 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.

X: This is the last number of windows moved. This number will be negative if the last move was backwards.

FEED: This is the number of windows you want to move. Use the arrow up/down keys to select up to 10 windows at a time.

FWD: This soft-key will move the filter tape forward amount of the FEED value.

BKWD: This soft-key will move the filter tape backward 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 concentration output voltage and the DAC (digital-to-analog-converter) electronics. Use the up/down arrow keys to set the voltage anywhere from **0.000 to 1.000 volts** in 0.100 increments. Measure the VOLT OUT +/- terminals on the back of the APDA-371 with a high quality voltmeter and verify that the actual voltage matches the APDA display value within ±0.001 volts at each point. Then attach the voltmeter to the input of your datalogger and repeat the test to verify that the correct voltages get to the input. If the analog output does not match the value on the TEST > DAC screen, contact the Service department for instructions. Note: 1 millivolt = 1 microgram of concentration in most applications. The DAC output cannot go negative.

7.13 CALIBRATE Test Menu

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 APDA-371 has been logging **D** errors. Each APDA-371 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%. If not, the most common cause is a dirty membrane (dust or lubricant on the foil). The membrane 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 membrane foil is a thin sheet of polyester and is extremely 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

REF MBRN: This indicates if the reference membrane is extended **(>)** or withdrawn **(<)** from the beta particle path.

COUNT (I_0): The total 4-minute beta count through the filter tape only, no membrane.

COUNT (I): The total 4-minute beta count through both the filter and the membrane.

CAL MASS M: This is the calculated calibration mass **(m)** derived from the two count values, the mass which the unit has just measured for the membrane. An average of several of these values should match the **ABS** value within 5%.

START: This 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

The TEST > INTERFACE screen is used to test the relay inputs and outputs on the back of the APDA-371. The two inputs (TELEM FAULT and EXT RESET) are tested by applying the appropriate signal to the terminals on the APDA, then verifying that the value on the screen changes in response. The five relay outputs (TAPE BREAK, FLOW ERROR, DATA ERROR, MAINTENANCE and RANGE) are tested by turning them ON or OFF using the arrow keys, then verifying that the outputs on the terminals respond accordingly. Note: RANGE not used.

7.15 FLOW Test Menu

The TEST > FLOW screen is where the very important flow calibrations are performed on most APDA-371 units. See section 5.6. This screen is also useful to check the ambient temperature and barometric pressure sensors, and for pump and flow controller tests.

7.16 ALIGN Test Menu – Photo Sensor Tests

The TEST > ALIGN menu system is used primarily to factory-test the photo sensors which monitor all of the mechanical movement in the APDA-371. 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:** Remove the filter tape for these tests, or it will break.

		TEST MODE	
NOZZLE	SHUTTLE	IDLER	CAPSTAN
LATCH	REF		
SELECT			EXIT

The ALIGN Menu

NOZZLE: This screen tests the two nozzle photo sensors. 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 photo sensor which monitors the position of the shuttle beam (the two 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.

IDLER: This screen tests the photo sensor which monitors the position of the right-side tape tensioner (the spring-loaded tape roller on the right). When the tensioner is in its left position under its spring tension, 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. The tensioner must be moved by hand. The left side tensioner assembly has no sensors to check.

CAPSTAN: This screen tests the two photo sensors which watch the rotation of the Capstan shaft. 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 rotate 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.

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

The TEST > FILTER-T screen is used to calibrate the filter temperature sensor located in the air stream beneath the filter tape. When this screen is entered, the APDA will automatically raise the nozzle and turn the pump on. This allows ambient room air to equilibrate the filter temperature sensor without the heating effects of the Smart Heater. Allow the pump to run for at least 5 minutes to allow the sensor to equilibrate. Press the RESET hot key to clear out any past calibration values, then enter the ambient room temperature from your reference standard into the REFERENCE field and press the CALIBRATE hot key. The APDA reading should change to match within **+/- 1 deg C**. The RESET hot key can be used to revert to default calibrations and start over if difficulty is encountered. Older revisions of APDA firmware contain a different test screen for this sensor.

```
FILTER TEMPERATURE CALIBRATION


      BAM:   26.1 C
REFERENCE:   26.1 C


CALIBRATE    RESET                Exit
```

The FILTER-T Test Screen

7.19 RH Test Menu – Filter Humidity Sensor

The TEST > RH screen is used to calibrate the filter relative humidity sensor located in the air stream beneath the filter tape. This screen works just like the FILTER-T screen described above. Allow the pump to run for at least 5 minutes to allow the sensor to equilibrate. Press the RESET hot key to clear out any past calibration values, then enter the ambient room relative humidity from your reference standard into the REFERENCE field and press the CALIBRATE hot key. The APDA reading should change to match within **+/- 4% RH**. The RESET hot key can be used to revert to default calibrations and start over if difficulty is encountered. Older revisions of APDA firmware contain a different test screen for this sensor.

8 EXTERNAL DATALOGGER INTERFACE SYSTEM

This section describes the configuration of the APDA-371 to work with a separate, external datalogger. The APDA-371 provides an analog concentration output voltage, as well as an array of relay inputs and outputs. These allow the APDA-371 to function as a sensor in a larger array of data collection instruments. There are a variety of dataloggers available which are compatible with the APDA-371 outputs, so consult the manual for your datalogger for the specific setup requirements.

