TÜV RHEINLAND ENERGY GMBH

Report on the performance test of the APDA-372 ambient dust monitor for suspended particulate matter PM_{10} and $PM_{2.5}$ manufactured by HORIBA Europe GmbH,

TÜV-Report No.: 936/21226418/C
Cologne, 07 December 2016

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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, 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 Energy GmbH to carry out performance testing of the APDA-372 ambient dust monitor for suspended particulate matter PM_{10} and $PM_{2.5}$. 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
- 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
- European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005
- Guideline "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated January 2010.

The APDA-372 measuring systems uses scattered light with a combination of a polychromatic LED and a 90° scattering detection to determine dust concentrations. A pump sucks in ambient air via a Sigma2 sampling inlet (4.8 l/min @ 25 °C and 1013 hPa). The air is then transported to the measuring system via a sampling tube. A heater for the IADS (Intelligent Aerosol Drying System) is integrated in the sampling tube to prevent condensation effects on particles. The aerosol passes through the aerosol sensor immediately downstream of the sampling tube. This is where both the particle size and the number of particles is measured in real time, simultaneously but separately relying on the scattered-light method.

The tested certification range was:

Component	Certification range
PM_{10}	0–10,000 µg/m³
$PM_{2,5}$	0–10,000 µg/m³

With the exception of a modified front design (“Horiba” replaces “Palas” and “APDA-372” replaces “Fidas® 200”) and an adapted software, the APDA-372 ambient dust monitor ambient dust monitor is absolutely identical to the Fidas® 200 measuring system designed and completely manufactured by PALAS GmbH. The Fidas® 200 measuring system is the indoor version of the Fidas® 200 S measuring system for suspended particulate matter, PM_{10} and $PM_{2.5}$ fractions, which has already been performance tested and publically announced as such. Approval of the Fidas® 200 measuring system is planned by way of a notification submitted to the relevant body.

The announcement history of the Fidas® 200 measuring system for PM_{10} and $PM_{2.5}$ manufactured by PALAS GmbH is as follows:

1. Fidas® 200 S for suspended particulate matter PM_{10} and $PM_{2,5}$, UBA announcement of 27 February 2014 (BAnz AT 01.04.2014 B12, Chapter IV Number 5.1)

   A further statement dated 27 September 2014 will be submitted to the relevant body regarding approval of the Fidas® 200 indoor version as well as changes introduced to the hardware and software since the system was first approved.

The initial announcement and the statement dated 27 September 2014 were taken into account for the relevant notification proposal and listed in the appendix.

No actual tests were performed for the performance test of the APDA-372 ambient dust monitor. The publication is based on document inspections and on-site audits.

The measuring system is exclusively manufactured by PALAS GmbH based in Karlsruhe. 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 Karlsruhe demonstrated that the instruments are absolutely identical in design.

The minimum requirements were satisfied during the performance test.

TÜV Rheinland Energy 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} and $PM_{2,5}$ fraction.

The present report contains a certification proposal for the APDA-372 ambient dust monitor for suspended particulate matter PM_{10} and $PM_{2.5}$. The appendices include the report on performance testing and the text of the notification regarding the Fidas® 200 S for suspended particulate matter PM_{10} and $PM_{2.5}$ as well as the operation manual for the APDA-372 ambient dust monitor measuring system for suspended particulate matter PM_{10} and $PM_{2.5}$.

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DAkkS Deutsche Akkreditierungsstelle D-PL-11120-02-00

Report on the performance test of the APDA-372 ambient dust monitor for suspended particulate matter PM_{10} and $PM_{2.5}$ manufactured by HORIBA Europe GmbH

AMS designation:	APDA-372 ambient dust monitor for suspended particulate matter PM_{10} and $PM_{2.5}$
Manufacturer:	HORIBA Europe GmbH Hans-Mess-Straße 6 61440 Oberursel
Test period:	April 2012 to September 2013
Date of report:	07 December 2016
Report Number:	936/21226418/C
Editor:	Dipl.-Ing. Guido Baum guido.baum@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-372 for suspended particulate matter PM_{10} and $PM_{2.5}$

Manufacturer:

HORIBA Europe GmbH, Oberursel

Field of application:

For continuous and parallel monitoring of suspended particulate matter, PM_{10} and $PM_{2.5}$ fraction, in ambient air from stationary sources

Measuring ranges during performance testing:

Component	Certification range	Unit
PM_{10}	0–10,000	µg/m³
$PM_{2,5}$	0–10,000	µg/m³

Software versions:

Measuring system:
100380.0014.0001.0001.0011

Algorithm implemented for evaluation: PM_ENVIRO_0011

PDAnalyze evaluation software: 1.010

Restrictions:

none

Notes:

1. The measuring system complies with the requirements of guideline “Demonstration of Equivalence of Ambient Air Monitoring Methods” for the component PM_{10} and $PM_{2.5}$.
2. One of the tested instruments did not meet the requirements for the variation coefficient R^2 as defined in EN 12341 during the campaign in Cologne, summer.
3. The measuring system is designed for indoor use at temperature controlled sites.
4. The sensitivity of the particle sensor has to be checked once a month using CalDust 1100.
5. The instrument must be calibrated on-site regularly using a gravimetric PM_{10} reference method in accordance with EN 12341.
6. The instrument must be calibrated on-site regularly using a gravimetric $PM_{2.5}$ reference method in accordance with EN 14907.
7. This report on the performance test is available online at www.qal1.de.

Test Report:

TÜV Rheinland Energy GmbH, Cologne
Report No.: 936/21226418/C dated 07 December 2016

Cologne, 07 December 2016

Dipl.-Ing. Guido Baum B.-Eng. Stefan Heift

Appendices

- Report on the performance test of the Fidas® 200 S air quality monitoring system manufactured by PALAS GmbH measuring components suspended particulate matter PM_{10} and $PM_{2.5}$ 936/21227195/C dated 12 October 2016
- Text of the notification regarding the Fidas® 200 S and Fidas® 200 air quality monitoring systems manufactured by PALAS GmbH, statement issued on 27 September 2014
- Operation manual for the APDA-372 ambient dust monitor

TÜV RHEINLAND
ENERGIE UND UMWELT GMBH

Deutsche Akkreditierungsstelle D-PL-11120-02-00

Report on supplementary testing of the Fidas® 200 S respectively Fidas® 200 measuring system manufactured by PALAS GmbH for the components suspended particulate matter PM_{10} and $PM_{2.5}$

TÜV-report: 936/21227195/C
Cologne, 12 October 2016

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The department of Environmental Protection of TÜV Rheinland Energie und Umwelt GmbH
is accredited for the following work areas:

- Determination of air quality and emissions of air pollution and odour substances;
- Inspection of correct installation, function and calibration of continuously operating emission measuring instruments, including data evaluation and remote emission monitoring systems;
- Combustion chamber measurements;
- Type approval testing of measuring systems for continuous monitoring of emissions and ambient air, and of electronic data evaluation and remote emission monitoring systems;
- Determination of stack height and air quality projections for hazardous and odour substances;
- Determination of noise and vibration emissions and pollution, determination of sound power levels and execution of sound measurements at wind energy plants

according to EN ISO/IEC 17025.

The accreditation is valid up to 22-01-2018. DAkkS-register number: D-PL-11120-02-00.

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Report on supplementary testing of the Fidas® 200 S respectively Fidas® 200 measuring system manufactured by PALAS GmbH for the components suspended particulate matter PM10 and PM2.5

Instrument tested:	Fidas® 200 S respectively Fidas® 200
Manufacturer:	PALAS GmbH Greschbachstraße 3b 76229 Karlsruhe Germany
Test period:	April 2012 until September 2013 (Initial type approval) July 2014 until February 2015 (Supplementary testing)
Date of report:	12 October 2016
Report number:	936/21227195/C
Editor:	Dipl.-Ing. Guido Baum Tel.: +49 221 806-5463 guido.baum@de.tuv.com

Scope of report:

Report:		264	pages
Annex	Page	265	pp.
Manual	Page	320	pp.
Manual	of	247	pages
Total		569	pages

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1. General and certification proposal

1.1 General

According to Directive 2008/50/EC dated 21st May 2008 (replaces air quality framework directive 96/62/EC dated 27th September 1996 including the related daughter directives 1999/30/EC, 2000/69/EC, 2002/3/EC as well as the Council decision 97/101/EC) on “ambient air quality and cleaner air for Europe”, the reference method for measuring the PM_{10} concentration as per “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 of equality” given in EN 12341 and the reference method for measuring the $PM_{2,5}$ concentration as per “Ambient air quality – Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter” given in EN 14907 shall be used. A Member State can, in the case of particulate matter, use any other method which the Member State concerned can demonstrate displays a consistent relationship to the reference method. In that event the results achieved by that method must be corrected to produce results equivalent to those that would have been achieved by using the reference method (2008/50/EC, Annex VI, B).

The Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods” [5] which was developed by an ad-hoc EC working group in January 2010

(Source: http://ec.europa.eu/environment/air/quality/legislation/pdf/equivalence.pdf)

describes a method for testing for equivalence of non-standardised measurement methods.

The requirements set out in the Guide for equivalence testing have been included in the last revision of the VDI Standards 4202, Sheet 1 and VDI 4203, Sheet 3.

In this type approval testing the following limit values were applied:

	$PM_{2.5}$	**PM_{10}**
Daily limit DL (24 h)	Not defined	50 µg/m³
Annual limit AL (1 a)	25 µg/m³*	40 µg/m³

as well as for the calculations according to the Guide [5]

	$PM_{2.5}$	**PM_{10}**
Limit value	30 µg/m³	50 µg/m³

The 2002 VDI guideline 4202, Sheet 1 describes the “Minimum requirements for suitability tests for ambient air quality systems”. General parameters for the related tests are set out in VDI Standard 4203, Sheet 1 “Testing of automated measuring systems – General concepts” of October 2001 and further specified in VDI 4203, Sheet 3 “Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants” of August 2004.

VDI Standards 4202, Sheet 1 and 4203, Sheet 3 underwent extensive revision and were newly published in September 2010. Unfortunately, after this revision there are some ambiguities and contradictions in relation to the type approval testing of particulate measuring systems as far as minimum requirements on the hand and the general relevance of test items on the other hand are concerned. The following test items require clarification:

6.1 5.3.2 Repeatability standard deviation at zero point

→ no minimum requirement defined

6.1 5.3.3 Repeatability standard deviation at reference point

→ not relevant to particulate measuring systems

6.1 5.3.4 Linearity (lack of fit)

→ not relevant to particulate measuring systems

6.1 5.3.7 Sensitivity coefficient of surrounding temperature

→ no minimum requirement defined

6.1 5.3.8 Sensitivity coefficient of supply voltage

→ no minimum requirement defined

6.1 5.3.11 Standard deviation from paired measurements

→ no minimum requirement defined

6.1 5.3.12 Long-term drift

→ no minimum requirement defined

6.1 5.3.13 Short-term drift

→ not relevant to particulate measuring systems

6.1 5.3.18 Overall uncertainty

→ not relevant to particulate measuring systems, covered by 5.4.10.

In order to determine a concerted procedure for dealing with the inconsistencies in the guidelines, an official enquiry was directed to the competent body in Germany.

The following procedure was suggested:

As before, the test items 5.3.2, 5.3.7, 5.3.8, 5.3.11, and 5.3.12 are evaluated based on the minimum requirements set out in VDI 4202, Sheet 1 of 2002 (i.e. using the reference values B_0, B_1, and B_2).

The test items 5.3.3, 5.3.4, 5.3.13, and 5.3.18 are omitted as they are not relevant to particulate measuring systems.

The competent body in Germany approved of the suggested procedure by decisions of 27 June 2011 and 7 October 2011.

The reference values which shall be used according to the applied guidelines explicitly refer to the measured component $PM_{10.}$ Therefore, the following reference values are suggested for the measured component $PM_{2.5}$:

	$PM_{2,5}$	**PM_{10}**
B_0	2 µg/m³	2 µg/m³
B_1	25 µg/m³	40 µg/m³
B_2	200 µg/m³	200 µg/m³

B_1 shall merely be adjusted to the level of the limit value for the annual mean.

PALAS GmbH has commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out a supplementary test of the Fidas® 200 S respectively Fidas® 200 measuring system for the components suspended particulate matter PM_{10} and $PM_{2.5}$ according to the following standards:

- VDI Standard 4202, Sheet 1, “Performance criteria for type approval tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants”, September 2010/June 2002
- VDI Standard 4203, Sheet 3, “Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants”, September 2010/August 2004
- Standard 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 of equality”, German version EN 12341: 1998
- Standard EN 14907, “Ambient air quality – Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter”, German version EN 14907: 2005
- Guidance document “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of January 2010

The measuring system Fidas® 200 S was type-approved and published as follows:

- Fidas® 200 S for suspended particulate matter PM_{10} and $PM_{2.5}$ with announcement of Federal Environment Agency UBA of 27 February 2014 (BAnz AT 01.04.2014 B12, chapter IV, number 5.1)

Furthermore a notification on modifications was submitted for the measuring system to the 35th expert meeting "Test reports" in Autumn 2014 (Statement of TÜV Rheinland Energie und Umwelt GmbH of 27 September 2014) and the following modifications have been approved:

- The measuring system Fidas® 200 S for the components suspended particulate matter PM_{10} and $PM_{2.5}$ of the company PALAS GmbH is also available as an indoor-version for installation at temperature-controlled sites under the designation Fidas® 200 for the components suspended particulate matter PM_{10} and $PM_{2.5}$.
- The measuring system gets an additional port for a digital output signal on the instrument rear side.
- The LED of the Fidas® sensor of the type Osram Ostar Projektion Art.-Nr. LE B H3W has been discontinued and has been replaced by a LED of the type Osram Ostar Stage Art.-Nr. LE ATB S2W
- The presentation of the software version of the measuring system has been modified.

  The software version published so far depicts now as follows:

  100327.0007.0001.0001.0011
- The current software version of the measuring system is:

  100380.0014.0001.0001.0011

The publication of the mentioned modifications in the Federal Gazette "Bundesanzeiger" has happened with announcement of Federal Environment Agency UBA of 25 February 2015 (BAnz AT 02.04.2015 B15, chapter IV, 14th notification).

The supplementary test at hand has been carried out with the following objectives:

1. In the course of the instrument approval in the UK (based on German type-approval), extension of the equivalence test by 2 UK comparison campaigns to a total of 6 comparison campaigns, evaluation with the evaluation algorithm PM_ENVIRO_0011. The investigations on site have been carried out by the British test institutes Bureau Veritas UK and National Physical Laboratory NPL. The obtained measuring data have been evaluated in parallel and independently by TÜV Rheinland and Bureau Veritas UK.

   Description in chapter 7 “Extension of the equivalence test by English comparison campaigns” from page 208

2. Update of the type approval publication based on the statement of TÜV Rheinland Energie und Umwelt GmbH of 27 September 2014.

   Description in chapter 8 “Description of instrument modifications based on the statement of 27 September 2014” from page 246

3. Addition of the test dust MonoDust1500 as additional test standard for checking the instrument sensitivity.

   Description in chapter 3.3 AMS scope and setup from page 47

Apart from the explicit investigations for qualification of the instrument version Fidas® 200 (refer to chapter 9 "Description of instrument modifications based on the statement of 27 September 2014"), all tests have been carried out with the instrument version Fidas® 200 S.

The obtained test results and the subsequent conclusions and statements described in the chapter 6 (Test results of initial type approval) and chapter 7 (Extension of the equivalence test by English comparison campaigns) are valid to full extent for both instrument versions except for the investigations on the influence of ambient temperature (Fidas® 200 S for outdoor installation, Fidas® 200 for indoor installation).

The measuring system Fidas® 200 S respectively Fidas® 200 operates according to the principle of scattered light measurement using a combination of a polychromatic LED and 90° scattered light detection to measure dust concentrations. By means of a pump ambient air is sucked in via a Sigma-2 sampling head (4.8 l/min @ 25 °C and 1013 hPa) and led through the sampling line into the actual measuring system. The sampling line contains a heater for the IADS (Intelligent Aerosol Drying System) to avoid condensation on the particles. After passing through the sampling line, the aerosol directly passes through the aerosol sensor where particle number concentration and particle size are measured simultaneously in real time, yet separately, by means of optical light scattering.

The tests were performed in the laboratory and during a field test that lasted several months.

The field test which lasted several months was performed at the test sites given in Table 1.

Table 1: Description of test sites

	Cologne, parking lot, summer	Cologne, parking lot, winter	Bonn, street crossing, winter	Bornheim, motorway parking area, summer
Period	05/2012 – 09/2012	11/2012 – 02/2013	02/2013 – 05/2013	05/2013 – 07/2013
No. of paired values: candidates	101	66	60	58
Characteristics	Urban background	Urban background	Influenced by traffic	Rural structure + motorway
Level of ambient air pollution	Low to average	Average to high	Average to high	Low

Additional investigations on the equivalence have been done in two comparison campaigns in the UK according to Table 2.

Table 2: Description of test sites (UK)

	Teddington, winter	Teddington, summer
Period	02/2014 – 04/2014	04/2014 – 06/2014
No. of paired values: candidates	45	45
Characteristics	Urban background	Urban background
Level of ambient air pollution	Average	Average

The following table gives an overview on the results of the performed equivalence tests :

Table 3: Results of equivalence tests

Campaigns	Evaluation algorithms	PM_x	Slope	Inter-cept	All Data W_{CM}<25 % Raw data	Calibration yes/no	All Data W_{CM}<25 % Cal. data
D	PM_ENVIRO_0011	PM_{10}	1.058	-1.505	yes	yes*	yes
	PM_ENVIRO_0011	$PM_{2.5}$	1.076	-0.339	no	yes	yes
D+UK	PM_ENVIRO_0011	PM_{10}	1.037	-1.390	yes	yes*	yes
	PM_ENVIRO_0011	$PM_{2.5}$	1.060	-0.210	no	yes	yes

* Calibration necessary due to significance of slope and/or intercept

The minimum requirements were fulfilled during type approval testing [11] as well as during the supplementary testing.

TÜV Rheinland Energie und Umwelt GmbH therefore suggests its approval as a type approval tested measuring system for continuous monitoring of ambient air pollution by suspended particulate matter PM_{10} and $PM_{2.5}$.

1.2 Certification proposal

Due to the positive results achieved, the following recommendation is put forward for the notification of the AMS as a performance-tested measuring system:

AMS designation:

Fidas® 200 S respectively Fidas® 200 for suspended particulate matter PM_{10} and $PM_{2.5}$

Manufacturer:

PALAS GmbH, Karlsruhe

Field of application:

Continuous and parallel measurement of the PM_{10} and $PM_{2.5}$ fractions in ambient air (stationary operation).

Measuring ranges during type approval testing:

Component	Certification range	Unit
PM_{10}	0 – 10 000	µg/m³
$PM_{2,5}$	0 – 10 000	µg/m³

Software version:

100380.0014.0001.0001.0011

Restrictions:

None

Notes:

1. The measuring system Fidas® 200 S is also available as an indoor version for installation at temperature controlled sites under the designation Fidas® 200.
2. The requirements according to the guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" are met for the four comparison campaigns (initial testing) as well as for the six comparison campaigns (supplementary testing) for the measured components PM_{10} und $PM_{2.5}$.
3. One of the candidates did not meet the requirements in regard to the variation coefficient R^2 as specified in Standard EN 12341:1998 at the Cologne site (summer).
4. The sensitivity of the particle sensor shall be checked with CalDust 1100 or Mono Dust1500 once a month.
5. The measuring system shall be calibrated on site with the gravimetric PM_{10} respectively $PM_{2.5}$ reference method as per EN 12341:2014 on a regular basis.
6. This report on the type approval testing can be viewed on the internet at www.qal1.de.
7. Supplementary test (Extension of equivalence test, Description of instrument modifications, Addition of test standard Mono Dust 1500) to the announcements of Federal Environment Agency UBA of 27 February 2014 (BAnz AT 01.04.2014 B12, chapter IV, number 5.1) and of 25 February 2015 (BAnz AT 02.04.2015 B5, chapter IV, 14th notification).

Test report:

TÜV Rheinland Energie und Umwelt GmbH, Cologne

Report no.: 936/21227195/C of 12 October 2016

1.3 Summary of test results

Compilation of test results "Initial type approval test"

Performance criterion	Specification	Test result	Fulfilled	Page
4 Requirements on instrument design				
4.1 General requirements				
4.1.1 Measured value display	Shall be available.	The measuring system provides a display that shows the measured values.	yes	80
4.1.2 Easy maintenance	Necessary maintenance of the measuring systems should be possible without larger effort, if possible from outside.	Maintenance work can be carried out from the outside with commonly available tools and reasonable time and effort.	yes	81
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.	All functions described in the operator's manual are available, can be activated, and work properly.	yes	84
4.1.4 Setup times and warm-up times	Shall be specified in the instruction manual.	Setup and warm-up times were determined.	yes	86
4.1.5 Instrument design	Shall be specified in the instruction manual.	The instrument design specifications listed in the operator's manual are complete and correct.	yes	87
4.1.6 Unintended adjustment	It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation.	The measuring system is secured against illicit or unintentional adjustments of instrument parameters. Additional protection against unauthorized access is provided by the lockable door of the weatherproof housing.	yes	88
4.1.7 Data output	The output signals shall be provided digitally and/or as analogue signals	The test signals are provided digitally (via Ethernet, RS232, and USB).	yes	89

Performance criterion	Requirement	Test result	Fulfilled	Page
5. Performance criteria				
5.1 General	The manufacturer's specifications in the instruction manual shall not contradict the results of the type approval test.	No differences between the instrument design and the descriptions given in the manuals were found.	yes	91
5.2 General requirements				
5.2.1 Certification ranges	Shall comply with the requirements of Table 1 of VDI Standard 4202, Sheet 1.	Assessment of AMS in the range of the relevant limit values is possible.	yes	92
5.2.2 Measuring range	The upper limit of measurement of the measuring systems shall be greater or equal to the upper limit of the certification range.	The upper limit of measurement is greater than the corresponding upper limit of the certification range.	yes	93
5.2.3 Negative output signals	Negative output signals or measured values may not be suppressed (life zero).	Negative output signals are directly displayed by the AMS and can be output via corresponding data outputs. Yet, they are not to be expected due to measuring principle and instrument design.	yes	94
5.2.4 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.	All parameters are secured against loss by buffering. When mains voltage returns the AMS goes back to failure-free operation mode and automatically resumes measuring after reaching the "device ready" instrument status.	yes	95
5.2.5 Operating states	The measuring system shall allow the control of important operating states by telemetrically transmitted status signals.	The measuring systems can be monitored and operated extensively from an external PC via modem or router.	yes	96
5.2.6 Switch-over	Switch-over between measurement and functional check and/or calibration shall be possible telemetrically by computer control or manual intervention.	In principle, all necessary operations for performing a functional check can be monitored directly on the system or via telemetric remote control.	yes	97
5.2.7 Maintenance interval	If possible 3 months, minimum 2 weeks.	The maintenance interval of 4 weeks has been determined by regular checks of the particle sensor with CalDust 1100.	yes	98

Performance criterion	Specification	Test result	Fulfilled	Page
5.2.8 Availability	Minimum 95 %.	The availability was 99.4 % for SN 0111 and 99.1 % for SN 0112 without test-related downtimes. Including test-related downtimes it was 90.6 % for SN 0111 and 90.3 % for SN 0112.	yes	99
5.2.9 Instrument software	The version of the instrument software to be tested shall be displayed during switch-on of the measuring system. The test institute shall be informed on changes in the instrument software, which have influence on the performance of the measuring system.	The version of the instrument software is displayed during switch-on of the measuring system and can be viewed at all times in the “expert user menu”. The test institute is informed on any changes in the instrument software. Mass concentration values are determined by means of the PM_ENVIRO_0011 evaluation algorithm. The validation of an additional evaluation algorithm demands explicit attestation of compliance with the minimum requirements on the basis of the raw datasets obtained during this type approval test.	yes	101
5.3 Requirements on measuring systems for gaseous air pollutants				
5.3.1 General	Minimum requirement according to VDI 4202, Sheet 1.	The test was carried out on the basis of the performance criteria stated in VDI Standard 4202, Sheet 1 (September 2010). However, the test items 5.3.2, 5.3.7, 5.3.8, 5.3.11, and 5.3.12 were evaluated on the basis of the performance criteria stated in the 2002 version of VDI Standard 4202, Sheet 1 (i.e. applying the reference values B_0, B_1, and B_2). The test items 5.3.3, 5.3.4, 5.3.13, and 5.3.18 were omitted as they are irrelevant to particulate measuring devices.	yes	103
5.3.2 Repeatability standard deviation at zero point	The repeatability standard deviation at zero point shall not exceed the requirements of Table 2 in the certification range according to Table 1 of VDI Standard 4202, Sheet 1 (September 2010). For PM: Max. B_0.	The tests resulted in detection limits of 8.7 x 10^{-4} µg/m³ (PM_{10}) and 8.7 x 10^{-4} µg/m³ ($PM_{2.5}$) for System 1 (SN 0111), and 6.6 x 10^{-7} µg/m³ (PM_{10}) and 6.6 x 10^{-7} µg/m³ ($PM_{2.5}$) for System 2 (SN 0112).	yes	105
5.3.3 Repeatability standard deviation at reference point	The repeatability standard deviation at reference point shall not exceed the requirements of Table 2 in the certification range according to Table 1 of VDI Standard 4202, Sheet 1 (September 2010).	Not applicable.	-	107

Performance criterion	Specification	Test result	Fulfilled	Page
5.3.4 Linearity (lack of fit)	The analytical function describing the relationship between the output signal and the value of the air quality characteristic shall be linear.	Particulate measuring systems for PM_{10} shall be tested according to performance criterion 5.4.2 “Equivalency of the sampling system”. Particulate measuring systems for $PM_{2.5}$ shall be tested according to performance criterion 5.4.10 “Calculation of expanded uncertainty between candidates”.	-	108
5.3.5 Sensitivity coefficient of sample gas pressure	The sensitivity coefficient of the sample gas temperature at reference point shall not exceed the specifications of Table 2 of VDI Standard 4202, Sheet 1 (September 2010).	Not applicable.	-	109
5.3.6 Sensitivity coefficient of sample gas temperature	The sensitivity coefficient of the surrounding temperature at zero and reference point shall not exceed the specifications of Table 2 of VDI Standard 4202, Sheet 1 (September 2010).	Not applicable.	-	110
5.3.7 Sensitivity coefficient of surrounding temperature	The sensitivity coefficient of the surrounding temperature at zero and reference point shall not exceed the specifications of Table 2 of VDI Standard 4202, Sheet 1 (September 2010). For PM: Zero point value for ΔTu of 15 K between +5 °C and +20 °C or 20 K between +20 °C and +40 °C shall not exceed B_0. The measurement value in the range of B_1 shall not exceed ± 5 % for ΔTu of 15 K between +5 °C and +20 °C or for 20 K between +20 °C and +40 °C	The ambient temperature range tested at the AMS installation site was -20 °C to +50 °C. Looking at the values that were output by the AMS, the maximum dependence of ambient temperature in the range of -20 °C to +50 °C at zero was -1.1×10^{-5} µg/m³ for $PM_{2.5}$ and -1.1×10^{-5} µg/m³ for PM_{10}. At reference point, no deviations > 5.0 % for $PM_{2.5}$ and > 4.6 % for PM_{10} in relation to the default temperature of 20 °C were observed.	yes	111

Performance criterion	Specification	Test result	Fulfilled	Page
5.3.8 Sensitivity coefficient of supply voltage	The sensitivity coefficient of the electric voltage at reference point shall not exceed the specifications made in Table 2 of VDI Standard 4202, Sheet 1 (September 2010). For PM: Change in measured value at B_1 maximum B_0 within the voltage interval (230 +15/-20) V.	No deviations > 0.8 % for $PM_{2.5}$ and > 0.7 % for PM_{10} in relation to the default value of 230 V due to changes in supply voltage were detected.	yes	115
5.3.9 Cross-sensitivity	The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table 2 of VDI Standard 4202, Sheet 1 (September 2010) at zero and reference point.	Not applicable.	-	117
5.3.10 Averaging effect	For gaseous components the measuring system shall allow the formation of hourly averages. The averaging effect shall not exceed the requirements of Table 2 of VDI Standard 4202, Sheet 1 (September 2010).	Not applicable.	-	118
5.3.11 Standard deviation from paired measurements	The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test. It shall not exceed the specifications stated in Table 2 of VDI Standard 4202, Sheet 1 (September 2010). For PM: RD ≥ 10 related to B_1.	In the field test, the reproducibility for the complete dataset was 29 for $PM_{2.5}$ and 36 for PM_{10}.	yes	119

Performance criterion	Specification	Test result	Fulfilled	Page
5.3.12 Long-term drift	The long-term drift at zero point and reference point shall not exceed the requirements of Table 2 in the field test of VDI Standard 4202, Sheet 1 (September 2010) in the field test. For PM: Zero point: within 24 h and within the maintenance interval a maximum of B0. As reference point: within 24 h and within the maintenance interval a maximum 5 % of B1.	For $PM_{2.5}$, the maximum deviation at zero point was 0.1 µg/m³ in relation to the previous value and 0.1 µg/m³ in relation to the start value. Thus, it lies within the permissible limits of B_0 = 2 µg/m³. For PM_{10}, the maximum deviation at zero point was 0.1 µg/m³ for in relation to the previous value and 0.1 µg/m³ in relation to the start value. Thus, it lies within the permissible limits of B_0 = 2 µg/m³. The sensitivity drift values that were determined during testing are max. -4.7 % for $PM_{2.5}$ and -8.1 % for PM_{10} in relation to the respective start value. Therefore, they exceed the permissible deviation of ± 5 % of B_1. The manufacturer suggests adjustment of the AMS as soon as the deviation from the nominal channel 130 is ± 1.5 channels (according to the matrix in chapter 4.2 Laboratory test this corresponds to a 4 % deviation for $PM_{2.5}$ as well as for PM_{10}). On the basis of the results obtained in the drift tests, a sensitivity check shall be carried out once a month.	no	121
5.3.13 Short-term drift	The short-term drift at zero point and reference point shall not exceed the requirements of Table 2 of VDI Standard 4202, Sheet 1 (September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test.	Not applicable.	-	130
5.3.14 Response time	The response time (rise) of the measuring systems shall not exceed 180 s. The response time (fall) of the measuring systems shall not exceed 180 s. The difference between the response time (rise) and response time (fall) of the measuring system shall not exceed 10 % of response time (rise) or 10 s, whatever value is larger.	Not applicable.	-	131

Performance criterion	Specification	Test result	Fulfilled	Page
5.3.15 Difference between sample and calibration port	The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements of Table 2 of VDI Standard 4202, Sheet 1 (September 2010).	Not applicable.	-	132
5.3.16 Converter efficiency	In the case of measuring systems with a converter, the efficiency of the converter shall be at least 98 %.	Not applicable.	-	133
5.3.17 Increase of NO2 concentration due to residence in the AMS	In case of NO_x measuring systems, the increase of NO_2 concentration due to residence in the measuring system shall not exceed the requirements of Table 2 of VDI Standard 4202, Sheet 1 (September 2010).	Not applicable.	-	134
5.3.18 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 applicable EU Directives on air quality listed in Annex A, Table A1 of VDI Standard 4202, Sheet 1 (September 2010).	By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems. Please refer to module 5.4.10.	-	135
5.4 Requirements on measuring systems for particulate air pollutants				
5.4.1 General	Test according to the minimum requirement stated in Table 5 of VDI Standard 4202, Sheet 1. Furthermore, the particle mass concentration shall be related to a defined volume.	The test was carried out according to the minimum requirements set out in Table 5 of VDI Standard 4202, Sheet 1 (September 2010). The Fidas® 200 S measuring system is an optical measuring system which first determines the number and size of particles within a defined volume and then converts the obtained data to mass values by means of an algorithm. After that, the particle mass concentration is determined by relating the calculated mass to a sample volume.	yes	136

Performance criterion	Specification	Test result	Fulfilled	Page
5.4.2 Equivalency of the sampling system	The equivalency to the reference method according to EN 12341 [T2] shall be demonstrated.	The reference equivalence functions for the (uncorrected) datasets lie within the limits of the respective acceptance envelope for all test sites. Moreover, the variation coefficient R^2 of the calculated reference equivalence function in the concentration range concerned is ≥ 0,95 for all test sites with the exception of Cologne (summer; only for SN 0112). Nevertheless, the instruments passed the equivalence test according to 6.1 5.4.10 Calculation of expanded uncertainty between candidates at all test sites.	no	137
5.4.3 Reproducibility of the sampling systems	This shall be demonstrated in the field test for two identical systems according to EN 12341 [T2].	The two-sided confidence interval Cl95 of max. 1.88 µg/m³ is far below the permissible limit of 5 µg/m³.	yes	145
5.4.4 Calibration	The candidates shall be calibrated in the field test by comparison measurements with the reference method according to EN 12341 and EN 14907. Here, the relationship between the output signal and the gravimetrically determined reference concentration shall be determined as a steady function.	A statistical correlation between the reference measuring method and the output signal could be demonstrated.	yes	150
5.4.5 Cross sensitivity	Shall not exceed 10 % of the limit value.	No deviation of the measured signal from the nominal value > 0.5 µg/m³ caused by interference due to moisture in the sample could be observed for $PM_{2.5.}$ For PM_{10}, no deviation of the measured signal from the nominal value > -1.1 µg/m³ caused by interference due to moisture in the sample could be observed The reproducibility of the candidates using the reference method according to the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" [5] is ensured even for days with a relative humidity of > 70 %.	yes	153
5.4.6 Averaging effect	The measuring system shall allow the formation of 24 h mean values. The time of the sum of all filter changes within 24 h shall not exceed 1 % of this averaging time.	The measuring system allows the formation of daily mean values.	yes	157

Performance criterion	Specification	Test result	Fulfilled	Page
5.4.7 Constancy of sample volumetric flow	± 3 % of the rated value during sampling; instantaneous values ± 5 % of the rated value during sampling.	All determined daily mean values deviate less than ± 3 % from the rated value and all instantaneous values deviate less than ± 5 %.	yes	158
5.4.8 Tightness of the measuring system	Leakage shall not exceed 1 % of the sample volume sucked.	The criterion for passing the leakage test, which has been specified by the manufacturer, (flow at blocked inlet max. 0 ± 0.1 l/min) proved to be an appropriate parameter for monitoring instrument tightness. The detected maximum leak rate of 0.04 l/min is less than 1 % of the nominal flow rate which is 4.8 l/min.	yes	161
5.4.9 Determination of uncertainty between candidates ubs	Shall be determined according to chapter 9.5.3.1 of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" in the field test for at two identical systems.	The uncertainty between the candidates u_{bs} with a maximum of 0.84 µg/m³ for $PM_{2.5}$ and a maximum of 1.17 µg/m³ for PM_{10} does not exceed the required value of 2.5 µg/m³.	yes	164
5.4.10 Calculation of expanded uncertainty between candidates	Determination of the expanded uncertainty of the candidates according to chapters 9.5.3.2ff of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods".	Without application of correction factors, the determined uncertainties W_{CM} for PM_{10} for all datasets under consideration lie below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter. With the exception of Bornheim (summer) the determined uncertainties for $PM_{2.5}$ for all datasets under consideration and without application of correction factors lie below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter. Correction factors shall be applied according to chapter 6.1 5.4.11 Application of correction factors and terms.	no	176

Performance criterion	Specification	Test result	Fulfilled	Page
5.4.11 Application of correction factors and terms	If the maximum expanded uncertainty of the candidates exceeds the data quality objectives according to the European Directive on ambient air quality [8], the application of correction factors and terms is allowed. Values corrected shall meet the requirements of chapter 9.5.3.2 ff. of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods".	Due to application of the correction factors, the candidates meet the requirements on data quality of ambient air quality measurements for all datasets for $PM_{2.5}$ and PM_{10}. For PM_{10}, the requirements are met even without application of correction factors. The corrections of slope and intercept nevertheless lead to an improvement of the expanded measurement uncertainties of the full data comparison.	yes	199
5.5 Requirements on multiple-component measuring systems	Shall comply with the requirements set for each component also in the case of simultaneous operation of all measuring channels.	Upon assessing the minimum requirements, the measured values for both components were available at the same time.	yes	207

Compilation of test results
"Extension of equivalence test by English comparison campaigns, PM_ENVIRO_0011"

Performance criterion	Specification	Test result	Fulfilled	Page
5.4.9 Determination of uncertainty between candidates ubs	Shall be determined according to chapter 9.5.3.1 of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" in the field test for at two identical systems.	The uncertainty between the candidates u_{bs} with a maximum of 0.85 µg/m³ for $PM_{2.5}$ and a maximum of 1.19 µg/m³ for PM_{10} does not exceed the required value of 2.5 µg/m³.	yes	209
5.4.10 Calculation of expanded uncertainty between candidates	Determination of the expanded uncertainty of the candidates according to chapters 9.5.3.2ff of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods".	The determined uncertainties W_{CM} for PM_{10} for all datasets under consideration are below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter without the application of correction factors. The determined uncertainties W_{CM} for $PM_{2.5}$ for all datasets under consideration with exception of Bornheim, summer are below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter without the application of correction factors.	no	219
5.4.11 Application of correction factors and terms	If the maximum expanded uncertainty of the candidates exceeds the data quality objectives according to the European Directive on ambient air quality [8], the application of correction factors and terms is allowed. Values corrected shall meet the requirements of chapter 9.5.3.2 ff. of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods".	Due to application of the correction factors, the candidates meet the requirements on data quality of ambient air quality measurements for all datasets for $PM_{2.5}$ and PM_{10}. For PM_{10}, the requirements are met even without application of correction factors. The corrections of slope and intercept nevertheless lead to a (slight) improvement of the expanded measurement uncertainties of the complete data set.	yes	238

Compilation of test results
"Qualification of instrument version Fidas 200"

Performance criterion	Specification	Test result	Fulfilled	Page
5.3.7 Sensitivity coefficient of surrounding temperature	The sensitivity coefficient of the surrounding temperature at zero and reference point shall not exceed the specifications of Table 2 of VDI Standard 4202, Sheet 1 (September 2010). For PM: Zero point value for ΔTu of 15 K between +5 °C and +20 °C or 20 K between +20 °C and +40 °C shall not exceed B0. The measurement value in the range of B1 shall not exceed ± 5 % for ΔTu of 15 K between +5 °C and +20 °C or for 20 K between +20 °C and +40 °C	Looking at the values that were output by the AMS, the maximum dependence of ambient temperature in the range of +5 °C to +40 °C at zero was 5.5 x 10^{-5} µg/m³ for $PM_{2.5}$ and 5.7 x 10^{-5} µg/m³ for PM_{10}. At the reference point, no deviations > -2.2 % for $PM_{2,5}$ rspectively > -2.2 % for PM_{10} related to the base value at 20 °C could be determined for an ambient temperature in the range of +5 °C to +40 °C.	yes	246

2. Task definition

2.1 Nature of test

PALAS GmbH has commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out type approval testing respectively supplementary testing of the Fidas® 200 S respectively Fidas® 200 measuring system. The test was performed as a complete type approval test.

2.2 Objective

The measuring system shall determine the concentrations of suspended particulate matter PM_{10} and $PM_{2.5}$ within a concentration range of 0 to 10 000 µg/m³ (4,000 P/cm³ for 10 % coincidence errors).

The type approval test was carried out in accordance with the current standards for type approval tests and with regard to the most recent developments.

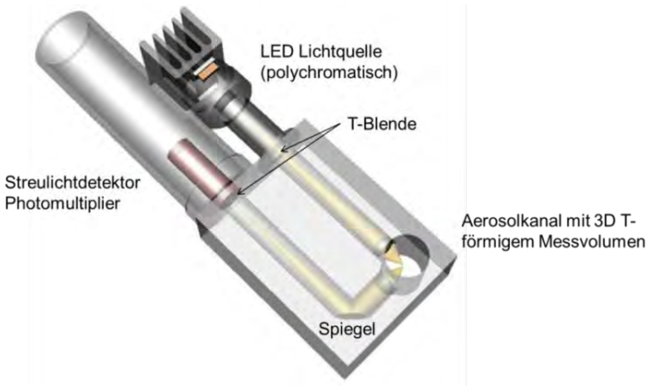
The testing was performed with respect to the following guidelines:

- VDI Standard 4202, Sheet 1, “Performance criteria for type approval tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants”, September 2010/June 2002 [1]
- VDI Standard 4203, Sheet 3, “Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants”, September 2010/August 2004 [2]
- European Standard 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 of equality”, German version EN 12341: 1998 [3]
- European Standard EN 14907, “Ambient air quality – Standard gravimetric measurement method for the determination of the $PM_{2,5}$ mass fraction of suspended particulate matter”, German version EN 14907: 2005 [4]
- Guidance document “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English Version: January 2010 [5]

3. Description of the AMS tested

3.1 Measuring principle

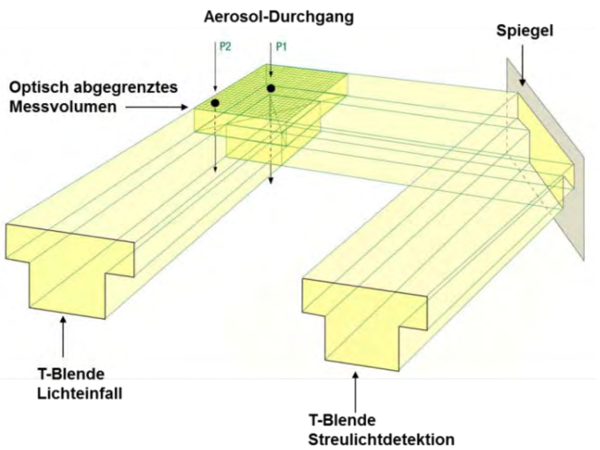
The Fidas® 200 S respectively Fidas® 200 is an optical aerosol spectrometer which determines particle size by means of scattered light analysis according to Lorenz-Mie.



Key
LED Lichtquelle (polychromatisch): LED light source (polychromatic)
T-Blende: T-aperture
Streulichtdetektor: light scattering detector
Photomultiplier: photomultiplier
Aerosolkanal mit 3D T-förmigem Messvolumen: aerosol channel with 3D T-shaped measurement volume
Spiegel: mirror

Figure 1: Design of the Fidas® sensor

The particles move separately through an optically differentiated measurement volume that is homogeneously illuminated with white light.



Key
Aerosol Durchgang: aerosol passage
Spiegel: mirror
Optisch abgegrenztes Messvolumen: accurately defined optical measurement volume
T-Blende Lichteinfall: T-aperture, incidence of light
T-Blende Streulichtdetektion: T-aperture, scattered light detection

Figure 2: Graphical representation of the T-aperture

By using a polychromatic light source (LED) in combination with 90° scattered light detection, a precise calibration curve without any ambiguities within Mie-range can be achieved. This enables working with an extremely high resolution.

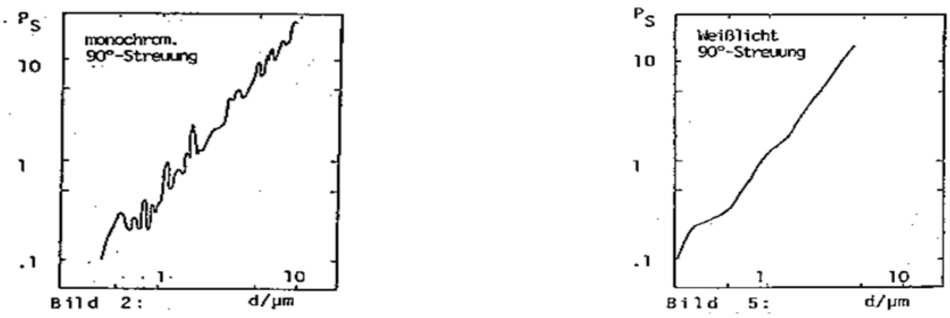


Figure 3: Calibration curve for 90° scattered light detection with monochromatic light source (left) and with polychromatic light source (right)

Each particle generates a scattered light impulse, detected at an angle of 85° to 90° degrees. The number concentration is deducted from the number of scattered light impulses. The intensity of the scattered light is a measure for the particle size-diameter. The signal length is measured as well.

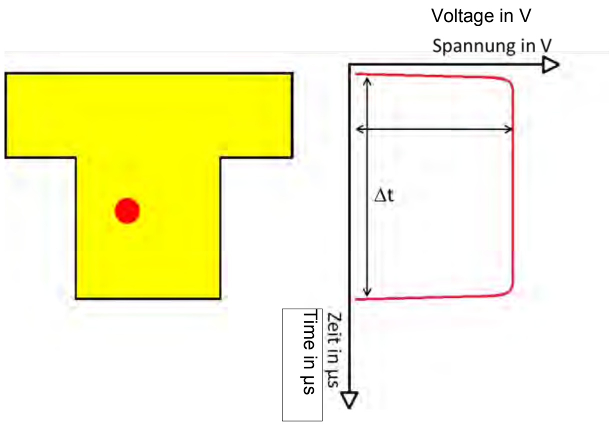


Figure 4: Measurement of scattered light signal at one single particle. Amplitude and signal length are being measured

Due to the specific T-aperture optics with simultaneous signal length measuring, border zone errors are eliminated. The term 'border zone error' refers to the merely partial illumination of particles at the end of the measuring range. This partial illumination results in the particles being classified as smaller in size than they actually are (see Figure 5, red curve). By means of the T-aperture, particles which only fly through the T's arm (shorter signal length) can be distinguished from particles which also pass the middle part of the T (longer signal length). The latter ones have certainly been illuminated completely in the upper part. Thus, border zone errors are eliminated in the Fidas® measuring system (see Figure 5, blue curve).