8.1 Analog Concentration Output Signal

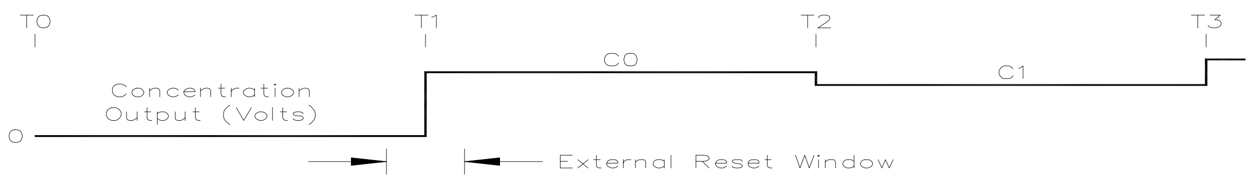
The primary link between the APDA-371 and an external datalogger is the analog concentration output signal. The analog output type is selectable between isolated voltage (0-1 or 0-10 volt DC) and isolated current (4-20 or 0-16 mA). The rear panel dipswitches are used to select the output as shown in the table below. The one-volt range is by far the most common. The full-scale value of the output voltage corresponds to the full-scale measurement of the APDA-371, determined by the RANGE and OFFSET setting. See Section 6.2. In the majority of applications, the analog output is set for **0-1 volt = 0 to 1.000mg or 0-1 volt = -.005 to .995mg**. If the OFFSET is set to -0.015 for $PM_{2.5}$, then the analog output is **0-1 volt = -.015 to .985mg.** The analog output should be tested as described in Section 7.12.

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

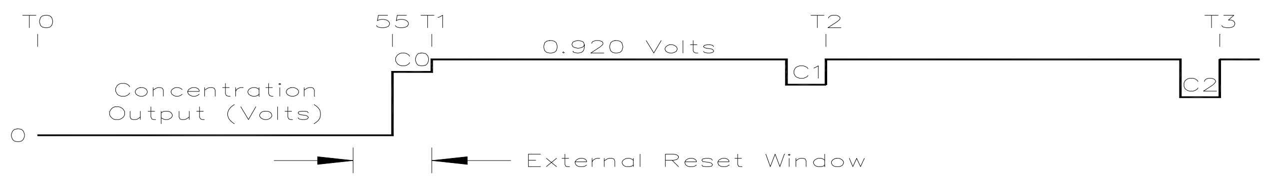
In most cases the analog output is the only channel available between the APDA-371 and the datalogger, and any errors generated by the APDA must be reported using the same voltage signal. The APDA-371 will set the analog output to its full-scale reading when any of the selected errors occur. The errors which cause this are selectable, and are described in section 6.5. The external datalogger should be programmed to recognize a full-scale reading as an error, not a valid concentration. This method is used because it is very rare for a concentration reading to exceed the range of the APDA-371. The digital data values stored in the APDA are unaffected and may be viewed with the display or by downloading.

8.2 *Early Cycle Mode Description*

During a standard APDA-371 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 (such as ESC) must have the concentration value available **before** the new hour starts, or the data will be stored in the wrong hour. The APDA-371 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. The APDA-371 clock and the datalogger clock will usually need to be synchronized because of the critical timing involved. 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 <u>next</u> hour following the measurement. In early mode the $\mathbf{C_0}$ voltage for the current hour is present for only the <u>last 5 minutes of the hour just-sampled</u> (minute 55 to 60), and all other times the concentration output voltage is 0.920 volts.

External Reset Windows

An external reset signal may be used to synchronize the APDA-371 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 clock will not reset if the cycle has not reached the I_3 count. The error log will contain the date and time of the reset attempt. If the I_3 count is in progress, or the cycle is past the I_3 count, then the measurement cycle is canceled. The error log will contain the date and time of the reset. A canceled cycle will also force the analog output to the full-scale values (1.000 volts in standard mode, or 0.920 volts in early mode).

Standard Mode Clock Resets:

Minute 0 to 5: An external reset signal will change the APDA 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 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.