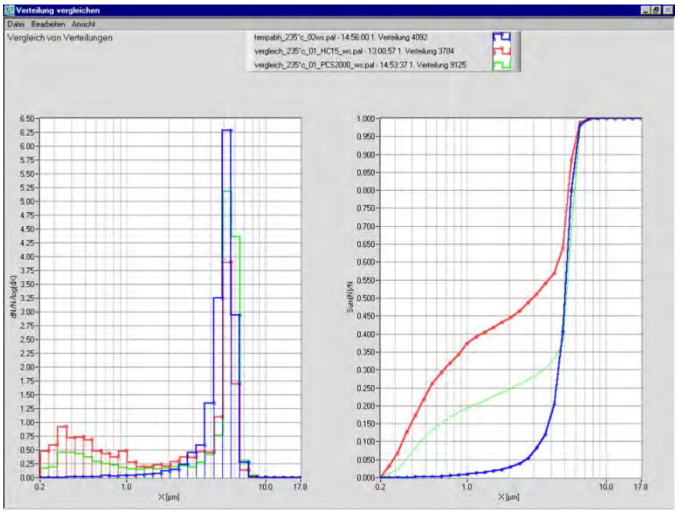


Figure 5: Comparison of an optical light scattering spectrometer with rectangular aperture (HC15, red) with an optical scattering light spectrometer with T-aperture (welas®, blue) upon application of monodisperse 5 µm particles

Measuring the signal length also enables the detection of coincidence (more than one particle in the optical detection volume), because the signal length is greater in this case. By means of a correction determined and verified by Dr-Ing Umhauer and Prof Dr Sachweh, this coincidence can then be adjusted online.

Due to improved optics, greater light intensity due to a white light source (LED), and improved signal analysis electronics, the lower detection limit for measuring ambient air quality could be lowered to 180 nm. In this way especially smaller particles, which occur in high concentrations in close proximity to streets, can be detected much better (see Figure 6).

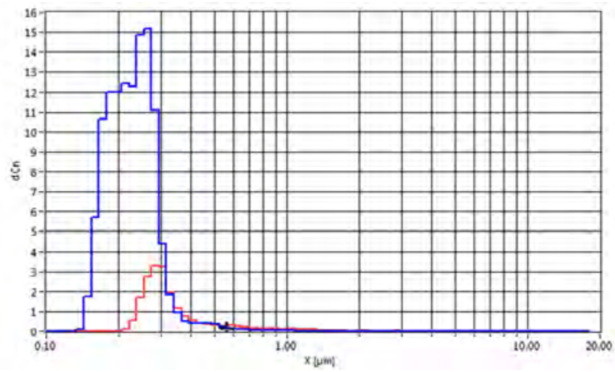


Figure 6: Comparison of results of a measurement carried out in close proximity to a street between the Fidas® measuring system (size range from 0.18 µm, blue curve) and another optical measuring system (size range from 0.25 µm, red curve)

The Fidas® 200 S respectively Fidas® 200 measuring system is characterized by the following features:

The described features

- precise calibration curve without ambiguity (white light and 90° scattered light detection)
- no border zone error (patented T-aperture technology)
- identification and correction of coincidence (digital analysis of individual particles)

yield the following advantages

- extreme high size resolution (large number of raw data channels)
- very precise particle size classification
- precise determination of concentrations

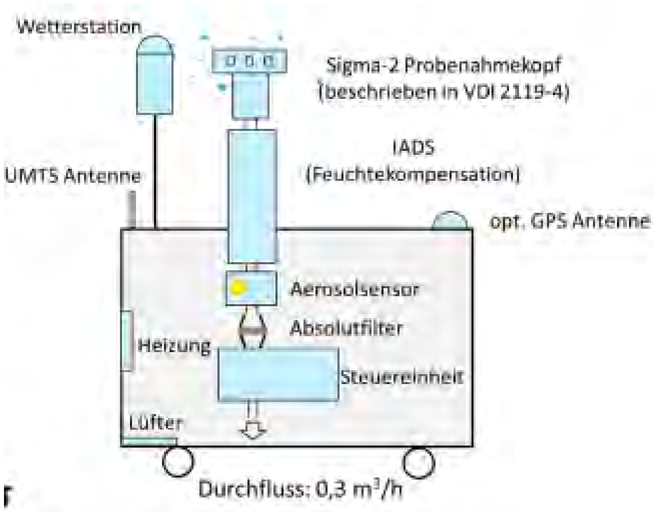
In addition to the continuous and simultaneous measurement of PM fractions, information on measured particle number concentration and particle size distribution is provided in high size resolution as well.

This additional information can be used to perform a “Source Apportionment” or to assess the relevance to health (larger particles enter more deeply into the human respiratory tract).

3.2 Principle of operation

The particle sample passes through the Sigma-2 sampling head (described in VDI 2119, Sheet 4) at a flow rate of 4.8 l/min (based on 25 °C and 1013 hPa) and is led into the sampling line which connects the sampling head to the Fidas control unit. The IADS (Intelligent Aerosol Drying System) moisture compensation module is used in order to avoid the possible effects of condensation, especially when ambient air humidity is high. The temperature of the IADS is controlled as a function of the ambient temperature and hu-midity (as measured by the weather station). The minimum temperature is 23°C. Moisture compensation is ensured via a dynamic adjustment of the IADS temperature up to a maximum heat capacity of 90 Watt."The IADS module is controlled via the Fidas Firmware. After passing through the IADS module the particle sample is led to the aerosol sensor where the actual measuring is performed. From the aerosol sensor the sample is then led through an absolute filter which can be used, for instance, to further analyse the collected aerosol. The measuring system Fidas® 200 S respectively Fidas® 200 is complete with an integrated weather station (WS600-UMB) to capture the measured quantities wind velocity, wind direction, amount of precipitation, type of precipitation, temperature, humidity, and pressure. The Fidas® 200 S respectively Fidas® 200 control unit contains the necessary electronics for operating the measuring system as well as the 2 parallel-connected sample pumps. Should one pump fail, proper operation is secured by the remaining pump.

Figure 7 provides a schematic view of the Fidas® 200 measuring system, Figure 8 shows the measurement steps of the Fidas® 200 S in chronological order.



Key
Wetterstation: weather station
Sigma-2 Probenahmekopf: Sigma-2 sampling head (described in VDI 2119-4)
UMTS Antenne: UMTS antenna
IADS (Feuchtekompensation): IADS (drying system)
Opt. GPS Antenne: opt. GPS antenna
Aerosolsensor: aerosol sensor
Absolutfilter: absolute filter
Heizung: heating
Steuereinheit: control unit
Lüfter: fan

Durchfluss/flow rate: 0.3 m^3/h

Figure 7: Schematic view of the Fidas® 200 S

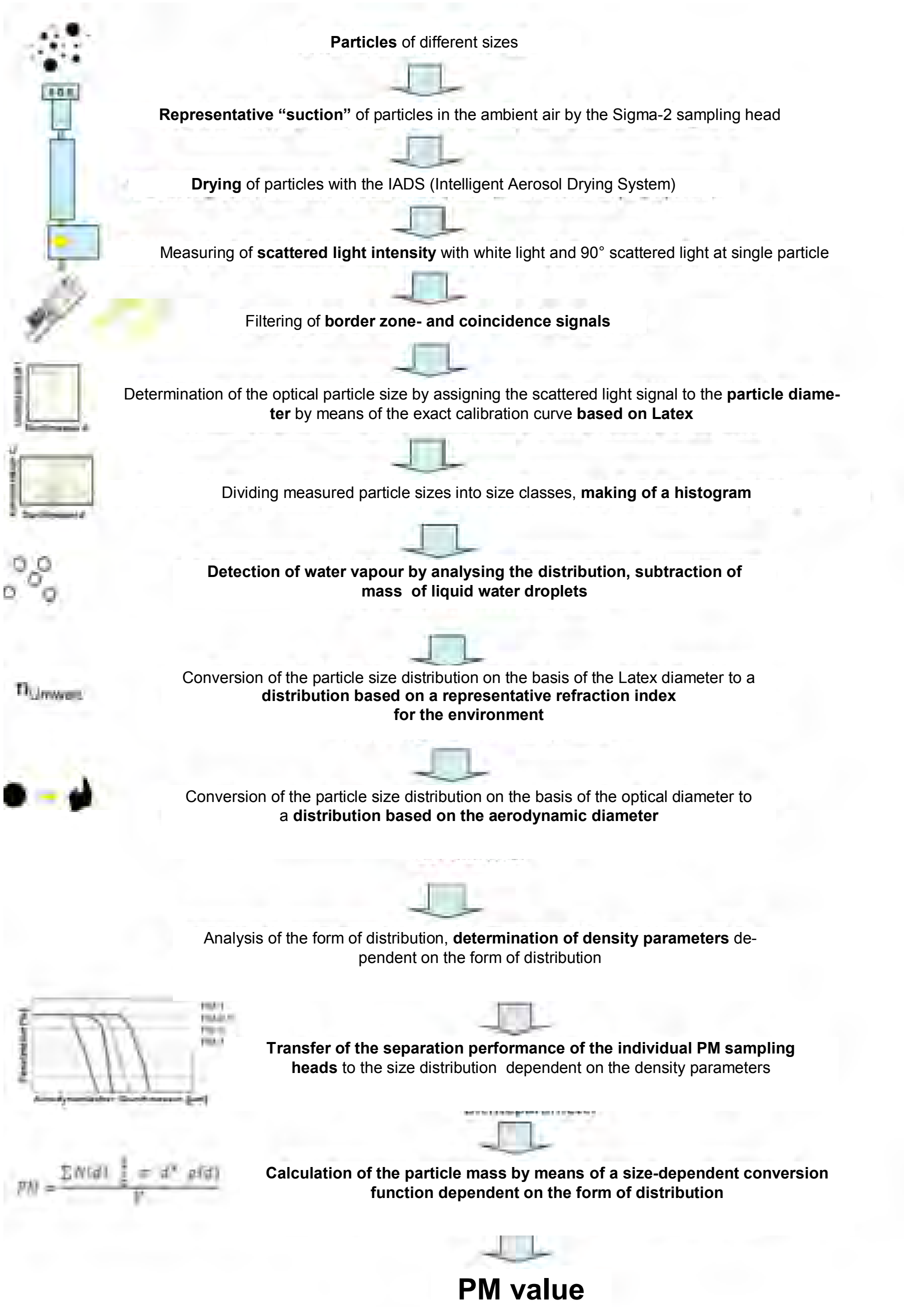


Figure 8: Overview of the measurement steps of the Fidas® 200 S / Fidas® 200

The Fidas® 200 S respectively Fidas® 200 measuring system saves data in the RAW format. In order to determine the mass concentration values, the stored raw data have to be converted by means of an evaluation algorithm. A size-dependent and weighted algorithm is used to convert particle size and number to mass concentrations. During initial type approval testing, conversion was performed using the evaluation algorithm PM_ENVIRO_0011.

3.3 AMS scope and setup

The Fidas® 200 S respectively Fidas® 200 measuring system for the measurement of ambient air pollution through suspended particulate matter is based upon the measurement principle of scattered light analysis.

The measuring system is available in the instrument versions Fidas® 200 S (for outdoor application, incl. weatherproof housing, tested in type approval test) and Fidas® 200 (for indoor application, for qualification refer to chapter 9 of this report)

The tested measuring system consists of a Sigma-2 sampling head, a sampling line with the IADS moisture compensation module, the Fidas® control unit with integrated aerosol sensor, the compact weather station WS600-UMB, a UMTS-antenna, a weatherproof housing (IP 65, only Fidas® 200 S), corresponding connection lines and cables, one bottle of CalDust 1100 or Mono Dust 1500), and manuals in German respectively English.

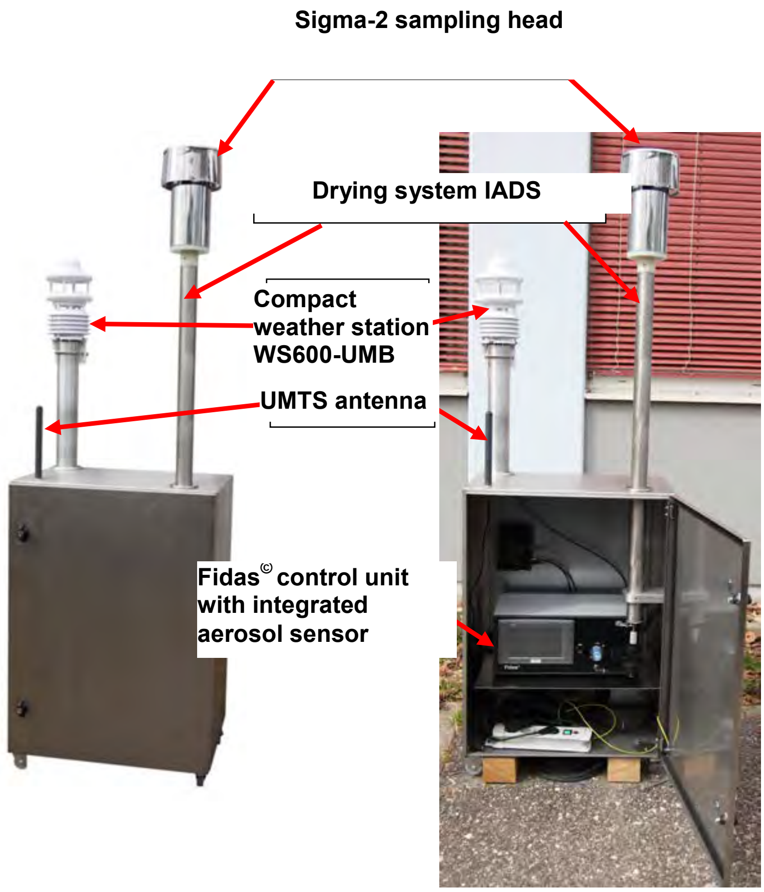


Figure 9 Overview Fidas® 200 S complete system (=Fidas® 200 in weatherproof housing)

Figure 10: Sigma-2-sampling head for the Fidas® 200 S / Fidas® 200

Figure 11: Sampling line with IADS for the Fidas® 200 S / Fidas® 200

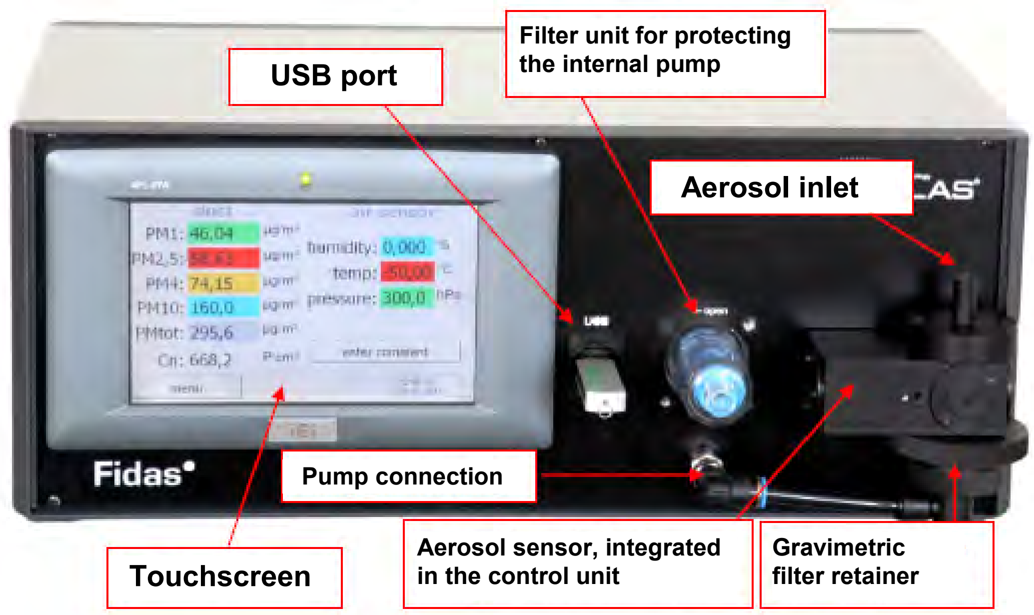


Figure 12: Control unit of the Fidas® 200 S / Fidas® 200

Figure 13: Weather station WS600-UMB

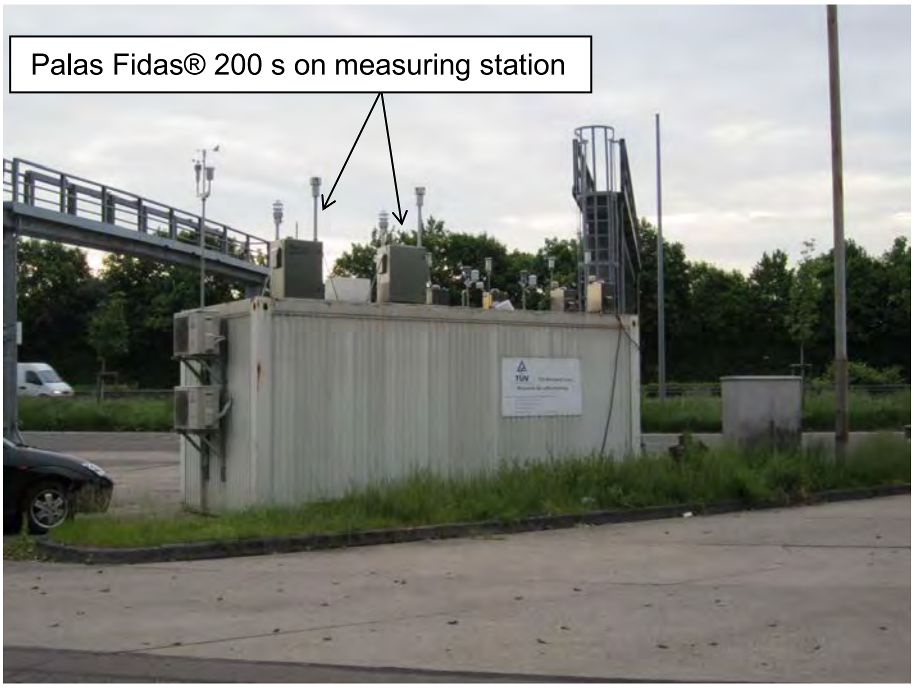


Figure 14: Fidas® 200 S measuring systems on measuring station

The measuring system can be operated using either the touch screen at the front side of the instrument or remotely via radio modem using the corresponding software (e.g. TeamViewer). The user can access measurement data and device information, change parameters, and perform tests to monitor the functionality of the measuring system.

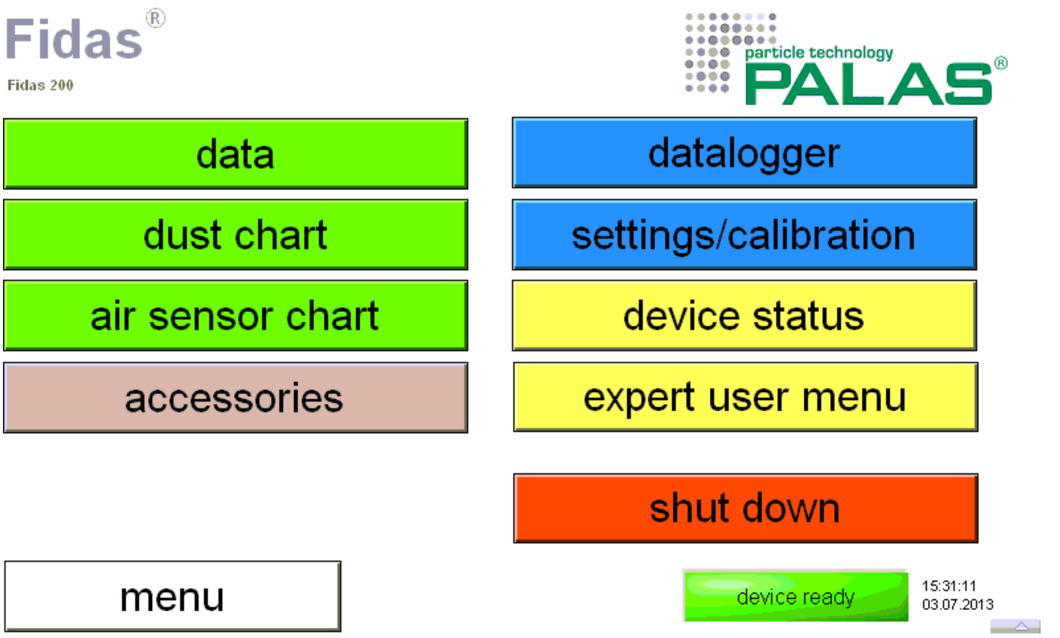


Figure 15: Main menu

The main window of the user display is on the top level – from here the user can access the respective submenus and the system can be shut down in a controlled manner.

“data” menu:	Display of measured values
“dust chart” menu:	Graphical representation of PM concentrations and particle number
“air sensor chart” menu:	Graphical representation of measured values obtained by the weather station
“accessories” menu:	Information on IADS, GPS position, weather station, alternative PM values (with other methods of evaluation) etc.
“data logger” menu:	Allows the user to enter commentaries, which are saved along with the dataset, and to transfer data from the internal memory to an USB flash drive or the like
“settings/calibration” menu:	Allows the user to check the calibration of the Fidas® sensor and if necessary recalibrate it. Furthermore, it shows the continuous estimate of the calibration with a deviation from the nominal value

“device status” menu: Provides an overview of the critical system parameters volume flow, coincidence, pump capacity, weather station, IADS, calibration, LED temperature, and mode of operation

“expert user menu” menu: Allows the user to switch to expert mode

Furthermore, the current device status is shown in the lower right corner – here the messages “device ready” marked in green or “check device status” marked in red are displayed. Detailed information can be obtained by selecting the submenu “device status”.

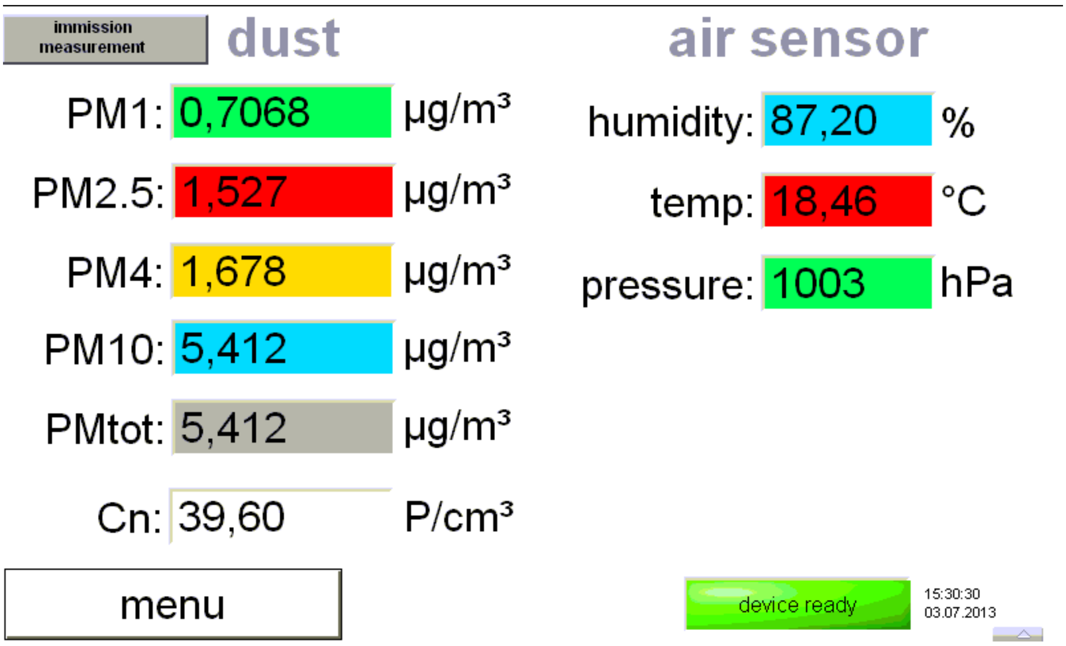


Figure 16: “data” menu

The “data” menu shows the current concentration values for the various fractions, the particle number as well as the current ambient temperature, atmospheric pressure, and relative humidity.

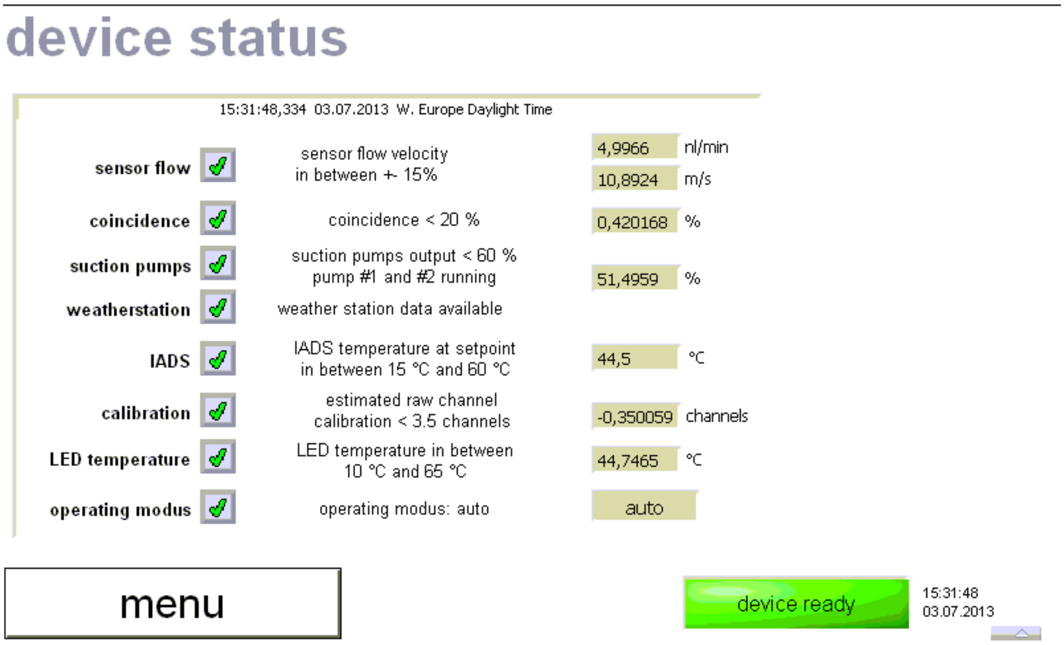


Figure 17: “device status” menu

In the “device status” menu the user can view various relevant parameters of the measuring system along with the respective nominal and actual values. Impermissible deviations of one (or more) parameters are indicated by a “red cross” as opposed to a “green check mark”.

The following parameters are monitored continuously:

Sensor flow	By means of a control circuit with mass flow meter and on the basis of the measured temperature and pressure values, the Fidas® 200 S regulates the volume flow to 4.8 l/min. This volume flow is then normalised to “standard atmospheric temperature and pressure (SATP)”, i.e. based on 25 °C and 1013 hPa. The second value indicates the particle velocity through the optical detection volume. An error message is displayed if the volume flow deviates from the nominal value by more than 15% or if the particle velocity deviates too much from the regulated volume flow.
Coincidence	Detection of more than one particle within the optical detection volume. An error message is displayed if this occurs at a rate of more than 20 %.

Suction pumps	The Fidas® 200 S provides two parallel-connected pumps for the volume flow. Should one pump fail the other one can take over. In this case the power consumption is greater which results in an error. Should both pumps wear off equally, an error is displayed when 60 % are exceeded. It is important to note that the device will keep measuring and that the data obtained can still be used. Nevertheless, the operator shall exchange the pumps as soon as possible.
Weather station	Shows that a weather station is connected correctly and that it transmits measured values.
IADS	Shows that the IADS is connected correctly and that the temperature is in compliance with the requirements.
Calibration	Online monitoring of the calibration; should the calibration deviate by more than 3.5 raw data channels, an error message is displayed. Note: In some cases, this value may lie outside the limits for a short time without compromising the device's proper functionality. There only is a need for action (i.e. field calibration with cal dust), if this is a long term trend (24 hours).
LED temperature	The LED light source is temperature-controlled. Should a problem occur within this control circuit, an error bit is set.
Operating modus	The operation mode shall be set to “auto”, otherwise the data might not be saved correctly or the device might not automatically restart after a failure in the mains voltage.

In addition to the direct communication via control keys/display there are numerous options to communicate via RS232-ports, USB-ports or Ethernet.

The following options are available:

- 1 x RS232 port for communication via Modbus for remote enquiry of measured values and external control of the measuring system (WebAccess). Application of the Bayern-Hessen protocol is also possible, but was not part of the type approval test.
- 1 x Ethernet port for connecting to a network or PC for data transmission as well as remote control, for instance via TeamViewer software
- 1 x USB port on the front side of the device, enables direct downloading of data for processing at an external PC
- 1 x USB port on the rear side of the device to connect, for instance, printer, keyboard, mouse or USB flash drive

To carry out an external zero point check, a zero filter shall be attached to the inlet of the instrument. Using this filter allows provision of air free from suspended particulate matter.

Figure 18: Zero filter

To test and if necessary adjust the sensitivity of the particle sensor, the instrument shall be supplied with particles of a defined size (CalDust 1100). The particle size distribution of this dust is monodisperse and the peak in the distribution of the raw data, which has been generated in the instrument, shall lie within the channel 130 ± 1.5 (this corresponds to a particle size of 0.93 µm) as specified by the manufacturer. If the peak lies outside this window, the value can be adjusted by means of the photomultiplier voltage. Due to this adjustment at one particle size, the sensitivity of the measuring system for all particle sizes is adjusted automatically as the instrument operates with only one A/D converter.

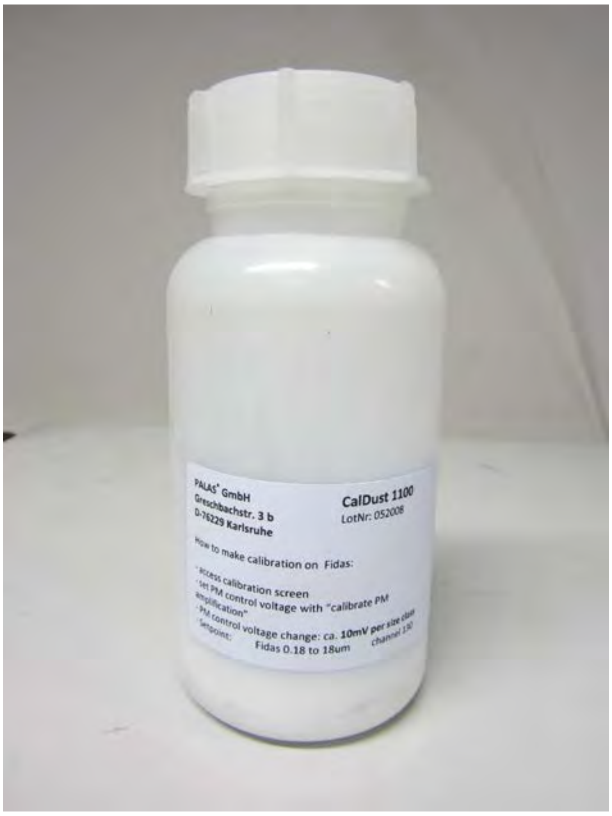


Figure 19: CalDust 1100 for verification / calibration of sensitivity

Test standard MonoDust1500

As an alternate to the test standard CalDust1100, the instrument manufacturer has qualified a further test standard MonoDust1500 for verification / calibration of the sensitivity.

Both MonoDust1500 and CalDust1100 are particles of the same manufacof turer, almost identical material composition and both are produced with the same production.

During extensive lab investigations, the instrument manufacturer has determined the size of the mono-disperse particles (= peak position) for MonoDust1500 and has checked, if reproducible measurements for checking the peak stability in the raw data distribution are also possible with MonoDust1500.

The following results have been obtained:

No.	Peak for 5 repeated measurements
1	141.2
2	141.2
3	141.1
4	141.0
5	141.1
	141.12

The alternate test standard MonoDust1500 delivers a stable measured value for the peak – in this case at approx. 141.1 - in a reproducible manner and is thus also suitable for verification / calibration of the sensitivity.

The instrument manufacturer intends to perform an explizit determination of the peak value (nominal or expected value) for each batch of the standard and to provide this value together with the test standard to the user.

Table 4 contains a list of important device-related characteristics of the Fidas® 200 S measuring system for suspended particulate matter in the ambient air

Table 4: Device-related data of the Fidas® 200 S / Fidas® 200 (manufacturer's data)

Dimensions / Weight	**Fidas® 200 S / Fidas® 200**
Measuring system	195 x 450 x 310 mm / 10 kg (control unit) 1810 x 600 x 400 mm / 48 kg (weatherproof housing with control unit, IADS, Sigma-2 and weather station)
Sampling line	Approx. 1.4 m between inlet and connecting adaptor IADS to aerosol sensor
Sampling head	Sigma-2 according to VDI 2119, Sheet 4
Power requirements	100/115/230 V, 50/60 Hz
Power input	approx. 200 W
Ambient conditions	
Temperature	-20 to +50 °C
Humidity	Outdoor-assembly, protection class IP65
Sample flow rate (Inlet)	4.8 l/min, based on 25 °C and 1013 hPa
Parameter IADS (Drying system)	
Control values	Ambient temperature and humidity
Max. Temperature	24 °C above ambient temperature
Aerosol sensor	
Measurement principle	Scattered light analysis, combination of white light LED and 90° scattered light detection
Measuring range (particle size)	0.18 – 18 µm
Resolution	32 classes per decade
Temporal resolution	During type approval testing: moving 15 min-average, updated every second; other configurations possible
Size of the measuring volume	Approx. 262 µm x 262 µm x 164 µm, the actual size of the measuring volume for the respective system can be found under "settings" in the software
Maximum concentration (coincidence error 10 %)	4 x 10^3 particles / cm^3

Weather station WS600-UMB	
Sensor for ambient temperature	Measuring range -50 to +60 °C
Sensor for rel. humidity	Measuring range 0 – 100 %
Sensor for ambient pressure	Measuring range 300 – 1200 hPa
Sensor for wind direction	Measuring range 0 – 359.9°
Sensor for wind velocity	Measuring range 0 – 60 m/s
Sensor for amount of precipitation	Measuring range 0.3 to 5 mm droplet size
Storage capacity data (internal)	1 GB (corresponds to approx. 100 days at a storage interval of 60 s for raw data)
Device inputs and outputs	1 x RS232 port for communication via Modbus for remote enquiry of measured values and external control of the measuring system (WebAccess) 1 x Ethernet port for connecting to a network or PC for data transmission as well as remote control, for instance via TeamViewer software 1 x USB port on the front side of the device, enables direct downloading of data for processing at an external PC 1 x USB port on the rear side of the device to connect, for instance, printer, keyboard, mouse or USB flash drive
Status signals / Error messages	Available (manual, chapter 4)

4. Test programme

4.1 General

The type approval test was carried out with two identical devices with the serial numbers SN 0111 and SN 0112. This also applies for the investigations at both English test sites, which have been carried out subsequent to the type approval test in Germany.

The test was performed using software version 100327. By means of the evaluation method PM_ENVIRO_0011, the obtained raw datasets were converted to concentration values.

The test comprised of a laboratory test for the assessment of performance characteristics as well as a field test, conducted over several months and at various field sites.

All obtained concentrations are given in µg/m³ (operating conditions). Additionally, the PM_{10} concentrations for evaluation according to Standard EN 12341 for standard conditions are given in µg/m³ (273 K, 101.3 kPa) as well.

In the following report, the performance criteria according to the considered guidelines [1, 2, 3, 4, 5] are stated in the caption of each test item with number and wording.

4.2 Laboratory test

The laboratory test was carried out with two identical devices of the type Fidas® 200 S with the serial numbers SN 0111 and SN 0112. The additional investigations for the qualification of the instrument version Fidas® 200 were carried out with the candidates SN 5048 and SN 5049. In conformity with the applicable standards [1, 2], the following performance criteria were tested in the laboratory:

- Description of device functions
- Determination of detection limit
- Dependence of zero point / sensitivity on ambient temperature
- Dependence of sensitivity on mains voltage
- Check of constancy of the volume flow rate
- In the laboratory test, the following devices were used for the determination of performance characteristics
- climatic chamber (temperature range from -20 °C to +50 °C, accuracy better than 1 °C)
- Isolation transformer
- 1 mass flow meter Model 4043 (Manufacturer: TSI)
- Zero filter for external zero point control
- CalDust 1100

The recording of measurement values at zero point was performed within the device. The stored raw datasets were read out via data download either per USB or remote connection (TeamViewer software) and converted to concentration values by means of the PDAnalyze software using the evaluation method PM_ENVIRO_0011.

The sensitivity test was carried out with monodisperse dust (CalDust 1100). When applying this calibration dust, the size distribution is expected to peak in channel 130 (this corresponds with a particle size of 0.93 µm). In order to make the quantification of deviations in the classification possible, the datasets obtained in the field test were used to calculate the effects of a peak shift of max. ±3 channels on a measured PM value.

If the peak shifts within channel 130, all other channels are shifted the same number of raw data channels. This is due to the employed A/D converter which has a logarithmic response curve. If, hypothetically, the total distribution of raw data shifts by ±3 channels and if the PM values were then recalculated on that basis, the effect on the measured PM values can be determined. To do so, a regression line between the actually measured PM values and the values obtained from the hypothetically shifted raw data distribution was calculated by plotting these values against each other in a XY plot. The results from these calculations are illustrated in the following matrix:

Table 5: Matrix on the influence of a peak shift on the mass concentration (PM_ENVIRO_0011)

	PM2,5		PM10	
channel shift	slope	offset	slope	offset
-3	1,086	0,03889	1,0877	0,0331
-2	1,056	0,025	1,057	0,012
-1	1,029	0,0122	1,028	0,048
0	1	0	1	0
1	0,973	-0,00785	0,976	-0,0047
2	0,945	-0,0197	0,947	0,038
3	0,918	-0,031	0,9224	0,083

For instance in case of application of the evaluation method PM_ENVIRO_0011, if there is a shift by -3 channels, the actual PM values bear relation to the hypothetically determined PM values in the following way:

$PM_{2.5}$_actual=1.086*$PM_{2,5}$_hypothetical+0.03889
PM_{10}_actual=1.0877*PM_{10}_hypothetical+0.0331.

A shift by -3 channels results in the particle size being determined too small. As a consequence, the $PM_{2.5}$ value is measured too low by the factor 1.086.

For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for PM_{10} were defined. The concentration value to be expected depending on the peak shift was then calculated according to the following matrix

The results of the laboratory tests are summarised in chapter 6.

4.3 Field test

The field test was carried out with two identical measuring systems:

System 1: SN 0111

System 2: SN 0112

The following performance criteria were tested in the field:

- Comparability of the candidates according to the Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”
- Comparability of the candidates with the reference method according to the Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”
- Consistency of sample volume flow
- Calibration capability, analytical function
- Reproducibility
- Zero drift and sensitivity
- Leak tightness of the sampling system
- Dependence of the measured values on sample humidity
- Maintenance interval
- Availability
- Total uncertainty of tested systems

The additional investigations in the UK have been carried out for the following test points:

- Comparability of the candidates according to the Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”
- Comparability of the candidates with the reference method according to the Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”

The following auxiliary devices were used during the field test:

- TÜV Rheinland measuring cabinet, air conditioned to approx. 20 °C, respectively DEFRA measuring cabinet in Teddington (UK)
- Weather station (WS 500 of ELV Elektronik AG) respectively MK III Series of Rainwise (US) in the UK for the detection of meteorological parameters such as ambient temperature, atmospheric pressure, humidity, wind velocity, wind direction and amount of precipitation.
- 2 reference measuring systems LVS3 for PM_{10} as per item 5 (Germany) respectively SEQ47/50 (UK)
- 2 reference measuring systems LVS3 for $PM_{2.5}$ as per item 5 (Germany) respectively SEQ47/50 (UK)
- 1 gas meter, dry
- 1 mass flow meter Model 4043 (Manufacturer: TSI)
- Power consumption measuring device type Metratester 5 (manufactured by Gossen Metrawatt)
- Zero filter for external zero point checks
- CalDust 1100

During the field test, two Fidas® 200 S systems and two reference systems for $PM_{2.5}$ and PM_{10} were operated simultaneously for a period of 24 hours. The reference system (Germany) operates discontinuously, that is to say the filter needs to be changed manually after sampling.

During the testing, the impaction plates of the PM_{10} and $PM_{2.5}$ sampling heads of the reference systems were cleaned and lubricated with silicone grease approx. every 2 weeks in order to ensure a safe separation and deposition of particulates. The Sigma-2 sampling heads of the candidates were cleaned approx. every 3 months according to manufacturer's information. The sampling head shall always be cleaned in accord with the instructions provided by the manufacturer. Local concentrations of suspended particulate matter shall also be considered in this procedure.

Before and after each change of test site, the flow rate was tested on each candidate as well as on each reference system with a dry gas meter and a mass flow meter, which connects to the system inlet via hose line.

Measuring sites and AMS placement

For the field test, the measuring systems were set up in such a way that only the sampling heads and the virtual impactors were installed on the outside of the measuring cabinet above its roof. The central units of both candidates were placed within the air-conditioned measuring cabinet. The entire reference equipment (LVS3) was installed outdoors on the roof of the cabinet.

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

Table 6: Field test sites

No.	Test site	Period	Characterisation
1	Cologne, summer	05/2012 – 09/2012	Urban background
2	Cologne, winter	11/2012 – 02/2013	Urban background
3	Bonn, road junction, winter	02/2013 – 05/2013	Influence of traffic
4	Bornheim, summer	05/2013 – 07/2013	Rural structure + influence of traffic

Table 7: Additonal field test sites (UK)

No.	Test site	Period	Characterisation
1	Teddington, winter	02/2014 – 04/2014	Urban background
2	Teddington, summer	04/2014 – 06/2014	Urban background

Figure 20 to Figure 31 show the course of PM concentrations at the measuring locations in the field as recorded by the reference measuring systems.

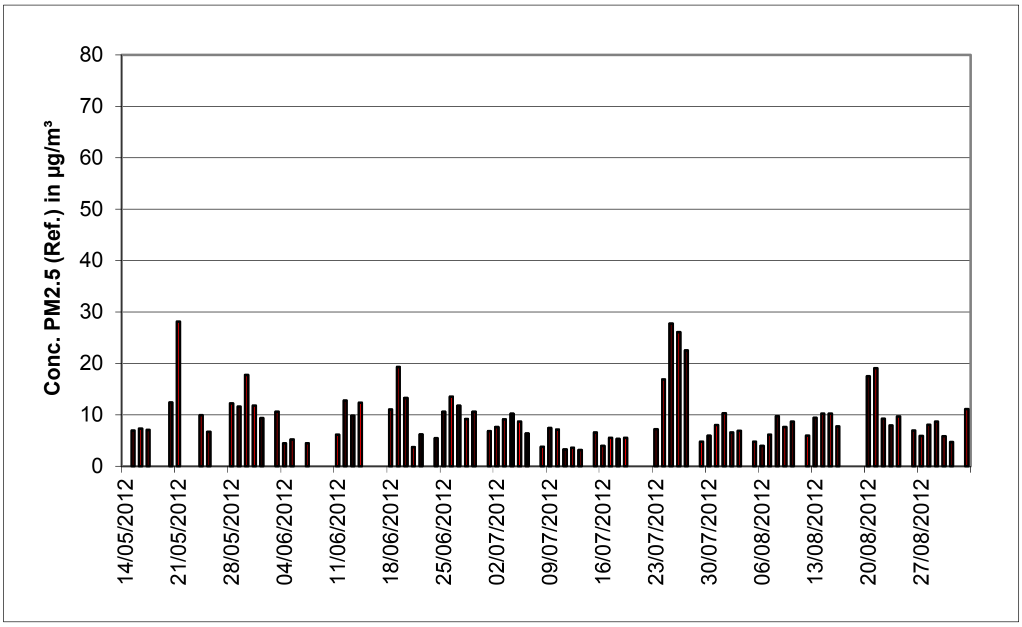


Figure 20: Course of $PM_{2.5}$ concentrations (reference) at test site "Cologne, summer"

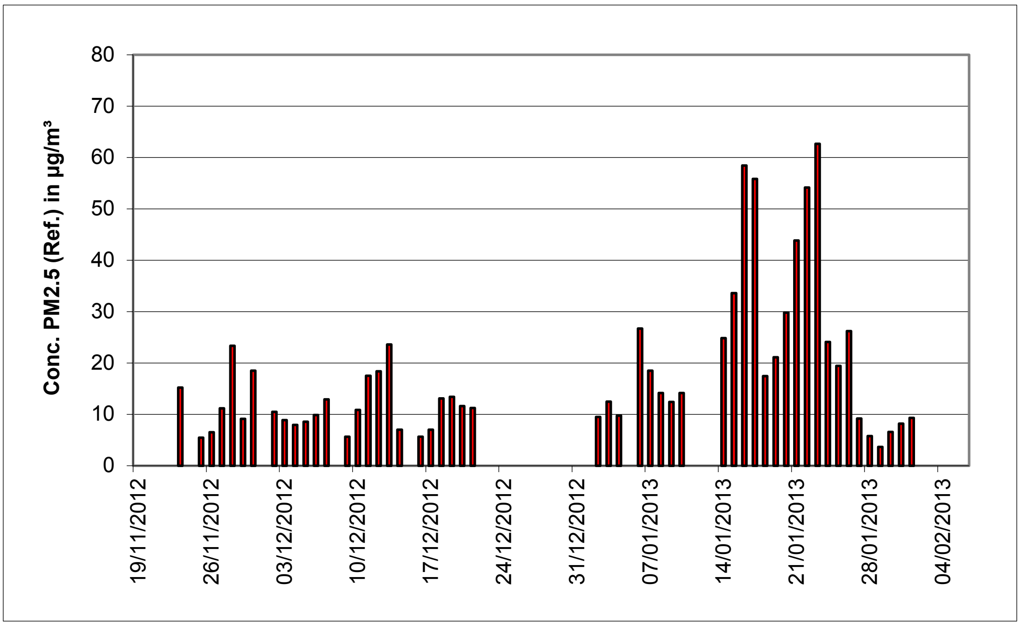


Figure 21: Course of $PM_{2.5}$ concentrations (reference) at test site "Cologne, winter"