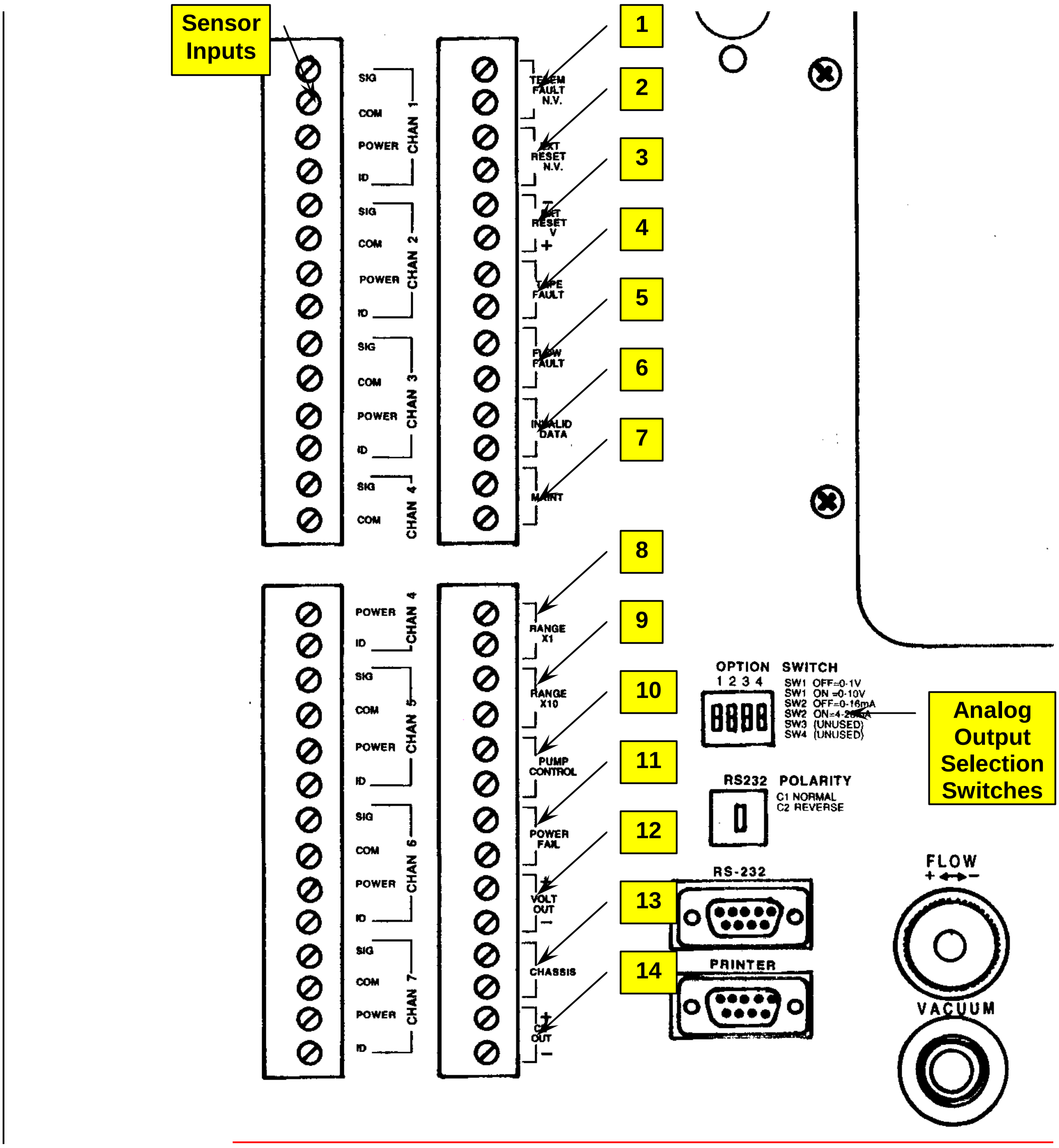
Minute 0 to 50: The external reset signal has no effect. The error log will contain the date and time of the reset attempt.

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, input and output relay connections are provided on rear panel of the APDA-371 to allow the unit to be used with an external data logger in a synchronous mode of operation. The function of each input and output is described below. Many of the relay outputs described below are related to APDA-371 error conditions described in section 6.5.

Note: A **contact-closure input** to the APDA-371 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 or current to the terminals. **Contact-closure outputs** from the APDA-371 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. **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.



APDA-371 Back Panel Relay Connections

1. **TELEM FAULT N.V.** Telemetry Fault Non-Voltage. This input can be used to signal the APDA-371 that the external telemetry system (datalogger) is not operational. This is a contact-closure input which must be activated for a minimum of 2-seconds. If activated, the APDA will continue to function and will log a “U” error (see section 6.5) and activate the DATA ERROR relay output. This input can be set to normally-open or normally-closed in the SETUP > INTERFACE menu.
2. **EXT RESET N.V.** External Reset Non-Voltage. This input is can be used to synchronize the APDA-371 clock to the external datalogger, and is often used in EARLY cycle mode (see section 8.2). 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. **EXT RESET V** External Reset Voltage. This input is the same as above except the input is activated by a voltage logic 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" or tape error is generated (see section 6.5). Polarity is normally-open.
5.	**FLOW FAULT**	This is a contact-closure output which will be activated whenever an "F" or flow error is generated (see section 6.5). 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 APDA (see section 6.5). Polarity is normally-open.
7.	**MAINT**	This is a contact-closure output which will be activated whenever a maintenance "M" flag is generated (see section 6.5). Polarity is normally-open.
8.	**RANGE X1**	This contact-closure output is no longer supported. The relay for this channel is now used by the Smart Heater.
9.	**RANGE X10**	This contact-closure output is no longer supported. The relay for this channel is now used by the Smart Heater.
10.	**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.
11.	**POWER FAIL**	This is a contact-closure output which will be activated (closed) whenever a power failure of the 5 volt DC system or an "L" error occurs (see section 6.5).
12.	**VOLT OUT**	This is the analog concentration output voltage terminal. Typically 0-1 VDC. See section 8.1. Polarity must be observed on this output.
13.	**CHASSIS**	These are the earth-ground terminals. These must be attached to a solid ground point for best operation of the unit.
14.	**CL OUT**	Current Loop 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 APDA and the datalogger. Output is selectable between 4-20mA or 0-16mA.