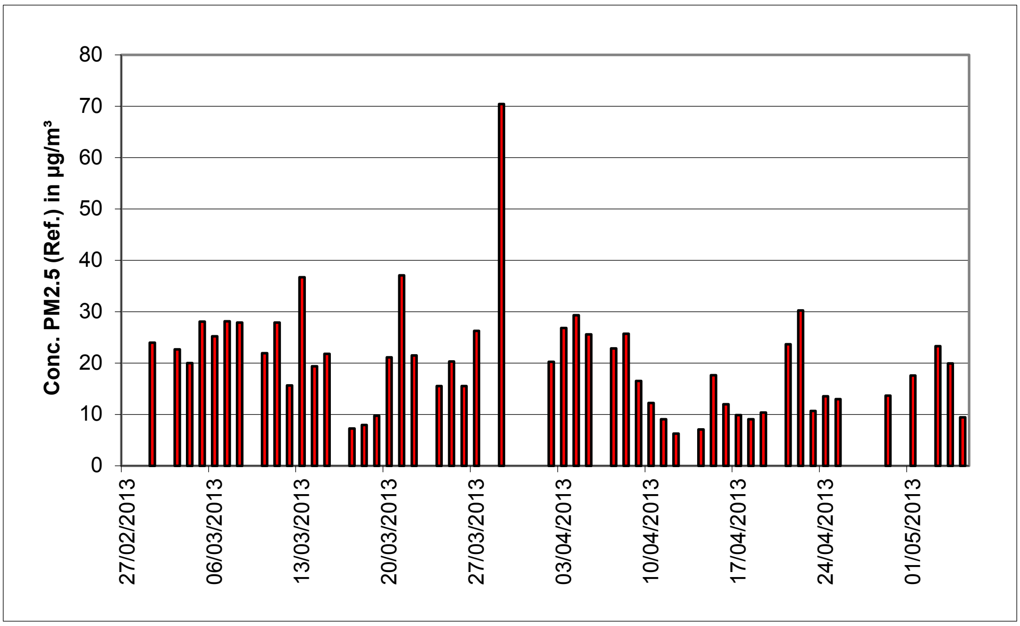


Figure 22: Course of $PM_{2.5}$ concentrations (reference) at test site “Bonn, winter”

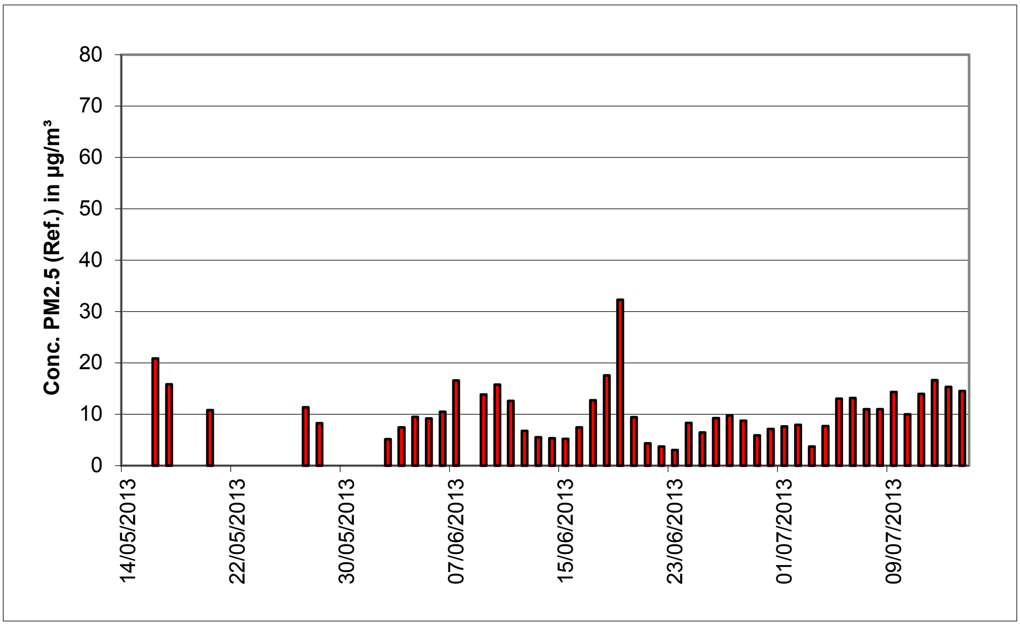


Figure 23: Course of $PM_{2.5}$ concentrations (reference) at test site “Bornheim, summer”

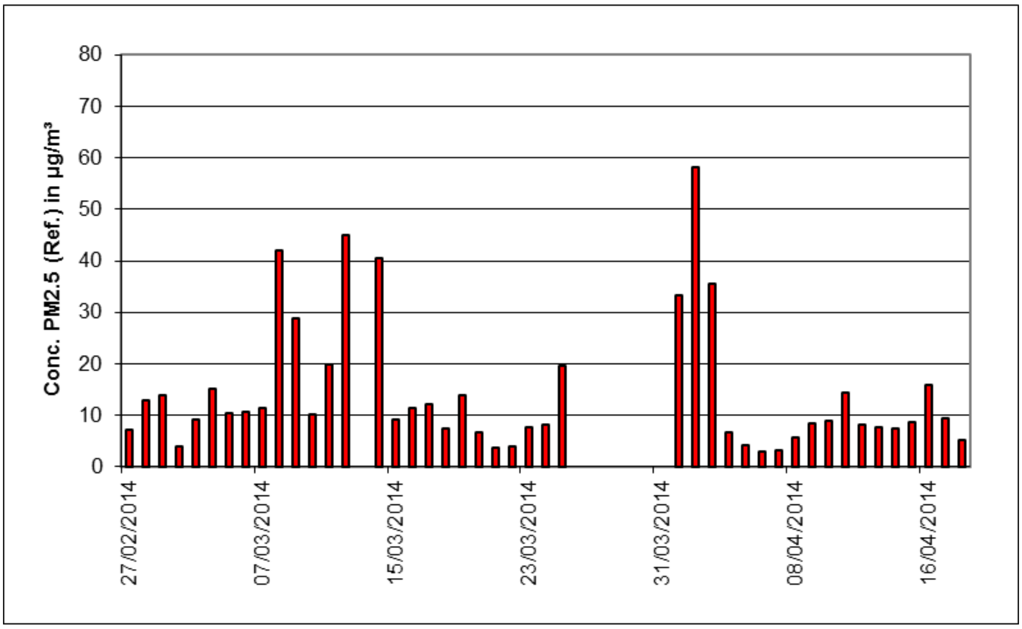


Figure 24: Course of $PM_{2.5}$ concentrations (reference) at test site "Teddington, winter"

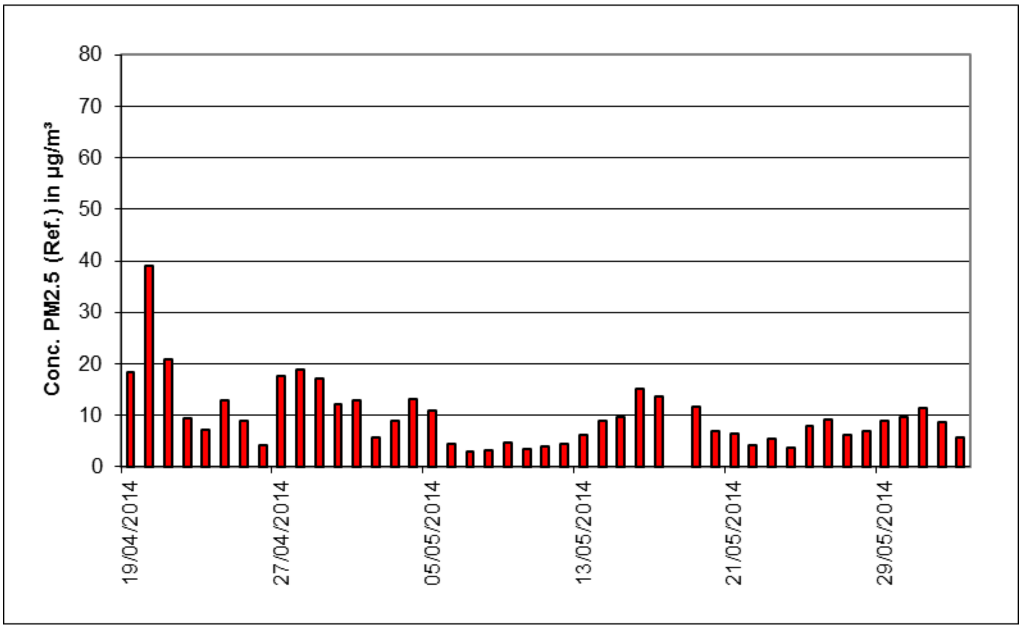


Figure 25: Course of $PM_{2.5}$ concentrations (reference) at test site "Teddington, summer"

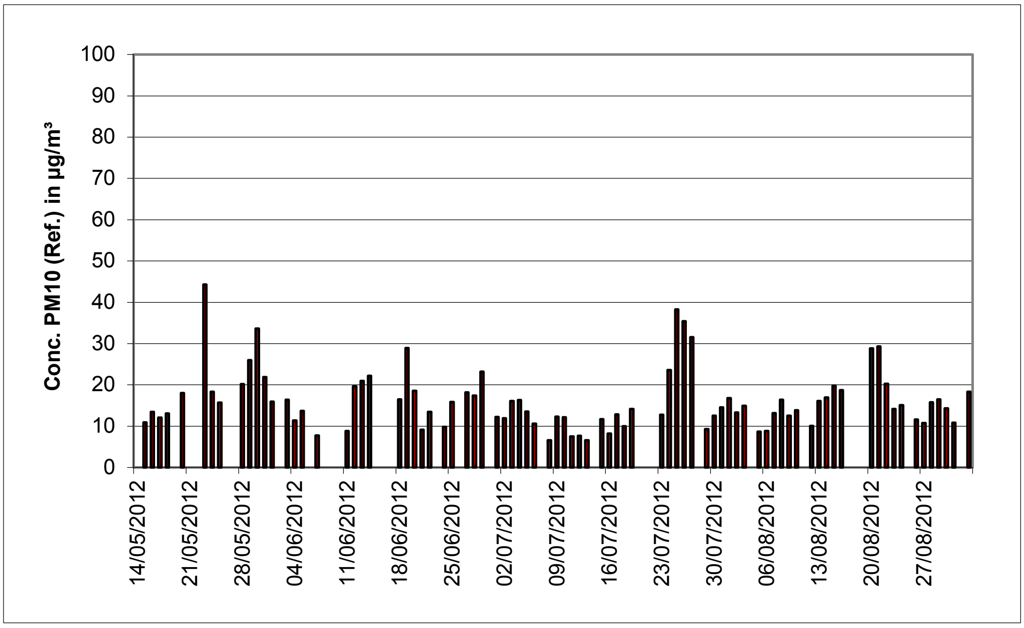


Figure 26: Course of PM_{10} concentrations (reference) at test site "Cologne, summer"

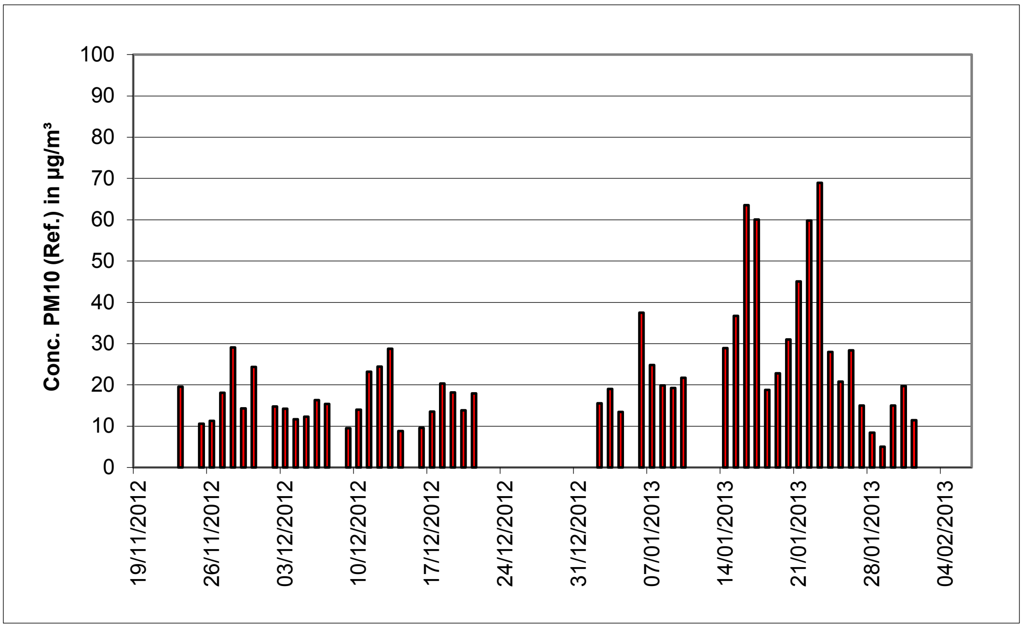


Figure 27: Course of PM_{10} concentrations (reference) at test site "Cologne, winter"

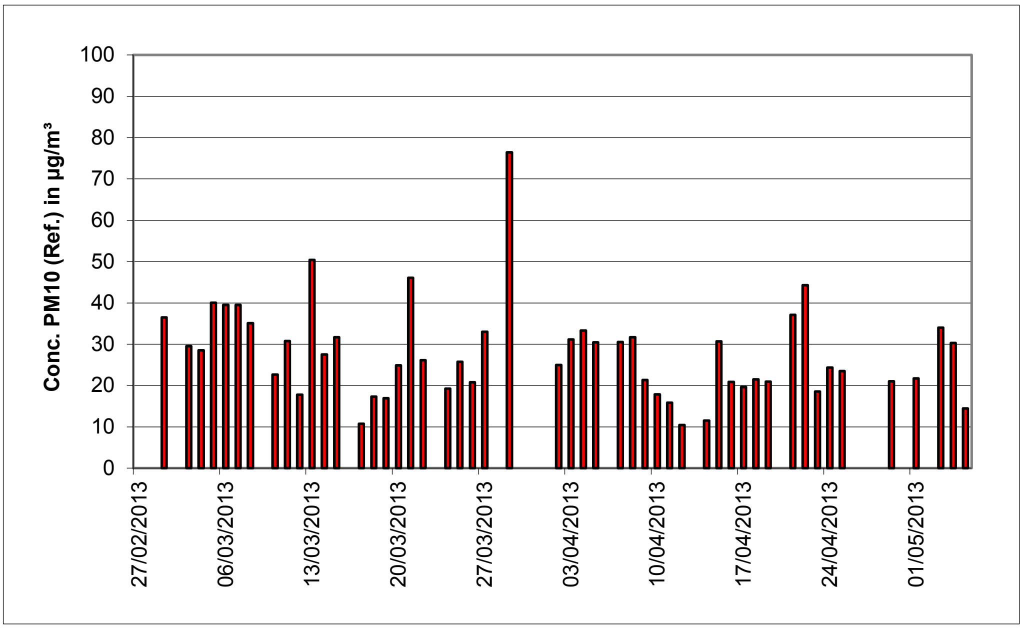


Figure 28: Course of PM_{10} concentrations (reference) at test site “Bonn, winter”

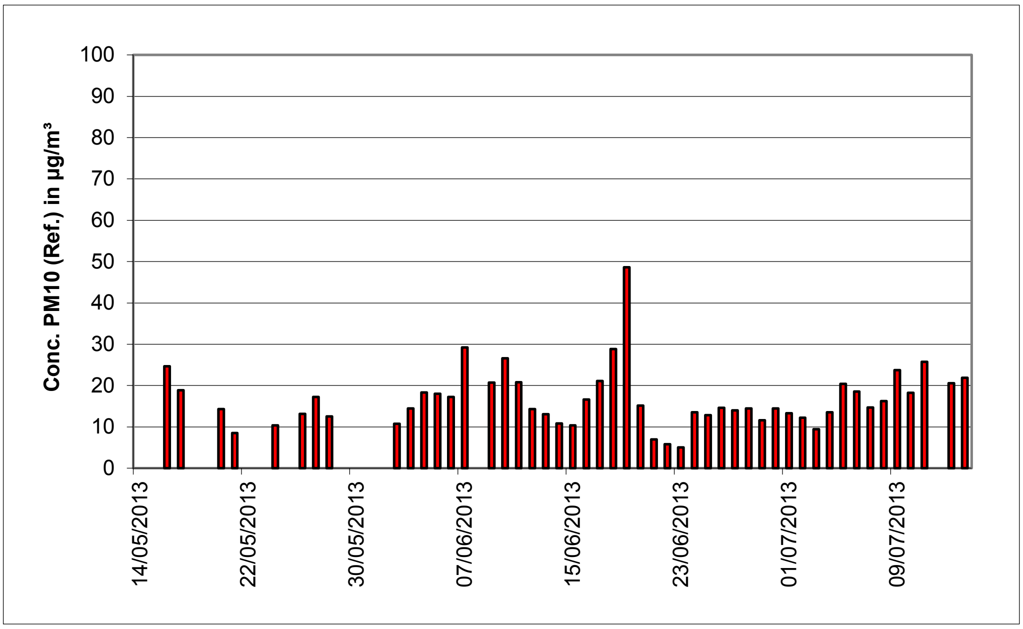


Figure 29: Course of PM_{10} concentrations (reference) at test site “Bornheim, summer”

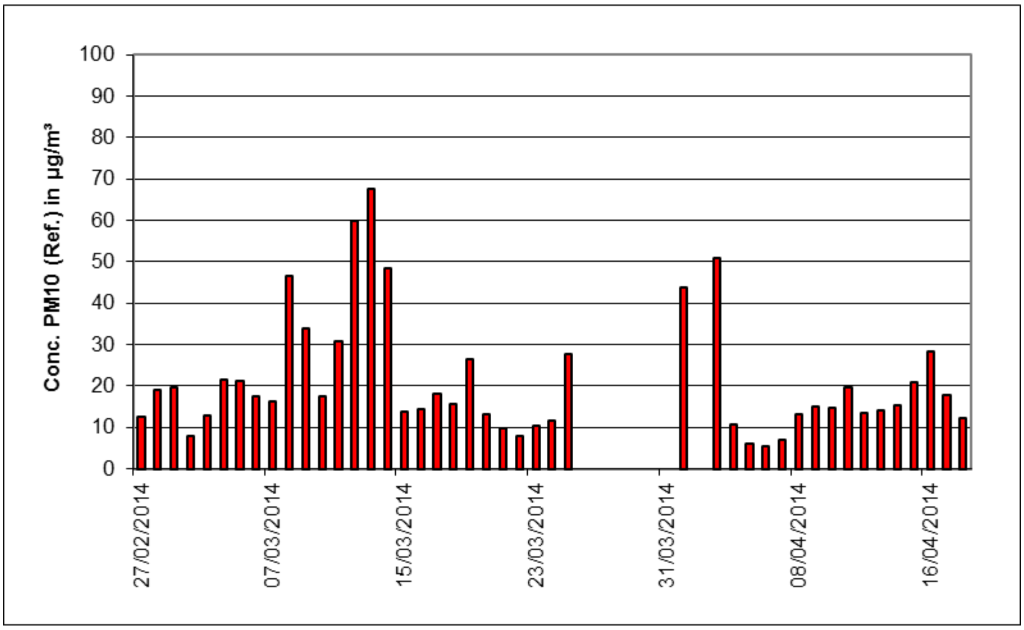


Figure 30: Course of PM_{10} concentrations (reference) at test site "Teddington, winter"

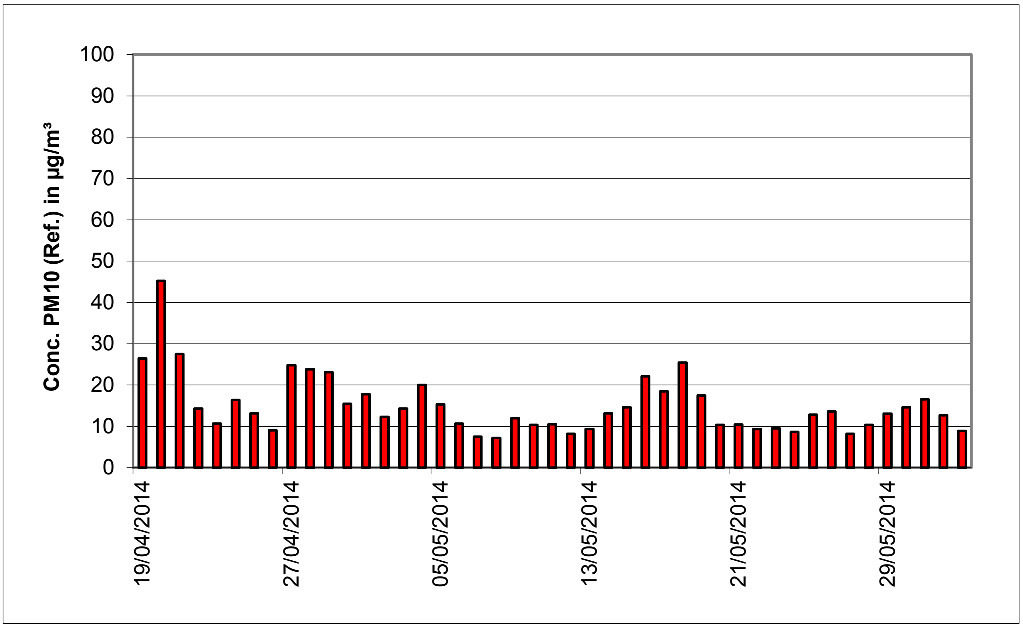


Figure 31: Course of PM_{10} concentrations (reference) at test site "Teddington, summer"

The following figures show the measuring cabinet at the field test sites Cologne, Bonn and Bornheim (initial testing) as well as Teddington UK (supplementary testing).

Figure 32: Field test site Cologne, summer & winter

Figure 33: Field test site Bonn, winter

Figure 34: Field test site Bornheim, summer

Figure 35: Field test site Teddington, UK

In addition to the measuring systems for the measurement of ambient air pollution through suspended particulate matter, a data acquisition system for meteorological parameters was installed on the cabinet/at the test site where the measurement was carried out. Ambient temperature, ambient pressure, humidity, wind velocity, wind direction, and the amount of precipitation were monitored continuously. 30-minutes mean values were stored.

The cabinet setup and the arrangement of the sample probes had the following dimensions:

Germany:

- Height of cabinet roof: 2.50 m
- Sampling height for tested system 1.70 m / 0.51 m above cabinet roof
- Sampling height for reference system 4.20 / 3.01 m above ground
- Height of wind vane: 4.5 m above ground

UK:

- Height of cabinet roof: 2.50 m
- Sampling height for tested system 1.70 m / 0.70 m resp. 1 m above cabinet roof
- Sampling height for reference system 4.20 / 3.20 m resp. 3.50 m above ground
- Height of wind vane: 4.0 m above ground

The following Table 8 therefore contains an overview of the most important meteorological parameters that have been obtained during the measurements at the 4 field test sites as well as an overview of the concentrations of suspended particulate matter during the test period. All single values are provided in annexes 5 and 6.