8.4 Digital Datalogger Interfacing with the APDA-371

Applications involving digital data transfer between the APDA-371 and other manufacturer's digital dataloggers, such as DR DAS™ and Campbell CR-1000™ models among others, have become more common. This typically requires a considerable amount of programming experience with the particular type of logger to be used. Any digital files from the APDA-371 must be obtained from either the RS-232 two-way serial port, or the RS-232 output-only printer port. There are several possible pitfalls which can be encountered when collecting APDA-371 data with a digital datalogger.

The most straight-forward way to accomplish digital datalogger interface with the APDA is to configure the printer output port as a fixed width data output as described in Sections 9.5 and 9.4. This causes the APDA-371 to output a single fixed-width string of data at the end of each sample hour without having to be prompted. The digital logger must be programmed to wait for the data string, then process it appropriately.

The alternative is to program the digital datalogger to send the APDA-371 the appropriate commands to retrieve data, just like you would when downloading the data with a computer as described in Section 9.4. Typically, the APDA would be sent the appropriate commands to respond with CSV files 6,3 (new data since last download) or 6,4 (last hourly data record only). The digital logger must receive and sort the files appropriately.

The most important consideration when collecting the data in this manner is to remember that the APDA-371 only measures concentration data once per hour, and during other parts of the hour (especially near the beginning and end of each hour) the APDA is often moving tape transport parts and making mechanical adjustments which **prevent the unit from responding to digital data requests** due to a busy processor. See Section 4. The best solution is to program the digital logger to make a single data request to the APDA at some time during the sample period near the middle of each hour, such as between minute 25 and minute 50. This is especially important if large amounts of data are to be downloaded at once, since it can take more than 10 minutes to download the entire data log. If the download overlaps a mechanical motion by the APDA, then the data can be delayed by several seconds in the middle, or even interrupted entirely. Small digital files (such as the last hourly record only) can be downloaded very quickly, and may be accomplished at almost any time during the hour as long as the timing is carefully controlled. It is highly recommended that the APDA clock be regularly synchronized by the external datalogger to prevent timing problems due to clock drift.

If a datalogger is programmed to digitally request data from the APDA-371 continuously throughout the hour (such as every minute), then there will almost certainly be a number of requests each hour which will be ignored by the APDA due to mechanical interrupts.

HORIBA is often able to provide more technical information and support to help our customers develop effective programs for operating certain types of digital dataloggers with the APDA-371. In addition, we are always eager to hear about new ways that users have found to implement this type of interface. Contact HORIBA Technical Service.

9 RS-232 SERIAL COMMUNICATIONS – DATA RETRIEVAL

This section describes the methods used to retrieve digital data files through the RS-232 serial communications system on the APDA-371. The unit has a two-way serial port which may be used with a computer, laptop, modem, digital datalogger, or data transfer module. There is also a configurable output-only serial printer port. Access to the data through the serial port is a simple menu driven interface.

9.1 Serial Port Connections and Settings

The RS-232 serial port on the back of the APDA-371 handles data transfer and may also be used for instrument setup and operation status checks. The serial port may also be used with an optional modem for remote communications through a phone line (See Section 9.6).

Desktop Computer Connections: The APDA-371 can be connected to almost any standard PC that has an RS-232 serial port available (COM1 to COM4). Connect the RS-232 port on the back of the APDA-371 to the COM port connector on the computer with a female-to-female 9-pin null RS-232 cable. (Belkin F3B207-06 is recommended and available from HORIBA). **CAUTION:** Do not confuse the parallel printer port or video adapter port on your computer with a serial port. Connecting the APDA-371 to these may cause damage to your computer and the APDA. If in doubt, consult the computer manual before connecting.

Laptop Computer Connections: The APDA-371 can be connected to most laptop computers. Most older laptops have a regular 9-pin RS-232 serial port, just like a desktop computer. Modern 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. HORIBA recommends the Belkin F5U109, available from HORIBA 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. HORIBA does not recommend converters sold under the Radio Shack brand name. 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 APDA. This type of adapter is very reliable, but more expensive and takes longer to install and configure. See www.quatech.com for more information.

Communication Settings: The APDA-371 communicates at 9600 Baud, 8 data bit, no parity, one stop bit. 9600 baud is the default setting which may be changed. The APDA-371 settings must match these in the SETUP > SAMPLE menu. If unable to communicate, try changing the RS-232 Polarity switch on the back of the APDA-371. This swaps the polarity of the TX and RX lines (2&3) and functions as a null modem. **NOTE: The APDA-371 user interface must be in the main top-level menu or OPERATE menu before serial port communication can be established.** The serial port is disabled in all other menus. Also, the LCD display and keypad on the APDA-371 are disabled whenever RS-232 communication is in progress.

9.2 HORIBA Communications Software

The APDA-371 is compatible with several communications software programs available from HORIBA:

MicroMet® Plus: A powerful and comprehensive data logging program for meteorological applications which is configurable to collect and manage all data from the APDA-371.

Comet™: A simple and easy to use communications terminal program which can retrieve data from HORIBA data loggers, including the APDA-371. This program replaces the old TUS (Terminal Utility Software) program.