The most important meteorological parameters of the Englsih comparison campaigns can be found in Table 9 and in the annexes 7 and 8.

Table 8: Ambient conditions at the field test sites, daily mean values

	Cologne, summer	Cologne, winter	Bonn, winter	Bornheim, summer
Number of value pairs Reference PM_{10}	82	52	50	49
Number of value pairs Reference $PM_{2.5}$	82	52	50	47
$PM_{2.5}$ ratio in PM_{10} [%]				
Range	38.2 – 73.7	41.6 – 97.2	42.2 – 96.5	39.1 – 84.6
Mean value	55.8	73.8	70.6	60.0
Ambient temperature [°C]				
Range	8.9 – 30.7	-3.3 – 11.9	-3.4 – 20.0	6.4 – 27.2
Mean value	19.1	4.6	7.8	16.6
Ambient pressure [hPa]				
Range	993 – 1021	988 – 1027	985 – 1021	989 – 1020
Mean value	1008	1004	1004	1007
Rel. humidity [%]				
Range	39.9 – 87.2	70.0 – 91.2	42.8 – 85.8	52.6 – 89.1
Mean value	67.0	81.2	63.4	70.1
Wind velocity [m/s]				
Range	0.1 – 2.7	0.0 – 3.3	0.4 – 4.2	0.2 – 4.7
Mean value	0.7	0.9	1.6	1.5
Amount of precipitation [mm/d]				
Range	0.0 – 29.5	0.0 – 25.7	0.0 – 13.2	0.0 – 34.6
Mean value	2.9	2.9	0.9	3.5

Table 9: Ambient conditions at the UK field test sites, daily mean values

	Teddington, winter	Teddington, summer
Number of value pairs Reference PM_{10}	44	45
Number of value pairs Reference $PM_{2.5}$	44	44
$PM_{2.5}$ ratio in PM_{10} [%]		
Range	37.0 – 90.0	34.3 – 86.3
Mean value	61.9	62.9
Ambient temperature [°C]		
Range	-1.9 – 21.1	1.7 – 26.5
Mean value	9.9	13.6
Ambient pressure [hPa]		
Range	965 – 1016	981 – 1017
Mean value	997	995
Rel. humidity [%]		
Range	25.1 – 100	29.3 – 99.9
Mean value	74	73.3
Wind velocity [m/s]		
Range	0.0 – 4.8	0.0 – 5.4
Mean value	0.6	0.7
Amount of precipitation [mm/d]		
Range	0.0 – 10.2	0.0 – 22.9
Mean value	0.9	2.6

Sampling duration

According to Standard EN 12341, the sampling time shall be 24 h. However, for low concentrations longer sampling times are permissible while for high concentrations shorter sampling times are allowed as well.

According to Standard EN 14907, the sampling time shall be 24 h ± 1 h.

During the field test, a sampling time of 24 h was set for all devices (10:00 – 10:00 (Cologne, Teddington) and 7:00 – 7:00 (Bonn, Bornheim)).

Data handling

Before the respective analyses for each test site were carried out, the paired reference values determined during the field test were subject to a statistical outlier test according to Grubbs (99 %) in order to prevent any effects of evidently implausible data on the test results. Value pairs identified as significant outliers may be discarded from the pool of values as long as the critical value of test statistic does not fall below the target. According to the Guide [5] of January 2010, not more than 2.5 % of data pairs shall be determined as outliers and discarded.

As far as candidates are concerned, the measured values are usually not discarded unless there are proven technical reasons for implausible values. Throughout the testing no values measured by the candidates were discarded.

Table 10 and Table 11 provide an overview of the number of value pairs that were identified as significant outliners and therefore removed at each site (reference).

Table 10: Results of the Grubbs' outlier test – reference PM_{10}

Graph Number	Site	Sampler	Number of data-pairs	Maximum Number that can be deleted	Number Identified	Number Deleted	Number of data-pairs remaining
A	Cologne Summer	PM_{10} Reference	83	2	1	1	82
B	Cologne Winter	PM_{10} Reference	52	0	1	0	52
C	Bonn Winter	PM_{10} Reference	50	1	0	0	50
D	Bornheim Summer	PM_{10} Reference	50	1	2	1	49
E	Teddington Winter	PM_{10} Reference	45	1	1	1	44
F	Teddington Summer	PM_{10} Reference	45	1	0	0	45

Table 11: Results of the Grubbs' outliner test – reference $PM_{2.5}$

Graph Number	Site	Sampler	Number of data-pairs	Maximum Number that can be deleted	Number Identified	Number Deleted	Number of data-pairs remaining
A	Cologne Summer	$PM_{2.5}$ Reference	84	2	3	2	82
B	Cologne Winter	$PM_{2.5}$ Reference	52	1	0	0	52
C	Bonn Winter	$PM_{2.5}$ Reference	50	1	0	0	50
D	Bornheim Summer	$PM_{2.5}$ Reference	47	1	0	0	47
E	Teddington Winter	$PM_{2.5}$ Reference	45	1	1	1	44
F	Teddington Summer	$PM_{2.5}$ Reference	45	1	1	1	44

The following value pairs were discarded:

Table 12: Discarded reference PM_{10} value pairs according to Grubbs

Test site	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Cologne, summer	21.05.2012	45.7	41.6
Bornheim, summer	12.07.2013	28.7	33.5
Teddington, winter	02.04.2014	84.9	82.0

Table 13: Discarded reference $PM_{2.5}$ value pairs according to Grubbs

Test site	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Cologne, summer	18.05.2012	7.1	16.0
Cologne, summer	23.05.2012	27.3	35.0
Teddington, winter	13.03.2014	54.9	57.0
Teddington, summer	18.05.2014	18.9	17.7

Filter handling– mass determination

The following filters were used in the type approval test:

Table 14: Used filter materials

Measuring system	Filter material, type	Manufacturer
Reference systems LVS3 resp. SEQ47/50 (only UK)	Emfab™, ∅ 47 mm	Pall

The filters were handled in compliance with Standard EN 14907.

Details on filter handling and weighing processes are describes in annex 2 of this report.

5. Reference measurement method

In accordance with Standards EN 12341 and EN 14907, the following devices were used in the testing:

1. as reference device for PM_{10}: Small Filter Device Low Volume Sampler LVS3
Manufacturer: Ingenieurbüro Sven Leckel,
Leberstraße 63, Berlin, Germany
Date of construction: 2007
PM_{10} sampling head

2. as reference device for $PM_{2.5}$: Small Filter Device Low Volume Sampler LVS3
Manufacturer: Ingenieurbüro Sven Leckel,
Leberstraße 63, Berlin, Deutschland
Date of construction: 2007
$PM_{2.5}$ sampling head

During the additional comparison campaigns in the UK, filter changers of the type SEQ47/50 have been used as reference devices for the measured components PM_{10} and $PM_{2.5.}$ From a technical point of view, the filter changer is based on the single filter device LVS3. The filter changing mechanism together with the clean and sampled filter magazine allows a continuous 24h-sampling for a period of up to 15 days. The entire sampling system is conditioned by a sheath air – for this the respective sample tube is installed inside of a purged sheath air tube made of aluminium.

During the testing, two reference systems for each PM_{10} and $PM_{2.5}$ were operated simultaneously with a flow rate of 2.3 m³/h. Under real operating conditions the volume flow control accuracy is < 1 % of the nominal flow rate.

Through the sampling head of the small filter device LVS3 resp. SEQ47/50, the sample air is sucked in via a rotary vane vacuum pump. The sample volume flow is then measured by means of a measuring orifice between filter and vacuum pump. The suctioned air then streams out of the pump via a separator for the abrasion of the rotary vanes and towards the air outlet.

As soon as the sampling is complete the electronic measurement equipment displays the sucked-in sample air volume in standard or operating m³.

The PM_{10} and $PM_{2.5}$ concentrations were determined by dividing the amount of suspended particulate matter on each filter that had been determined gravimetrically in the laboratory by the respective sampling volume in operating m³.

6. Test results of initial type approval

6.1 4.1.1 Measured value display

The AMS shall have a means to display the measured values.

6.2 Equipment

Additional equipment is not required.

6.3 Method

It was checked whether the AMS has a means to display the measured values.

6.4 Evaluation

The measuring system provides a display that shows the measured values. In addition to the current measurements of the PM_{10} and $PM_{2.5}$ fractions, the “data” submenu also shows the measurements of the PM_1, PM_4, and PM_{total} fractions as well as particle number, ambient temperature, humidity, and ambient pressure (moving 15-minutes mean during type approval testing, updated every second, other adjustments possible).

6.5 Assessment

The measuring system provides a display that shows the measured values.

Performance criterion met? yes

6.6 Detailed presentation of test results

Figure 36 shows the user interface with the current concentrations.

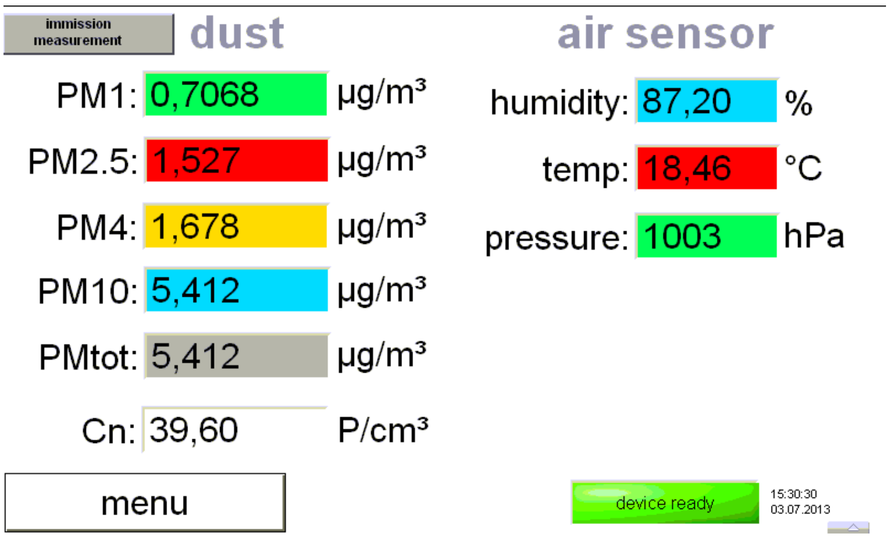


Figure 36: Display of measured concentrations

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

Additional equipment is not required.

6.3 Method

Necessary regular maintenance work was carried out according to the instructions given in the manual.

6.4 Evaluation

The operator shall carry out the following maintenance work:

1. Check of system status.
   The system status can be monitored and controlled directly or online.
2. The sensitivity of the particle sensor shall be checked using CalDust 1100 or MonoDust1500 once a month, adjustment if deviation from nominal value 130 is greater than ±1.5 channels (CalDust 1100) respectively if deviation from delivered nominal value is greater than ±1.5 channels (MonoDust1500), but at least every three months.
3. As a matter of principle, the sampling head shall be cleaned according to the instructions provided by the manufacturer. Local concentrations of suspended particulate matter shall be taken into account (during type approval testing approx. every 3 months).
4. The system’s leak tightness shall be inspected every 3 months according to the manufacturer’s information.
5. A flow rate check shall be carried out every 3 months according to the manufacturer’s information.
6. The sensors of the weather station WS600-UMB shall be checked once a year (or when necessary) according to the specifications provided by the manufacturer.
7. Cleaning the optical sensor is only required if the photomultiplier-voltage exceeds the calibration value obtained after the last cleaning or on delivery by more than 15 %.
8. The filter shall be cleaned or changed if the suction pump capacity exceeds 50 %.

Maintenance work shall be carried out according to the instructions provided in the manual (chapter 3). In general, all work can be carried out with commonly available tools.

6.5 Assessment

Maintenance work can be carried out from the outside with commonly available tools and reasonable time and effort. In order to perform operations according to items 2, 4 and 5, the device shall be switched to calibration mode. Prior to these operations in calibration mode, the IADS is set to 35 °C for the reproducible conditioning of the particle flow and the conditions of volume flow and gas dynamics. The checking procedure itself takes about 15–30 min so that regular measuring can be resumed approx. 1 h after the calibration mode has been started at the latest. The operations described in items 7 and 8 shall only performed when the device is on standstill. However, such works are seldom. During the type approval testing period which lasted for more than a year there was no need for said operations. In the meantime, maintenance work is limited to the check of contaminations, plausibility and possible status/error messages.

Performance criterion met? yes

6.6 Detailed presentation of test results

During the testing, work on the devices was carried out on the basis of operations and work processes described in the manuals. By adhering to the described procedures no difficulties were observed. Up to this point, all maintenance could be carried out without difficulty and with conventional tools.

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.

6.2 Technical equipment

Operator's manual, zero filter, CalDust 1100.

6.3 Method

The system status is monitored continuously and problems are indicated by a series of different status messages. The current status of the monitored parameters can be viewed directly on the instrument display or they can be taken from the data record. If any parameter lies outside of the permissible limits a corresponding error bit is displayed.

The zero point of the measuring system can also be checked externally by applying a zero filter to the instrument's inlet. The use of this filter allows the provision of particulate-free air.

During the testing, the zero point was determined using a zero filter approx. every 4 weeks.

The measuring system continuously monitors the sensitivity of the particle senor internally. Should there be a deviation from the nominal value by more than 3.5 raw data channels, a bug status is set.

The sensitivity test was carried out with monodisperse dust (CalDust 1100). When applying this calibration dust, the size distribution is expected to peak in channel 130 (this corresponds with a particle size of 0.93 µm). In order to make the quantification of deviations in the classification possible, the datasets obtained in the field test were used to calculate the effects of a peak shift of max. ±3 channels on a measured PM value. For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for PM_{10} were defined. The concentration value to be expected depending on the peak shift was then calculated according to the matrix in chapter 4.2 Laboratory test.

In the course of the testing, the sensitivity of the particle sensor was determined at the beginning and at the end of each campaign.

6.4 Evaluation

All functions described in the operator’s manual are available or can be activated. The current instrument status is continuously monitored and different warning messages are displayed in the case of problems.

External zero point checks by means of a zero filter can be carried out at any time. Using the calibration dust CalDust 1100, the sensitivity of the particle sensor can also be checked at all times.

6.5 Assessment

All functions described in the operator’s manual are available, can be activated, and work properly. The current instrument status is continuously monitored and different warning messages are displayed in the case of problems.

The results of the external zero point checks by means of zero filter that were carried out during the field tests as well as the sensitivity tests on the particle sensor that were carried out periodically are described in Chapter 6.1 5.3.12 Long-term drift in this report.

Performance criterion met? yes

6.6 Detailed presentation of test results

See chapter 6.1 5.3.12 Long-term drift

6.1 4.1.4 Setup times and warm-up times

The AMS' setup and warm-up times shall be stated in the manual.

6.2 Equipment

A timer was provided additionally.

6.3 Method

The measuring systems were activated according to the manufacturer's specifications. The amounts of time required for setup and warm-up were recorded separately.

Structural measures taken before installation, like for instance the opening of the cabinet roof, have not been assessed here.

6.4 Evaluation

The setup time comprises the time needed for all necessary works from system installation to start-up.

The Fidas® 200 S measuring system is equipped with weatherproof housing and thus designed for outdoor installation. As a result, all that is needed at the installation site is a 220V power connection.

The following steps are required for the installation of the measuring system:

- Unpacking and Installation of the AMS
- Installation of weather station, antenna, GPS-receiver, sampling pipe, Fidas® control unit and sampling head
- Connection of all supply and control lines
- Power connection
- Power-up of AMS
- After a warm-up period of at least 1 h, calibration / verification according to chapter 3.1 in the manual. This test comprises 5 steps:
  - Automatic offset alignment
  - Testing of tightness of the overall system
  - Verification/adjustment of sensitivity of the particle sensor
  - Examination of particle flow within the particle sensor
  - Check of volume flow
- (as needed) installation of the gravimetric filter
- Check of instrument setting concerning the implemented evaluation algorithm, date and time etc.
- Examination of sensors for ambient temperature and pressure as well as flow rate
- Optional connection of peripheral logging or control systems (network connection, USB flash drive, Modbus via RS232) to the corresponding ports

These operations, and therefore the setup time for the first-time installation, require approx. 2 h. If mounted once, the measuring system is easy to transport as a whole and can be moved from one measuring test site to another.

The warm-up time is the time between the start of operation of the measuring system and the point when it is ready for measurement.

Upon power-up (boot of Windows operating system and Fidas® start-up manager), the measuring process starts automatically. Depending on the averaging time that has been set it takes a few minutes until the first measurements are displayed. As soon as the status “device ready” is displayed (marked in green on the lower right side of the display), the system is fully operational. After that the device provides the sliding 30-min mean values of the mass concentrations which are updated every second (this setting was chosen for type approval testing). The warm-up usually takes about 10-15 min.

If necessary, any changes to basic parameters can quickly be carried out by personnel that are familiar with the AMS. However, normal measuring operation is discontinued and the device is switched to „expert user mode“.

6.5 Assessment

Setup and warm-up times were determined.

The measuring system can easily be operated at various measuring sites. The setup time amounts to approximately 2 h at first-time installation. The warm-up time amounts to 10-15 min, depending on the necessary stabilisation time.

Performance criterion met? yes

6.6 Detailed 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. These 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

Additionally, a measuring device for recording the energy consumption and scales were used to test this performance criterion.

6.3 Method

The supplied instruments were compared to the descriptions in the manuals. The specified energy consumption is determined over a 24 h-standard operation during the field test.

6.4 Evaluation

The measuring system Fidas® 200 S is equipped with weatherproof housing and thus designed for outdoor installation. The AMS shall be installed in horizontal position.

Dimensions and weight of the AMS match the information given in the operator's manual.

According to the manufacturer, the energy requirements of the AMS with the inserted pump are about 200 W at maximum for the complete system. During a 24 h test the total power demand of the AMS was determined. During this test, the stated value was not exceeded at any time.

6.5 Assessment

The instrument design specifications listed in the operator's manual are complete and correct.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

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 Technical equipment

No additional tools are required here.

6.3 Method

The measuring system is operated either directly via touch screen display on the front site of the AMS or indirectly from an external computer using internet / web access (for instance with the TeamViewer software) via the RS232 or Ethernet ports.

The menu levels which are not protected by password mostly allow reviewing measurements, parameters etc. While changing the IADS' mode of operation as well as adjusting the particle sensor is also possible on these levels, this can only be done by typing in several key sequences.

Nevertheless, parameters implemented in the system can only be changed in "expert user mode".

Moreover, the door of the weatherproof housing is protected by two locks which prevent unauthorized access to the measuring system.

6.4 Evaluation

Unintended and unauthorised adjustment of instrument parameters can be avoided by password protection. Even without password protection, the change of operation mode of the IADS and the adjustment the particle sensor can only be done by pressing several key sequences. Moreover, additional protection against unauthorised intervention is given by installing the system in a locked measuring cabinet.

6.5 Assessment

The measuring system is secured against illicit or unintentional adjustments of instrument parameters. Additional protection against unauthorized access is provided by the lockable door of the weatherproof housing.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

6.1 4.1.7 Data output

The output signals shall be provided digitally (e.g. RS232) and/or as analogue signals (e.g. 4 mA to 20 mA).

6.2 Equipment

PC with "TeamViewer" software or USB flash drive

6.3 Method

For the test, a PC with "TeamViewer" software (via Ethernet / GPS modem) as well as a USB flash drive was used.

Via USB port, raw datasets can directly be stored to a USB flash drive. By means of the "TeamViewer" software they can also be downloaded from an external PC with internet connection via GPS modem. Both options have been used during type approval testing. Furthermore, data can be output via UDP protocol using the network interface or they can be uploaded to the manufacturer's web server automatically.

The AMS offers the possibility to output measured signals or communicate via serial port RS232 (Modbus, Bayern.Hessen protocol, ASCII).

The AMS does not provide analogue output signals.

6.4 Evaluation

The measured signals are offered as follows on the rear side of the instrument:

- 1 x RS232 port for communication via Modbus for remote enquiry of measured values and external control of the measuring system (WebAccess). Application of the Bayern-Hessen protocol is also possible, but was not part of the type approval test.
- 1 x Ethernet port for connecting to a network or PC for data transmission as well as remote control, for instance via TeamViewer software
- 1 x USB port on the front side of the device, enables direct downloading of data for processing at an external PC
- 1 x USB port on the rear side of the device to connect, for instance, printer, keyboard, mouse or USB flash drive

6.5 Assessment

The test signals are provided digitally (via Ethernet, RS232, and USB).

Connection of additional measuring and peripheral devices via the corresponding ports is possible.

Performance criterion met? yes

6.6 Detailed presentation of test results

Figure 37 shows the instrument's rear side with the various data outputs.

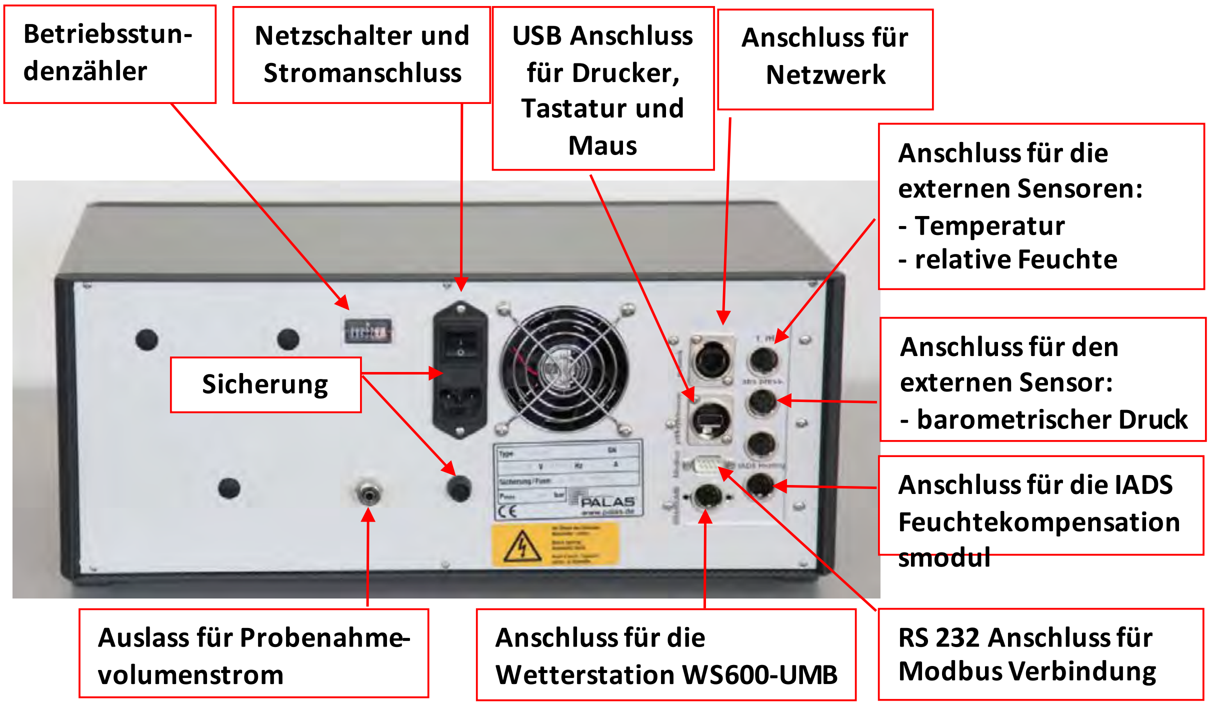


Figure 37: Rear side of the Fidas® 200 S control unit

Key

Betriebsstundenzähler: Operating hour meter

Netzschalter und Stromanschluss: Power switch and power connection

USB Anschluss für Drucker Tastatur und Maus: USB-connection for printer, keyboard and mouse

Anschluss für Netzwerk: Network connection

Anschluss für die externen Sensoren: Temperatur, rel. Feuchte: Connection for external sensors: temperature, rel. humidity

Anschluss für den externen Sensor: barometrischer Druck:

Connection for external sensor: barometric pressure

Anschluss für die IADS Feuchtekompensation: Connection for the IADS moisture compensation

RS 232 Anschluss für Modbus Verbindung: RS 232 connection for Modbus connection

Anschluss für die Wetterstation WS600-UMB:

Connection fort he weather station WS600-UMB

Auslass für Probenahmevolumenstrom:

Exhaust for sample flow

6.1 5.1 General

The manufacturer's information provided in the operator's manual shall not contradict the findings of the type approval test.