9.3 Downloading Data Using HyperTerminal

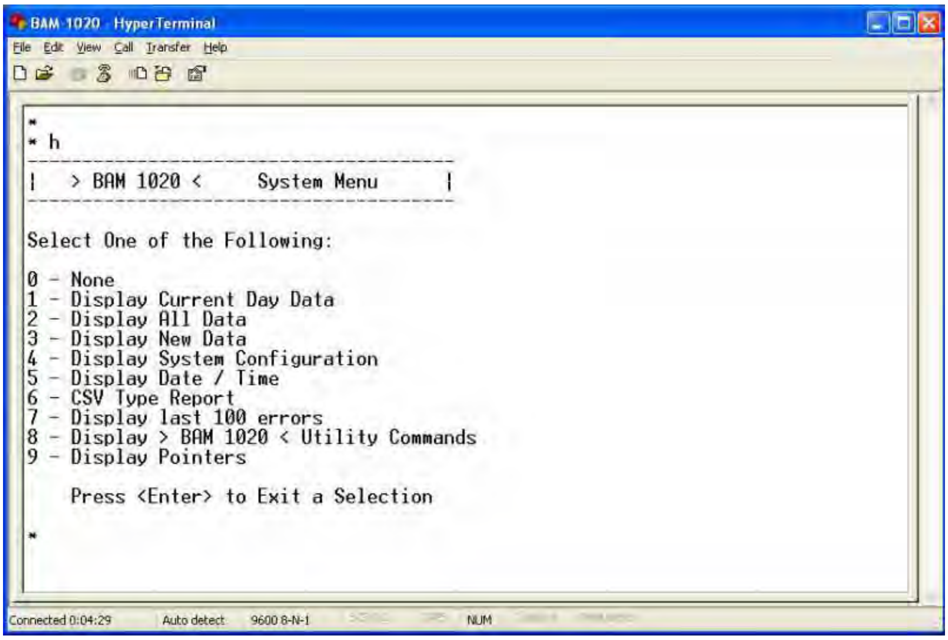
The APDA-371 data can be easily downloaded through the serial port using HyperTerminal® or other simple terminal programs. Nearly all PCs running Microsoft Windows 95® or later operating systems have the HyperTerminal program included. This section describes how to set up this program for communication with the APDA-371. **Note:** The APDA-371 display must be on the Main Menu in order to establish communications.

1. Connect the RS-232 port on the back of the APDA 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 “APDA-371” 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 could also set up the program to dial the APDA 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 APDA-371.
6. Once communication is established, press the **h** key. This should cause the APDA-371 System Menu to appear on the window as shown below. You can now send any of the characters in the menu to retrieve the desired files. The menu options are described in the following sections.
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.
8. When you exit HyperTerminal, it will ask if you want to save your connection. Click “Yes” and a file named APDA-371.ht will be created in the HyperTerminal folder, which will have all of the settings saved. Use this for future communications with the APDA.



Terminal Window showing APDA-371 menu

Windows 95® and HyperTerminal® are registered trademarks of their respective corporations.

9.4 System Menu File Descriptions

Once a serial connection between the computer and the APDA-371 has been established as shown above, you will have access to the main APDA-371 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 APDA will stop waiting for a command and you will have to send another **“h”** to reestablish the connection.

File 1: Display Current Day Data

This file will include a text view of the current day's data only. An example of the data format is shown below. The first column is the time, followed by a series of dashes. Each dash represents a possible error. 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. Notice that the values went full-scale during the two hours that errors were logged. This indicates invalid data. The Qtot column is total flow volume for the hour. With a flow rate of 16.67 LPM, and a sample time of 50 minutes, this value will be about .834 m^3 per hour. (16.7 * 50 / 1000 = .8335). The remaining six columns are the six datalogger inputs on the APDA. 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 those channels in this example is only noise.)

```
Report for 04/22/2005 - Day 112    > APDA 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 data text file example

File 2: Display All Data

This file will download a text file of all of the data stored in the APDA-371 memory, in the same format as the above example. Be sure to capture text (section 9.3) if downloading this file using HyperTerminal, as it can be fairly large.

File 3: Display New data

This file will contain text of all of the data stored by the APDA-371, since the last time the data was downloaded. Useful to avoid duplicate data in your database. A flag is set in the APDA indicating where the last download stopped.

File 4: Display System Configuration

This file will contain a list of most of the APDA-371 settings and calibration values as shown below. This is useful for verifying the setup on a remote APDA, and to send to the factory if service is required. The setting report has been updated and reformatted. Following is an example of the new settings report. Older firmware will show a slightly different report.

APDA 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
Fow 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
APDA 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 file example

File 5: Display Date / Time
This file will show the date, time and serial number of the APDA-371.

File 6: CSV Type Report
This command will give you three Comma-Separated-Value options which you can select by sending the appropriate number below. Each of the data files are the same as above, except the values in each column are separated by commas (,). This allows the text file to be opened directly by Microsoft Excel® or other 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 APDA data is downloaded by an external digital datalogger. Following is a list of the files available in CSV format:

2 – Display All Data	(All data)
3 – Display New Data	(Data since last download)
4 – Display Last Data	(Previous hour's data only)
5 – Display All Flow Stats	(All flow stats)
6 – Display New Flow Stats	(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)

Example of a CSV Report of the "LAST DATA" record:
The following example shows a CSV download of the last data record from the APDA-371. This file download does not reset the data pointer.

1. A series of three carriage returns is sent to the APDA through the serial port.
2. After the third carriage return, the APDA responds with a single asterisk (*) indicating that communication is established. If the APDA is moving the tape, it will respond with "BUSY". If the APDA is not in one of the OPERATION menus, it will not respond at all.
3. A single character "6" is sent to the APDA requesting the file 6 menu (CSV).
4. The APDA responds with the CSV menu options as shown below, ending with ">". The system requesting the files can ignore the menu response.
5. A single character "4" is sent to the APDA, requesting file 4 "Display Last Data".
6. The APDA responds with the Station ID number (in this case 5), 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. In this example, the "M" and "T" bits are high, indicating that the unit is taken out of operation, and that the tape has run out.

```
* 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, 0.0,0,0,30,57.0,27.1,0,0,1,0,0,0,0,0,0,0,0,0,1,
```

Example of CSV last data report

Example of a CSV Report of the "NEW DATA" records:

This file contains all of the data record since the last download, and resets the pointers.

In the following example, the data is retrieved exactly the same way as described above, except that file 3 "new data" is requested. The data starts at the first record since last time it was retrieved (oct 2, 2007 at 17:45). In this example, the MET SAMPLE was set to log the array every 15 minutes, but the particulate concentration value just repeats until the next hour.

```
* 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, 0.110,0,0,36,1.3,23.0,0,0,0,0,0,0,0,0,0,0,0,0,0,
10/02/07 18:00,  0.001, 0.700, 0.127,0,0,38,1.4,23.2,0,0,0,0,0,0,0,0,0,0,0,0,0,
10/02/07 18:15,  0.001, 0.700, 0.130,0,0,38,1.2,23.6,0,0,0,0,0,0,0,0,0,0,0,0,0,
10/02/07 18:30,  0.001, 0.700, 0.110,0,0,36,1.1,23.5,0,0,0,0,0,0,0,0,0,0,0,0,0,
10/02/07 18:45,  0.001, 0.700, 0.110,0,0,37,1.2,24.0,0,0,0,0,0,0,0,0,0,0,0,0,0,
10/02/07 19:00,  0.003, 0.700, 0.127,0,0,38,1.1,24.6,0,0,0,0,0,0,0,0,1,0,0,0,0,
10/02/07 19:15,  0.003, 0.700, 0.129,0,0,38,1.1,24.8,0,0,0,0,0,0,0,0,0,0,0,0,0,
10/02/07 19:30,  0.003, 0.700, 0.109,0,0,37,0.9,24.0,0,0,0,0,0,0,0,0,0,0,0,0,0,
```

Example of CSV new data report

The flow statistics fields available in the CSV menu are described below. These files are not available except on APDA units configured as FEM $PM_{2.5}$ units. A BX-596 sensor is required.

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

The 5 minute flow statistics averages are described below. These files are not available except on APDA 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	Minute average flow rate for the APDA sample period.
AT	Minute average ambient temperature for the APDA sample period.
BP	Minute average ambient pressure for the APDA sample period.

File 7: Display Last 100 Errors

This file will contain the date, time, and a description of each of the last 100 errors logged by the APDA-371. This is a useful file for troubleshooting, and it will often be requested by HORIBA technicians if service is required.

File 8: Display > APDA-371 < Utility Commands

This file contains a list of the ASCII commands can be sent to the APDA-371 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 appropriate command character is sent to the APDA to apply the functions shown in the table below.

Command	Command Function
a	**Printer Port Output Configuration.** This sets what is output on the 2nd serial 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 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 or ?	**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.

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

The Printer port on the back of the APDA-371 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 <u>the main RS-232 port</u>. (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 new 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 ¯ g/m3 is: **mm/dd/yy hh:mm:ss,+999999,+9.999**

If the APDA 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 APDA 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 HORIBA BX-996 modem is recommended for use with the APDA-371, as it is designed to reliably communicate when other modems may not. Note: the RS-232 Polarity switch on the back of the APDA-371 may need to be set to REVERSE polarity for communication using the modem. If you are using one of the HORIBA data acquisition programs such as MicroMet Plus or MicroMet AQ, 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.

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 APDA-371. Verify the connection to the APDA-371 by pressing the <Enter> key until the command prompt asterisk (*) appears. If not, verify the cabling and communications settings. Once connected, the access to the APDA-371 is the same menu driven interface as used for the direct PC connection.

9.7 Flash Firmware Upgrades

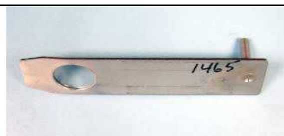
The APDA-371 now has the capability for flash firmware upgrades. This allows the field operator to reprogram the flash EEPROM through the serial port using the Flash Update Utility. Units with a firmware revision of 3.0 or higher can be flash upgraded. If the unit currently has a revision lower than 3.0, the EEPROM will have to be replaced with a flash compatible chip. The following tasks must be performed whenever firmware is upgraded or the EEPROM is replaced:

1. Download and save all data and error logs before proceeding. These will be cleared during the upgrade process!