6.2 Equipment

Not required here.

6.3 Method

The test results are compared with the information given in the manual.

6.4 Evaluation

Instances where the first draft of the manual deviated from the actual design of the instrument have been corrected.

6.5 Assessment

No differences between the instrument design and the descriptions given in the manuals were found.

Performance criterion met? yes

6.6 Detailed presentation of test result

For this module, refer to item 6.4.

6.1 5.2.1 Certification ranges

The certification range over which the AMS will be tested shall be determined.

6.2 Equipment

No additional tools are required here.

6.3 Method

The certification range over which the AMS will be tested shall be determined.

6.4 Evaluation

VDI Standard 4202, Sheet 1 lists the following minimum requirements for the certification ranges of measuring systems intended for the measurement ambient air pollution through suspended particulate matter:

Table 15: Certification ranges

Component	Minimum value cr	Maximum value cr	Limit value	Assessment period
	in µg/m³	in µg/m³	in µg/m³	
PM_{10}	0	100	50	24 h
$PM_{2,5}$	0	50	25	Calendar year

Certification ranges are related to the limit value with the shortest assessment period and used for the assessment period of the measuring system in the range of the limit value. This assessment of the measuring system in the range of the limit value is performed as part of the determination of the expanded uncertainty of the candidates according to the guide [5]. For this purpose, the following values are used as reference values in accordance with the specifications of the Guide:

PM_{10}: 50 µg/m³

$PM_{2.5}$: 30 µg/m³

Refer to test item 6.1 5.4.10 Calculation of expanded uncertainty between candidates in this report.

6.5 Assessment

Assessment of AMS in the range of the relevant limit values is possible.

Performance criterion met? yes

6.6 Detailed presentation of test results

Refer to test item 6.1 5.4.10 Calculation of expanded uncertainty between candidates in this report.

6.1 5.2.2 Measuring range

The upper limit of measurement of the measuring system shall be greater or equal to the upper limit of the certification range.

6.2 Equipment

No additional tools are required.

6.3 Method

It was examined whether the upper limit of measurement is greater or equal to the upper limit of the certification range.

6.4 Evaluation

The AMS can measure up to 4000 particles/cm³ (10 % coincidence error).This corresponds to a maximum concentration of 0-10.000 µg/m³ (measured with standardised SAE fine test dust).

Measuring range:	0 – 10 000 µg/m³
Upper limit of certification range:	PM_{10}: 100 µg/m³
	$PM_{2.5}$: 50 µg/m³

6.5 Assessment

The upper limit of measurement is greater than the corresponding upper limit of the certification range.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

6.1 5.2.3 Negative output signals

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

6.2 Equipment

No additional tools are required here.

6.3 Method

In the field test and during laboratory testing, it was examined whether the AMS has a means to output negative measured values as well.

6.4 Evaluation

While the AMS has a means to display negative values and transmit these values via the respective signal outputs, no negative output signals occurred during type approval testing. Due to measuring principle and instrument design, negative output signals are not to be expected.

6.5 Assessment

Negative output signals are directly displayed by the AMS and can be output via corresponding data outputs. Yet, they are not to be expected due to measuring principle and instrument design.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

6.1 5.2.4 Failure in the mains voltage

In case of malfunction of the measuring system or failure in the mains voltage for a period of up to 72 h, 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 here.

6.3 Method

A failure in the mains voltage was simulated and it was tested, whether the AMS remains undamaged and is ready for measurement after the restart of power supply.

6.4 Evaluation

The measuring systems do not require operation gas or calibration gas, therefore uncontrolled emission of gases is not possible.

When mains voltage returns after a power failure, the AMS automatically boots the Windows operating system as well as the Fidas® start-up manager and reaches the operation mode within a few minutes (see also item 6.1 4.1.4 Setup times and warm-up times).

6.5 Assessment

All parameters are secured against loss by buffering. When mains voltage returns the AMS goes back to failure-free operation mode and automatically resumes measuring after reaching the “device ready” instrument status.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

6.1 5.2.5 Operating states

The measuring system shall allow control of important operating states by telemetrically transmitted status signals.

6.2 Equipment

PC for data acquisition.

6.3 Method

A PC was connected indirectly to the AMS via Ethernet / UMTS to check data transfer and instrument status.

Moreover, the AMS can be monitored and controlled via serial ports.

The use of corresponding routers or modems enables telemonitoring and remote control.

6.4 Evaluation

The AMS allows extensive telemetric monitoring and control via various ports (Ethernet, RS232).

6.5 Assessment

The measuring systems can be monitored and operated extensively from an external PC via modem or router.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

6.1 5.2.6 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 here.

6.3 Method

The operator can monitor and partially control the AMS directly or via remote control.

Some functions such as checking the particle sensor can be accessed telemetrically but must be carried out on site.

6.4 Evaluation

All operating procedures that do not require practical work on site can be monitored by the user directly or via telemetrical remote control.

6.5 Assessment

In principle, all necessary operations for performing a functional check can be monitored directly on the system or via telemetric remote control.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

6.1 5.2.7 Maintenance interval

The maintenance interval of the measuring system shall be determined during the field test and specified. The maintenance interval should be three months, if possible, but at least two weeks.

6.2 Equipment

Not required here.

6.3 Method

The types of maintenance and the maintenance intervals required to ensure proper functioning of the AMS were determined in this performance criterion. In order to determine the maintenance interval, the results of the determination of the drift at zero and at reference point according to chapter 6.1 5.3.12 Long-term drift have been taken into account.

6.4 Evaluation

During the entire field test no impermissible drifts at zero have been observed in the candidates. Regular checks of the reference point by means of standardised CalDust 1100 as per 6.1 5.3.12 Long-term drift have shown that the permissible limits of 130 ± 1.5 channels cannot be ensured within a 3-monthly maintenance interval as has been suggested by the manufacturer. For that reason the check shall be performed once a month.

Thus, the maintenance interval is determined by regularly checking the particle sensor with CalDust 1100 (see also module 4.1.2).

During operating time, maintenance may be limited to contamination checks, plausibility checks and possible status and error messages.

6.5 Assessment

The maintenance interval of 4 weeks has been determined by regular checks of the particle sensor with CalDust 1100.

Performance criterion met? yes

6.6 Detailed presentation of results

For necessary maintenance work refer to item (module) 4.1.2 in this report or chapter 3 in the operator’s manual.

6.1 5.2.8 Availability

The availability of the measuring system shall be determined during the field test and shall be at least 95 %.

6.2 Equipment

Not required here.

6.3 Method

The start and end point of the availability checks are determined by the start and end point at each of the field test sites. For this purpose, all interruptions, for instance those caused by malfunctioning or maintenance work, are recorded as well.

6.4 Evaluation

Table 16 and Table 17 provide lists of operation times, time used for maintenance, and malfunction times. The measuring systems were operated over a period of 322 days in total during the field test. This period includes 27 days of zero filter operation and 1 day that was lost due to changing from inlet to zero filter (see also annex 5).

Downtimes caused by external influences which the instrument cannot be blamed for have been recorded on 10 June 2012, 31 December 2012, and 1 January 2013 (failure in the mains voltage). As a consequence of these external influences, the total operation time has been reduced to 319 days.

The following downtimes have been recorded:

SN 0111:

On 29 May 2012, the system was accidentally deactivated by pushing the "shut down" button on the remote control.

On 5 December 2012, a blown fuse in the heating of the weatherproof housing caused the device to fail.

SN 0112:

On 4 December 2012, 8 December 2012, and 9 December 2012, blown fuses in the heating of the weatherproof housing caused the device to fail.

Apart from that no further downtimes were recorded.

Downtimes caused by routine checks of the particle sensor and maintenance of the sampling heads as well as regular checks of flow rates and instrument tightness amount to 0.5 to 1 h per system. Daily mean values affected by this have not been discarded.

6.5 Assessment

The availability was 99.4 % for SN 0111 and 99.1 % for SN 0112 without test-related downtimes. Including test-related downtimes it was 90.6 % for SN 0111 and 90.3 % for SN 0112.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 16: Determination of availability (without test-related downtimes)

		System 1 (SN 0111)	System 2 (SN 0112)
Operating time	d	319	319
Downtime	d	2	3
Maintenance	d	-	-
Actual operating time	d	317	316
Availability	%	99.4	99.1

Table 17: Determination of availability (incl. test-related downtimes)

		System 1 (SN 0111)	System 2 (SN 0112)
Operating time	d	319	319
Downtime	d	2	3
Maintenance incl. zero filter	d	28	28
Actual operating time	d	289	288
Availability	%	90.6	90.3

6.1 5.2.9 Instrument software

The version of the instrument software to be tested shall be displayed during switch-on of the measuring system. The test institute shall be informed on changes in the instrument software, which have influence on the performance of the measuring system.

6.2 Equipment

Not required here.

6.3 Method

It was checked whether the measuring system has a means of displaying the instrument software. The manufacturer was advised to inform the test institute on any changes in the instrument software.

6.4 Evaluation

The current software version (Firmware Fidas® 200) is displayed during switch-on of the measuring system and can always be viewed in the “expert user mode” menu.

The type approval test was carried out with software version 100327.

The Fidas® 200 S measuring system saves data in the RAW format. In order to determine the mass concentration values, the stored raw data have to be converted by means of an evaluation algorithm. A size-dependent and weighted algorithm is used to convert particle size and number to mass concentrations. During type approval testing, conversion was performed using the evaluation algorithm PM_ENVIRO_0011. The validation of an additional evaluation algorithm demands explicit attestation of compliance with the minimum requirements on the basis of the raw datasets obtained during this type approval test.

The applied evaluation algorithm is stored directly in the device. Measured values which have been converted can be viewed on the display or transmitted via serial (Modbus, Bayern/Hessen, ASCII) or network output (UDP protocol). Moreover, the conversion of stored raw datasets to mass concentration values can also be performed externally on a PC with the PDAnalyze software using the PM_ENVIRO_0011 evaluation algorithm. During type approval testing, the PDAnalyze software was used in the 1.009 version. In the course of the testing, however, the software was enhanced to include the option “Specific Intervals” which allows the configuration of any desired time intervals when evaluating the data. In this way, the raw datasets can be converted to 24 h mean values without using spreadsheet software. This change results in a new software version 1.010 of PDAnalyze which has no effect on instrument performance.

6.5 Assessment

The version of the instrument software is displayed during switch-on of the measuring system and can be viewed at all times in the “expert user menu”. The test institute is informed on any changes in the instrument software. Mass concentration values are determined by means of the PM_ENVIRO_0011 evaluation algorithm. The validation of an additional evaluation algorithm demands explicit attestation of compliance with the minimum requirements on the basis of the raw datasets obtained during this type approval test.

Performance criterion met? yes

6.6 Detailed presentation of test results

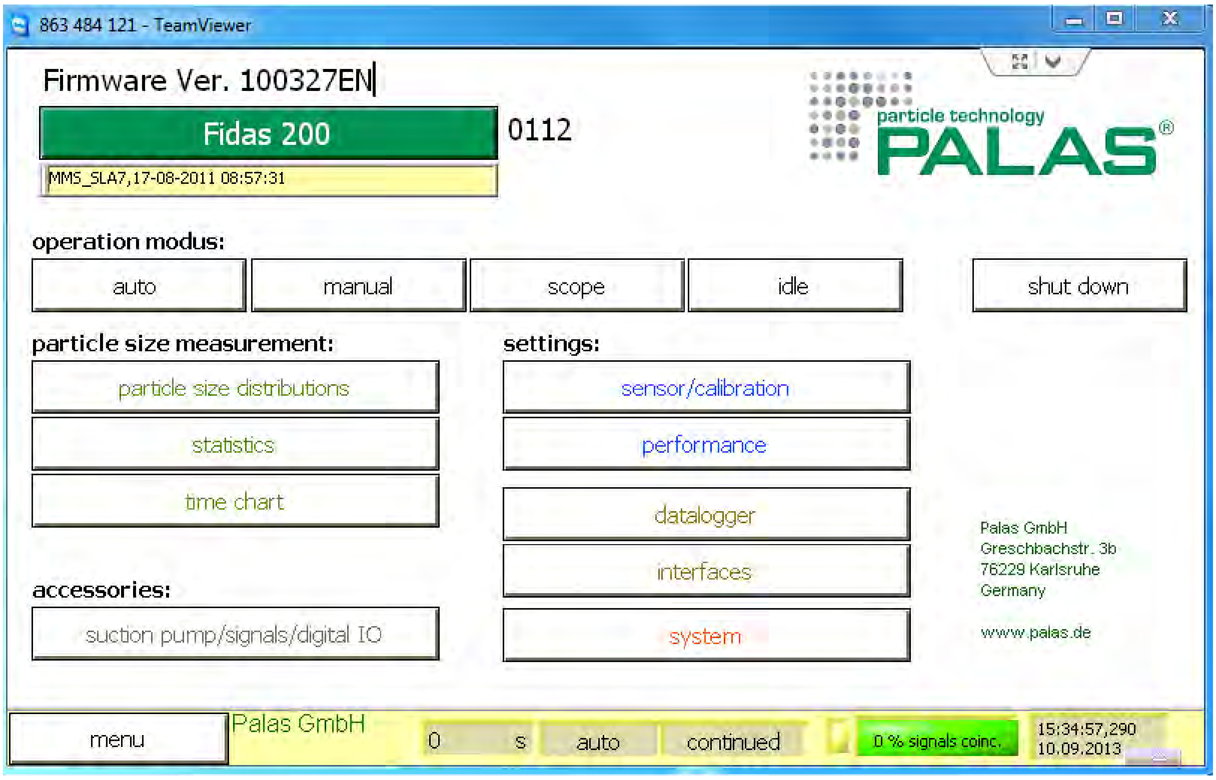


Figure 38: Display of software version – here 100327EN – the label “EN” was only used by Palas in order to mark the firmware used in the type approval test and will not appear in the future

6.1 5.3.1 General

The testing is performed on the basis of the minimum requirements stated in VDI Standard 4202, Sheet 1 (September 2010).

6.2 Equipment

Not required here.

6.3 Method

The testing is performed on the basis of the minimum requirements stated in VDI Standard 4202, Sheet 1 (September 2010).

6.4 Evaluation

After extensive revision, the VDI Standards 4202, Sheet 1 and 4203, Sheet 3 has been newly published in September 2010. Unfortunately, after this revision there are several ambiguities and inconsistencies in relation to concrete minimum requirements and the general significance of particular test items as far as the testing of particulate measuring systems is concerned. The following test items are in need of clarification:

6.1 5.3.2 Repeatability standard deviation at zero point

→ no performance criterion defined

6.1 5.3.3 Repeatability standard deviation at reference point

→ not applicable to particulate measuring devices

6.1 5.3.4 Linearity (lack of fit)

→ not applicable to particulate measuring devices

6.1 5.3.7 Sensitivity coefficient of surrounding temperature

→ no performance criterion defined

6.1 5.3.8 Sensitivity coefficient of supply voltage

→ no performance criterion defined

6.1 5.3.11 Standard deviation from paired measurements

→ no performance criterion defined

6.1 5.3.12 Long-term drift

→ no performance criterion defined

6.1 5.3.13 Short-term drift

→ not applicable to particulate measuring devices

6.1 5.3.18 Overall uncertainty

→ not applicable to particulate measuring devices

For this reason, an official enquiry was made to the competent body in Germany, to define a coordinated procedure for dealing with the inconsistencies in the guideline.

The following procedure was suggested:

The test items 5.3.2, 5.3.7, 5.3.8, 5.3.11, and 5.3.12 are evaluated as before on the basis of the minimum requirements stated in the 2002 version of VDI Standard 4202, Sheet 1 (i.e. applying the reference values B_0, B_1, and B_2).

The test items 5.3.3, 5.3.4, 5.3.13, and 5.3.18 are omitted as they are irrelevant to particulate measuring devices.

The competent body in Germany agreed with the suggested procedure by decisions of 27 June 2011 and 07 October 2011.

6.5 Assessment

The test was carried out on the basis of the performance criteria stated in VDI Standard 4202, Sheet 1 (September 2010). However, the test items 5.3.2, 5.3.7, 5.3.8, 5.3.11, and 5.3.12 were evaluated on the basis of the performance criteria stated in the 2002 version of VDI Standard 4202, Sheet 1 (i.e. applying the reference values B_0, B_1, and B_2). The test items 5.3.3, 5.3.4, 5.3.13, and 5.3.18 were omitted as they are irrelevant to particulate measuring devices.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

6.1 5.3.2 Repeatability standard deviation at zero point

The repeatability standard deviation at zero point shall not exceed the requirements of Table 2 in VDI Standard 4202, Sheet 1 (September 2010) in the certification range according to Table 1 in VDI Standard 4202, Sheet 1 (September 2010).

In case of deviating certification ranges, the repeatability standard deviation at zero point shall not exceed 2 % of the upper limit of this certification range.

Note:

With regard to dust measuring devices, this test item cannot be evaluated on the basis of the current version of VDI Standards 4202, Sheet 1 (September 2010) and 4203, Sheet 3 (September 2010). By resolution of the competent body in Germany (see module 5.3.1), reference is made to the following minimum requirement in the previous version of this guideline (VDI Standard 4202, Sheet 1; June 2002):

The detection limit of the measuring system shall not exceed the reference value B_0. The detection limit shall be determined during the field test.

6.2 Equipment

Zero filter for testing the zero point.

6.3 Method

The detection limits of the candidates, SN 0111 and SN 0112, were determined by means of zero filters which were installed at the inlets of instruments. Over a period of 15 days and 24 h/day, particulate-free sample air was fed into the systems. The detection limit was determined in the laboratory test because long-term provision of particulate-free air proved impossible under field conditions.

6.4 Evaluation

The detection limit X is calculated from the standard deviation s_{x0} from the measured values when particulate-free sample air is sucked in by the two candidates. It corresponds to the standard deviation from the mean value s_{x0} of the measured values x_{0i} for each candidate multiplied by the Student's factor:

$$X = t_{n-1;0.95} \cdot s_{x0} \qquad \text{with} \cdot s_{x0} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

Reference value: $B_0 = 2\ \mu g/m^3$

6.5 Assessment

The tests resulted in detection limits of 8.7 x 10^{-4} µg/m³ (PM_{10}) and 8.7 x 10^{-4} µg/m³ ($PM_{2.5}$) for System 1 (SN 0111), and 6.6 x 10^{-7} µg/m³ (PM_{10}) and 6.6 x 10^{-7} µg/m³ ($PM_{2.5}$) for System 2 (SN 0112).

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 18: Detection limit PM_{10}

		Device SN 0111	Device SN 0112
Number of values n		15	15
Average of the zero values $\overline{x}_0$	µg/m³	0,0001924	0,0000002
Standard deviation of the values $s_{\overline{x}0}$	µg/m³	0,0004064	0,0000003
Student-Factor $t_{n-1;0,95}$		2,14	2,14
Detection limit x	µg/m³	**8,7E-04**	**6,6E-07**

Table 19: Detection limit $PM_{2.5}$

		Device SN 0111	Device SN 0112
Number of values n		15	15
Average of the zero values $\overline{x}_0$	µg/m³	0,0001638	0,0000002
Standard deviation of the values $s_{\overline{x}0}$	µg/m³	0,0004036	0,0000003
Student-Factor $t_{n-1;0,95}$		2,14	2,14
Detection limit x	µg/m³	**8,7E-04**	**6,6E-07**

The single measured values used in the determination of the detection limit are given in Annex 1 of this report.

6.1 5.3.3 Repeatability standard deviation at reference point

The repeatability standard deviation at reference point shall not exceed the requirements of Table 2 in VDI Standard 4202, Sheet 1 (September 2010) in the certification range according to Table 1 in VDI Standard 4202, Sheet 1 (September 2010). The limit value or the alert threshold shall be used as reference point.

In case of deviating certification ranges, the repeatability standard deviation at reference point shall not exceed 2 % of the upper limit of this certification range. In this case a value c_t at 70 % to 80 % of the upper limit of this certification range shall be used as reference point.

Note:

By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.4 Linearity (lack of fit)

The analytical function describing the relationship between the output signal and the value of the air quality characteristic shall be linear.

Reliable linearity is given, if deviations of the group averages of measured values about the calibration function meet the requirements of Table 2 in VDI Standard 4202, Sheet 1 (September 2010) in the certification range according to Table 1 in VDI Standard 4202, Sheet 1 (September 2010).

For all other certification ranges the group averages of measured values about the calibration function shall not exceed 5 % of the upper limit of the corresponding certification range.

Note:

By resolution of the competent body in Germany (refer to module 5.3.1), this test item is irrelevant to particulate measuring systems. Particulate measuring systems for PM_{10} shall be tested according to performance criterion 5.4.2 “Equivalency of the sampling system”. Particulate measuring systems for $PM_{2.5}$ shall be tested according to performance criterion 5.4.10 “Calculation of expanded uncertainty between candidates”.

6.2 Equipment

Refer to modules 5.4.2. (PM_{10}) and 5.4.10 ($PM_{2.5}$)

6.3 Method

Particulate measuring systems for PM_{10} shall be tested according to performance criterion 5.4.2 “Equivalency of the sampling system”.

Particulate measuring systems for $PM_{2.5}$ shall be tested according to performance criterion 5.4.10 “Calculation of expanded uncertainty between candidates”.

6.4 Evaluation

Refer to modules 5.4.2. (PM_{10}) and 5.4.10 ($PM_{2.5}$)

6.5 Assessment

Particulate measuring systems for PM_{10} shall be tested according to performance criterion 5.4.2 “Equivalency of the sampling system”.

Particulate measuring systems for $PM_{2.5}$ shall be tested according to performance criterion 5.4.10 “Calculation of expanded uncertainty between candidates”.

Performance criterion met? -

6.6 Detailed presentation of test results

Refer to modules 5.4.2 (PM_{10}) and 5.4.10 ($PM_{2.5}$)

6.1 5.3.5 Sensitivity coefficient of sample gas pressure

The sensitivity coefficient of sample gas pressure at reference point shall not exceed the requirements of Table 2 in VDI Standard 4202, Sheet 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

This test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.6 Sensitivity coefficient of sample gas temperature

The sensitivity coefficient of sample gas temperature at reference point shall not exceed the requirements of Table 2 in VDI Standard 4202, Sheet 1 (September 2010). A value c_t *at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.*

Note:

This test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.7 Sensitivity coefficient of surrounding temperature

The sensitivity coefficient of surrounding temperature at zero and reference point shall not exceed the requirements of Table 2 in VDI Standard 4202, Sheet 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used at reference point.

Note:

In relation to particulate measuring systems, this test item cannot be evaluated according to the current versions of VDI Standards 4202, Sheet 1 (September 2010) and 4203, Sheet 3 (September 2010), because the minimum requirements are not defined. By resolution of the competent body in Germany (see module 5.3.1), reference is made to the following requirements stated in the earlier version of VDI Standard 4202, Sheet 1 (June 2002):

If the surrounding temperature changes by 15 K in the range +5 °C to +20 °C or by 20 K in the range +20 °C to +40 °C, the temperature dependence of the measured value at zero point shall not exceed the reference value B_0.

The temperature dependence of the measured value in the range of the reference value B_1 shall not be greater than ± 5 % of the measured value when a change in temperature by 15 K in the range of +5 °C to +20 °C or +20 °C to +40 °C occurs.

6.2 Equipment

Climatic chamber for a temperature range of -20 to +50 °C, zero filter for testing the zero point, CalDust 1100 for testing the reference point.

6.3 Method

According to the manufacturer, the permissible ambient temperature range amounts to -20 °C to +50 °C.

In order to test the dependence of zero point and measured values on the surrounding temperature, the complete measuring systems were operated within a climatic chamber.

For the zero point test particle free sampling air was applied to both measuring systems SN 0111 and SN 0112 by means of zero filters installed at the instrument inlets.

The reference point test comprised a check and evaluation of the peak position upon application of CalDust 1100 in order to test the stability of the sensitivity of both candidates SN 0111 and SN 0112.

The sensitivity test was carried out with monodisperse dust (CalDust 1100). When applying this calibration dust, the size distribution is expected to peak in channel 130 (this corresponds with a particle size of 0.93 µm). In order to make the quantification of deviations in the classification possible, the datasets obtained in the field test were used to calculate the effects of a peak shift of max. ±3 channels on a measured PM value. For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for PM_{10} were defined. The concentration value to be expected depending on the peak shift was then calculated according to the matrix in chapter 4.2 Laboratory test.

The ambient temperature within the climatic chamber was altered in the sequence

20 °C – -20 °C – 20 °C – 50 °C – 20 °C.

The measured values at zero point (3 x 24 h per temperature level) and the measured values at reference point (3 x 24 h per temperature level) were recorded after an equilibration period of 24 h per temperature level.

6.4 Evaluation

Zero point:

The measured concentration values obtained in the individual 24-hour measurements were collected and evaluated. The absolute deviation in µg/m³ per temperature level in relation to the default temperature of 20 °C is considered.

Reference value: B_0 = 2 µg/m³

Reference point:

The measured value's change in percentage for each temperature level in relation to the initial temperature of 20 °C is checked.

6.5 Assessment

The ambient temperature range tested at the AMS installation site was -20 °C to +50 °C. Looking at the values that were output by the AMS, the maximum dependence of ambient temperature in the range of -20 °C to +50 °C at zero was -1.1 x 10^{-5} µg/m³ for $PM_{2.5}$ and -1.1 x 10^{-5} µg/m³ for PM_{10}.

At reference point, no deviations > 5.0 % for $PM_{2.5}$ and > 4.6 % for PM_{10} in relation to the default temperature of 20 °C were observed.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 20: Dependence of zero point on ambient temperature, deviations in µg/m³, mean value of three measurements, PM_{10}, SN 0111 & SN 0112

Ambient temperature		Deviation	
Start temperature	End temperature	SN 0111	SN 0112
°C	°C	µg/m³	µg/m³
20	-20	0,0E+00	-1,1E-05
-20	20	0,0E+00	-9,8E-06
20	50	1,2E-06	-1,1E-05
50	20	2,8E-07	-1,1E-05

Table 21: Dependence of zero point on ambient temperature, deviations in µg/m³, mean value of three measurements, $PM_{2.5}$, SN 0111 & SN 0112

Ambient temperature		Deviation	
Start temperature	End temperature	SN 0111	SN 0112
°C	°C	µg/m³	µg/m³
20	-20	0,0E+00	-1,1E-05
-20	20	0,0E+00	-9,8E-06
20	50	1,2E-06	-1,1E-05
50	20	2,8E-07	-1,1E-05

Table 22: Dependence of sensitivity (CalDust 1100) on ambient temperature, deviation in %, mean value of three measurements, PM_{10}, SN 0111 & SN 0112

Ambient temperature		Deviation	
Start temperature	End temperature	SN 0111	SN 0112
°C	°C	[%]	[%]
20	-20	-4.4	4.6
-20	20	-0.2	0.1
20	50	-1.2	0.1
50	20	0.1	0.2

Table 23: Dependence of sensitivity (CalDust 1100) on ambient temperature, deviation in %, mean value of three measurements, $PM_{2.5}$, SN 0111 & SN 0112

Ambient temperature		Deviation	
Start temperature	End temperature	SN 0111	SN 0112
°C	°C	[%]	[%]
20	-20	-4.4	5.0
-20	20	-0.2	0.1
20	50	-1.3	0.1
50	20	0.1	0.2

For the respective results of the 3 individual measurements refer to annex 2 and annex 3.

6.1 5.3.8 Sensitivity coefficient of supply voltage

The sensitivity coefficient of supply voltage shall not exceed the requirements of Table 2 of VDI Standard 4202, Sheet 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

In relation to particulate measuring systems, this test item cannot be evaluated according to the current versions of VDI Standards 4202, Sheet 1 (September 2010) and 4203, Sheet 3 (September 2010), because the minimum requirements are not defined. By resolution of the competent body in Germany (see module 5.3.1), reference is made to the following requirements stated in the earlier version of VDI Standard 4202, Sheet 1 (June 2002):

Change in the measured value at reference value B_1 caused by the common changes in the mains voltage in the interval (230 +15/-20) V shall not exceed B_0.

6.2 Equipment

Isolation transformer, CalDust 1100 for testing the reference point.

6.3 Method

In order to examine the dependence of measured signal on supply voltage, the latter was reduced from 230 V to 210 V and then increased over an intermediate stage of 230 V to 245 V.

The reference point test comprised a check and evaluation of the peak position upon application of CalDust 1100 in order to test the stability of the sensitivity of both candidates SN 0111 and SN 0112.

The sensitivity test was carried out with monodisperse dust (CalDust 1100). When applying this calibration dust, the size distribution is expected to peak in channel 130 (this corresponds with a particle size of 0.93 µm). In order to make the quantification of deviations in the classification possible, the datasets obtained in the field test were used to calculate the effects of a peak shift of max. ±3 channels on a measured PM value. For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for PM_{10} were defined. The concentration value to be expected depending on the peak shift was then calculated according to the matrix in chapter 4.2 Laboratory test.

As the AMS is not designed for mobile use, separate testing of the dependence of measurement signal on mains frequency was abstained from.

6.4 Evaluation

At reference point, the changes in percentage of the determined measured values were examined for each voltage step in relation to the default voltage of 230 V.

6.5 Assessment

No deviations > 0.8 % for $PM_{2.5}$ and > 0.7 % for PM_{10} in relation to the default value of 230 V due to changes in supply voltage were detected.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 24 and Table 25 present a summary of test results.

Table 24: Dependence of measured value on supply voltage, deviation in %, PM_{10}, SN 0111 & SN 0112

Mains voltage		Deviation	
Start voltage	End voltage	SN 0111	SN 0112
V	V	[%]	[%]
230	210	0.0	0.5
210	230	0.1	0.7
230	245	0.3	0.6
245	230	0.2	0.0

Table 25: Dependence of measured value on supply voltage, deviation in %, $PM_{2.5}$, SN 0111 & SN 011212

Mains voltage		Deviation	
Start voltage	End voltage	SN 0111	SN 0112
V	V	[%]	[%]
230	210	0.0	0.5
210	230	0.1	0.8
230	245	0.3	0.6
245	230	0.2	0.0

For the individual results refer to annex 4 in this report.

6.1 5.3.9 Cross-sensitivity

The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table 2 (VDI Standard 4202, Sheet 1; September 2010) at zero and reference point.

Note:

This test item is irrelevant to particulate measuring systems. As minimum requirement 5.4.5 applies in this case, the test results are stated in module 5.4.5.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.10 Averaging effect

For gaseous components the measuring system shall allow the formation of hourly averages.

The averaging effect shall not exceed the requirements of Table 2 (VDI Standard 4202 Sheet 1; September 2010).

Note:

This test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.11 Standard deviation from paired measurements

The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test. It shall not exceed the requirements of Table 2 (VDI Standard 4202, Sheet 1; September 2010).

Note:

In relation to particulate measuring systems, this test item cannot be evaluated according to the current versions of VDI Standards 4202, Sheet 1 (September 2010) and 4203, Sheet 3 (September 2010), because the minimum requirements are not defined. By resolution of the competent body in Germany (see module 5.3.1), reference is made to the following requirements stated in the earlier version of VDI Standard 4202, Sheet 1 (June 2002):

The "Reproduzierbarkeit" [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 reference value.

6.2 Equipment

For the determination of reproducibility, the additional measuring systems described in chapter 5 were used.

6.3 Method

Reproducibility is defined as the maximum difference between two randomly chosen single values that have been obtained under equal conditions. Reproducibility was determined using two identical measuring systems that were operated simultaneously during the field test. For this purpose, all measurement data obtained during the entire field test was evaluated.

6.4 Evaluation

The reproducibility is calculated as follows:

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

- R = Reproducibility at B_1
- U = Uncertainty
- B_1 = 40 µg/m³ for PM_{10} and 25 µg/m³ for $PM_{2.5}$
- s_D = Standard deviation from paired measurements
- n = No. of paired measurements
- $t_{(n;0.95)}$ = Student's factor at confidence level of 95 %
- x_{1i} = Measured signal of system 1 (e.g. SN 0111) at i^{th} concentration
- x_{2i} = Measured signal of system 2 (e.g. SN 0112) at i^{th} concentration

6.5 Assessment

In the field test, the reproducibility for the complete dataset was 29 for $PM_{2.5}$ and 36 for PM_{10}.

Performance criterion met? yes

6.6 Detailed presentation of test results

The test results are summarised in Table 26 and Table 27. The graphical representation for PM_{10} is given in Figure 71 to Figure 75 and for $PM_{2.5}$ in Figure 64 to Figure 68.

Note: The determined uncertainties are related to reference value B_1 for each site:

Table 26: Concentration mean values, standard deviation, uncertainty range, and reproducibility in the field, measured component PM_{10}

Test site	Number	$\bar{c}$ (SN 0111)	$\bar{c}$ (SN 0112)	$\bar{c}_{ges}$	s_D	t	U	R
		µg/m³	µg/m³	µg/m³	µg/m³		µg/m³	
Cologne, summer	101	15,6	15,4	15,5	0,252	1,984	0,50	80
Cologne, winter	66	20,3	19,6	20,0	0,619	1,997	1,24	32
Bonn, winter	60	28,8	27,9	28,4	0,787	2,000	1,57	25
Bornheim, summer	58	17,2	16,3	16,7	0,825	2,002	1,65	24
All sites	285	19,8	19,2	19,5	0,567	1,968	1,12	36

Table 27: Concentration mean values, standard deviation, uncertainty range, and reproducibility in the field, measured component $PM_{2.5}$

Site	Number	$\bar{c}$ (SN 0111)	$\bar{c}$ (SN 0112)	$\bar{c}_{ges}$	s_D	t	U	R
		µg/m³	µg/m³	µg/m³	µg/m³		µg/m³	
Cologne, summer	101	9,9	9,9	9,9	0,109	1,984	0,22	115
Cologne, winter	66	17,0	16,4	16,7	0,517	1,997	1,03	24
Bonn, winter	60	21,7	21,1	21,4	0,640	2,000	1,28	20
Bornheim, summer	58	11,4	11,0	11,2	0,475	2,002	0,95	26
All sites	285	14,4	14,0	14,2	0,431	1,968	0,85	29

- $\bar{c}$ (SN 0111): Mean value of concentrations System SN 0111
- $\bar{c}$ (SN 0112): Mean value of concentrations System SN 0112
- $\bar{c}_{ges}$: Mean value of concentrations Systems SN 0111 & SN 0112

For individual values refer to annex 5 of the appendix.

6.1 5.3.12 Long-term drift

The long-term drift at zero point and reference point shall not exceed the requirements of Table 2 (VDI Standard 4202, Sheet 1; September 2010) in the field test. A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

In relation to particulate measuring systems, this test item cannot be evaluated according to the current versions of VDI Standards 4202, Sheet 1 (September 2010) and 4203, Sheet 3 (September 2010), because the minimum requirements are not defined. By resolution of the competent body in Germany (see module 5.3.1), reference is made to the following requirements stated in the earlier version of VDI Standard 4202, Sheet 1 (June 2002):

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

6.2 Equipment

Zero filter for testing the zero point, CalDust 1100 for testing the reference point.

6.3 Method

The test was carried out as part of the field test over a period of about 14 months altogether.

In the context of the regular monthly checks carried (including those at the beginning and end of tests at each field test site), both measuring systems were operated with zero filters applied to their inlets for at least 24 h. The measured zero values were then evaluated.

Furthermore, the stability of the sensitivity was checked with CalDust 1100 and evaluated at the beginning and at the end of the tests at each field test site.

6.4 Evaluation

While it is possible to assess zero point drift and drift of the measured value within a 24 h period, it is not useful for particulate measuring systems.

The evaluation at zero point is made on the basis of the measurement results of the regular external zero point measurement by comparing the respective values with the corresponding “measured values” of the previous test and the “measured value” of the first test.

The sensitivity test was carried out with monodisperse dust (CalDust 1100). When applying this calibration dust, the size distribution is expected to peak in channel 130 (this corresponds with a particle size of 0.93 µm). In order to make the quantification of deviations in the classification possible, the datasets obtained in the field test were used to calculate the effects of a peak shift of max. ±3 channels on a measured PM value. For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for PM_{10} were defined. The concentration value to be expected depending on the peak shift was then calculated according to the matrix in chapter 4.2 Laboratory test.

The evaluation at reference point is made on the basis of the measurement results of the regular sensitivity test by comparing the respective values with the corresponding “measured values” of the previous test and the “measured value” of the first test.

6.5 Assessment

For $PM_{2.5}$, the maximum deviation at zero point was 0.1 µg/m³ in relation to the previous value and 0.1 µg/m³ in relation to the start value. Thus, it lies within the permissible limits of B_0 = 2 µg/m³.

For PM_{10}, the maximum deviation at zero point was 0.1 µg/m³ for in relation to the previous value and 0.1 µg/m³ in relation to the start value. Thus, it lies within the permissible limits of B_0 = 2 µg/m³.

The sensitivity drift values that were determined during testing are max. -4.7 % for $PM_{2.5}$ and -8.1 % for PM_{10} in relation to the respective start value. Therefore, they exceed the permissible deviation of ± 5 % of B_1.

The manufacturer suggests adjustment of the AMS as soon as the deviation from the nominal channel 130 is ± 1.5 channels (according to the matrix in chapter 4.2 Laboratory test this corresponds to a 4 % deviation for $PM_{2.5}$ as well as for PM_{10}). On the basis of the results obtained in the drift tests, a sensitivity check shall be carried out once a month.

Performance criterion met? no

6.6 Detailed presentation of test results

Table 28 and Table 29 provide the obtained measured values for zero point as well as the calculated deviations in relation to the previous and the starting value in µg/m³. Figure 39 to Figure 42 provide a graphic representation of zero point drift over the course of testing.

The deviations of the measured values from the corresponding previous value in % are listed in Table 30 and Table 31.

Figure 43 and Figure 45 present graphical representations of the drift of measured values (in relation to the previous values).

Table 28: Zero point drift SN 0111 & SN 0112, PM_{10}, with zero filter

Date	SN 0111			Date	SN 0112		
	Measured Value	Deviation from previous value	Deviation from start value		Measured Value	Deviation from previous value	Deviation from start value
	µg/m³	µg/m³	µg/m³		µg/m³	µg/m³	µg/m³
5/10/2012	0.0	-	-	5/10/2012	0.0	-	-
5/11/2012	0.0	0.0	0.0	5/11/2012	0.0	0.0	0.0
5/12/2012	0.0	0.0	0.0	5/12/2012	0.0	0.0	0.0
5/13/2012	0.0	0.0	0.0	5/13/2012	0.0	0.0	0.0
6/16/2012	0.0	0.0	0.0	6/16/2012	0.0	0.0	0.0
6/17/2012	0.0	0.0	0.0	6/17/2012	0.0	0.0	0.0
7/20/2012	0.1	0.1	0.1	7/20/2012	0.0	0.0	0.0
7/21/2012	0.0	-0.1	0.0	7/21/2012	0.0	0.0	0.0
7/22/2012	0.0	0.0	0.0	7/22/2012	0.0	0.0	0.0
8/17/2012	0.0	0.0	0.0	8/17/2012	0.0	0.0	0.0
8/18/2012	0.0	0.0	0.0	8/18/2012	0.0	0.0	0.0
8/19/2012	0.0	0.0	0.0	8/19/2012	0.0	0.0	0.0
11/19/2012	0.0	0.0	0.0	11/19/2012	0.0	0.0	0.0
11/20/2012	0.0	0.0	0.0	11/20/2012	0.0	0.0	0.0
1/11/2013	0.0	0.0	0.0	1/11/2013	0.0	0.0	0.0
1/12/2013	0.0	0.0	0.0	1/12/2013	0.0	0.0	0.0
1/13/2013	0.0	0.0	0.0	1/13/2013	0.0	0.0	0.0
2/5/2013	0.0	0.0	0.0	2/5/2013	0.0	0.0	0.0
2/6/2013	0.0	0.0	0.0	2/6/2013	0.0	0.0	0.0
2/27/2013	0.0	0.0	0.0	2/27/2013	0.0	0.0	0.0
2/28/2013	0.1	0.1	0.1	2/28/2013	0.1	0.1	0.1
3/30/2013	0.0	-0.1	0.0	3/30/2013	0.0	-0.1	0.0
3/31/2013	0.0	0.0	0.0	3/31/2013	0.0	0.0	0.0
4/1/2013	0.0	0.0	0.0	4/1/2013	0.0	0.0	0.0
4/26/2013	0.0	0.0	0.0	4/26/2013	0.1	0.1	0.1
4/27/2013	0.0	0.0	0.0	4/27/2013	0.0	-0.1	0.0
4/28/2013	0.0	0.0	0.0	4/28/2013	0.0	0.0	0.0
5/14/2013	0.0	0.0	0.0	5/14/2013	0.0	0.0	0.0
5/15/2013	0.1	0.1	0.1	5/15/2013	0.1	0.1	0.1
6/22/2013	0.0	-0.1	0.0	6/22/2013	0.0	-0.1	0.0
6/23/2013	0.1	0.1	0.1	6/23/2013	0.1	0.1	0.1

Table 29: Zero point drift SN 0111 & SN 0112, $PM_{2.5}$, with zero filter

Date	SN 0111			Date	SN 0112		
	Measured Value	Deviation from previous value	Deviation from start value		Measured Value	Deviation from previous value	Deviation from start value
	µg/m³	µg/m³	µg/m³		µg/m³	µg/m³	µg/m³
5/10/2012	0.0	-	-	5/10/2012	0.0	-	-
5/11/2012	0.0	0.0	0.0	5/11/2012	0.0	0.0	0.0
5/12/2012	0.0	0.0	0.0	5/12/2012	0.0	0.0	0.0
5/13/2012	0.0	0.0	0.0	5/13/2012	0.0	0.0	0.0
6/16/2012	0.0	0.0	0.0	6/16/2012	0.0	0.0	0.0
6/17/2012	0.0	0.0	0.0	6/17/2012	0.0	0.0	0.0
7/20/2012	0.1	0.1	0.1	7/20/2012	0.0	0.0	0.0
7/21/2012	0.0	-0.1	0.0	7/21/2012	0.0	0.0	0.0
7/22/2012	0.0	0.0	0.0	7/22/2012	0.0	0.0	0.0
8/17/2012	0.0	0.0	0.0	8/17/2012	0.0	0.0	0.0
8/18/2012	0.0	0.0	0.0	8/18/2012	0.0	0.0	0.0
8/19/2012	0.0	0.0	0.0	8/19/2012	0.0	0.0	0.0
11/19/2012	0.0	0.0	0.0	11/19/2012	0.0	0.0	0.0
11/20/2012	0.0	0.0	0.0	11/20/2012	0.0	0.0	0.0
1/11/2013	0.0	0.0	0.0	1/11/2013	0.0	0.0	0.0
1/12/2013	0.0	0.0	0.0	1/12/2013	0.0	0.0	0.0
1/13/2013	0.0	0.0	0.0	1/13/2013	0.0	0.0	0.0
2/5/2013	0.0	0.0	0.0	2/5/2013	0.0	0.0	0.0
2/6/2013	0.0	0.0	0.0	2/6/2013	0.0	0.0	0.0
2/27/2013	0.0	0.0	0.0	2/27/2013	0.0	0.0	0.0
2/28/2013	0.1	0.1	0.1	2/28/2013	0.1	0.1	0.1
3/30/2013	0.0	-0.1	0.0	3/30/2013	0.0	-0.1	0.0
3/31/2013	0.0	0.0	0.0	3/31/2013	0.0	0.0	0.0
4/1/2013	0.0	0.0	0.0	4/1/2013	0.0	0.0	0.0
4/26/2013	0.0	0.0	0.0	4/26/2013	0.0	0.0	0.0
4/27/2013	0.0	0.0	0.0	4/27/2013	0.0	0.0	0.0
4/28/2013	0.0	0.0	0.0	4/28/2013	0.0	0.0	0.0
5/14/2013	0.0	0.0	0.0	5/14/2013	0.0	0.0	0.0
5/15/2013	0.0	0.0	0.0	5/15/2013	0.1	0.1	0.1
6/22/2013	0.0	0.0	0.0	6/22/2013	0.0	-0.1	0.0
6/23/2013	0.0	0.0	0.0	6/23/2013	0.0	0.0	0.0