2. Record the OFFSET value from the SETUP > SAMPLE screen, and the BKGD value from the SETUP > CALIBRATE screen. A download of the settings file is advised.
3. Update the firmware.
4. The baud rate will default to 38400. Reset as appropriate.
5. Recalibrate the filter temperature and filter RH sensors.
6. Set the values of OFFSET, CONC UNITS, and COUNT TIME in the SETUP > SAMPLE screen.
7. Set the values of CONC TYPE, FLOW TYPE, and BKGD in the SETUP > CALIBRATE screen. Review all other APDA-371 settings to make sure they are all correct.

10 ACCESSORIES and PARTS

10.1 *Consumables, Replacement Parts, and Accessories*

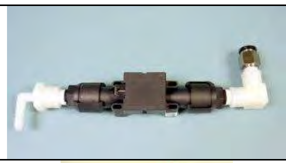
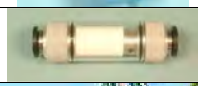
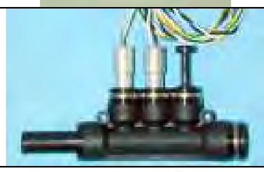
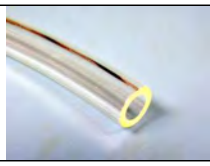
The following parts are available from HORIBA for maintenance, replacement, service, and upgrades. If unsure about a part you need, please contact the Service department. Some of these parts require technical skills or special considerations before use or installation.

Description	Part Number	Graphic
Consumables		
Filter Tape Roll, Glass Fiber, 60+ days per roll 30mm x 21m	**460130**	
Cotton-Tipped Applicators, nozzle cleaning, 100 pack Solon #362	**995217**	
Tools		
APDA-371 Service Tool Kit: Includes nozzle shims, spring scales, reel spacer, filter sensor removal tool	**BX-308**	
Leak Test Rubber Nozzle Seal	**7440**	
Membrane Assembly, Replacement, 0.800 mg/cm2	**8069**	
Membrane Assembly, Mid-Range, 0.500 mg/cm2	**BX-301**	
Mass Flow Calibration Kit, 0-20 SLPM	**BX-303**	
Flow Inlet Adapter Kit (Leak Test Valve) Includes short inlet tube	**BX-305**	
Zero Filter Calibration Kit, with valve Required for PM2.5 FEM monitoring Same as BX-305 but with 0.2 micron filter	**BX-302**	
Volumetric Flow Calibration Kit (BGI Delta Cal™) Flow, Temp, and Pressure Reference Standards HORIBA recommended flow meter	**BX-307**	

Pumps and Pump Parts

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 VAC, 60 Hz	**BX-123**	
Pump, Gast, Rotary Vane, 115 VAC, 50/60 Hz	**BX-121**	
Pump, Gast, Rotary Vane, 230 VAC, 50 Hz	**BX-122**	
Pump, Gast, Rotary Vane, 230 VAC, 60 Hz	**BX-124**	
Muffler, Medo/Gast Pump, Replacement	**580293**	
Pump Rebuild Kit, Gast	**680828**	
Pump Rebuild Kit, Medo	**680839**	
Pump Service Kit, Filter Replacement, Medo	**8588**	
Pump Controller (Relay Module) Medo/Gast	**BX-839**	

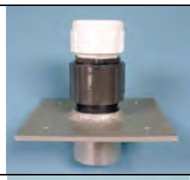
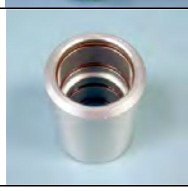
Flow Components

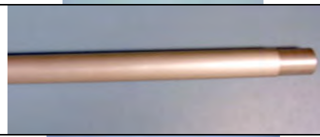
Flow Sensor, Mass, 0-20 LPM, Internal Assembly	**80324**	
Flow Controller Assembly, Replacement Only	**8776**	
Automatic Flow Controller Upgrade Kit	**BX-961**	
Filter Assembly, Pisco In-line	**580291**	
Filter Element Only, Pisco In-line	**580292**	
Filter Temperature and RH Sensor Kit	**BX-962**	
Filter 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**	
O-Ring, Inlet Receiver, 2 required	**720069**	
O-Ring Kit, APDA	**9122**	
Pump Tubing, Clear, 10mm O.D., 6.5mm I.D. Polyurethane, 25 foot roll standard	**960025**	

Electrical and Electronic Parts

Display, LCD, Front Panel	**2823**	
Circuit Board, CPU	**3230-8**	
Circuit Board, Interface	**3250-1**	
Circuit Board, Rear Panel Interconnect	**3260-1**	
Fuse, APDA-371, 3.15A, 250V, 5x20mm, 2 Req'd	**590811**	
Motor, with gear box, 4 RPM	**8105-1**	
Motor, with gear box, 10 RPM	**8106-1**	
Power Supply, 115 VAC, 60 Hz	**BX-115**	
Power Supply, 115 VAC, 50 Hz	**BX-116**	
Power Supply, 230 VAC, 60 Hz	**BX-230**	
Power Supply, 230 VAC, 50 Hz	**BX-231**	
Power Supply, 100 VAC, 60 Hz	**BX-100**	
Power Supply, 100 VAC, 50 Hz	**BX-101**	

Inlet Components

PM10 Inlet Head, EPA Specified	**BX-802**	
TSP Sampling Inlet Cap, with bug 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. Specify tube length, 8 feet std	**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, 220VAC	**9308**	
APDA 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**	
O-Rings, Cyclone, set of 6	**720097**	
O-Rings, PM10 Head, set of 3	**8965**	

Meteorological Sensors

590 Wind Direction Sensor, Auto ID	**BX-590**	
591 Wind Speed Sensor, Auto ID	**BX-591**	
592 Ambient Temperature Sensor	**BX-592**	
593 Ambient Relative Humidity Sensor	**BX-593**	
594 Ambient Barometric Pressure Sensor, Auto ID	**BX-594**	
595 Solar Radiation Sensor, Auto ID	**BX-595**	
596 AT/BP Combo Sensor Required for PM2.5 FEM monitoring	**BX-596**	
Real-Time Module (RTM), APDA Inlet Particle Sensor	**BX-894**	

Communications Components and Misc. Accessories

Serial Printer Kit	**BX-601**	
Converter for Parallel Printers	**BX-602**	
Modem Kit	**BX-996**	
Serial Cable, 6', DB-9 female/female, null, APDA to PC	**400658**	
Belkin F5U109 USB-to-RS-232 Adapter	**550067**	
Enclosure, Outdoor, Heated, Mfg by Shelter One	**BX-902**	
Enclosure, Outdoor, Heated and Air Conditioned Mfg by Ekto. Available with 2000 or 4000 BTU A/C.	**BX-903** **BX-904**	

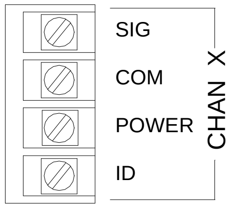
10.2 Series 500 Sensor Configurations

The APDA-371 has six channels of inputs available on the back of the unit for data logging external sensors. The 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 particular type of sensor. When one of these sensors is attached to the APDA, the unit senses this ID voltage and automatically configures the channel to read the sensor with all the correct scaling parameters.

Most APDA-371 units are equipped with at least the ambient temperature sensor BX-592 because ambient temperature is required on channel six for actual flow control. If the APDA is used for $PM_{2.5}$ monitoring, then the BX-596 sensor is required instead. This is a combination ambient temperature and barometric pressure sensor which attaches to channels six and seven, and provides the EPA required AT/BP measurements for actual flow control and flow statistics.

The scaling and setups values of the series 500 Sensors are provided in the chart below. The unit should automatically set these values in the SETUP > SENSORS menu. The ID MODE must be set to AUTO to identify the sensors, or set to MANUAL to change the parameters.

500 Series Sensor Setup Parameters								
Model	**Type**	**Units**	**Range**	**Mult**	**Offset**	**FS VOLT**	**S/V**	**Inv Slope**
BX-590	WD	Deg	0 to 360	360	0	1.0	V	N
BX-591	WS	mph m/s	0 to 100 0 to 44.704	100 44.70	0 0	1.0 1.0	S S	N N
BX-592	AT	^{0}F ^{0}C	-22 to +122 -30 to +50	144 80	-22 -30	1.0 1.0	S S	N N
BX-593	RH	%	0 to 100	100	0	1.0	S	N
BX-594	BP	inHg mmHg mbar	20 to 32 508.0 to 812.8 677.1 to 1083.6	6 152.40 203.19	26 660.40 880.46	1.0 1.0 1.0	S S S	N N N
BX-595	SR	Ly/min W/M2	0 to 2 0 to 2000	2 2000	0 0	1.0 1.0	S S	N N
BX-596	AT/BP	^{0}C mmHg	-40 to +55 525 to 825	95 300	-40 525	2.5 2.5	S S	N N



APDA-371 Back Panel Sensor Input Terminal

500 Series Sensor Wiring Connections for APDA-371

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/Pressure Combo Sensor	
Terminal Block	**Cable Wire Color**
Channel 6 SIG	Yellow
Channel 6 COM	Black/Shield
Channel 6 POWER	Red
Channel 6 ID	Green
Channel 7 SIG	White

Notes:

- BX-592 is always connected to channel 6 when used for flow control with a APDA-371.
- BX-592 or BX-596 is required for actual flow control.
- BX-596 is required for $PM_{2.5}$ monitoring, effective March 2007.

Mounting:

The 500 series sensors typically mount near the top of the APDA-371 inlet tube with a short cross-arm and related hardware. The sensors may also be mounted to a nearby tripod, such as HORIBA model 905.

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

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

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 APDA-371, 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

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

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

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

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

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

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 APDA-371 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 APDA-371 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 APDA-371 units with a manual flow valve, this value is on the order of ± 3%. For APDA-371 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 APDA-371 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 APDA which was configured to report data in EPA Standard conditions (298 K 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 303 K and the average pressure was 720 mmHg.

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

APDA-371 Audit Sheet

Model: APDA-371 **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

		APDA	Ref. Std.		APDA	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:	lpm	lpm	as left:	lpm	lpm	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 APDA:	as found	as left		

Analog Voltage Output Audit		N/A
DAC Test Screen	**APDA 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	**APDA Flow**
15.0 LPM	
16.7 LPM	
18.3 LPM	

Setup and Calibration Values								
Parameter	**Expecte d**	**Found**	**Parameter**	**Expected**	**Found**	**Parameter**	**Expecte d**	**Foun d**
Clock Time/Date			FLOW TYPE			AP		
RS232			Cv			FRl		
STATION #			Qo			FRh		
RANGE			ABS			Password		
APDA 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 APDA-371 Error Log					
Error	**Date**	**Time**	**Error**	**Date**	**Time**
1			4		
2			5		
3			6		

Audit Notes:

OPERATOR NOTES: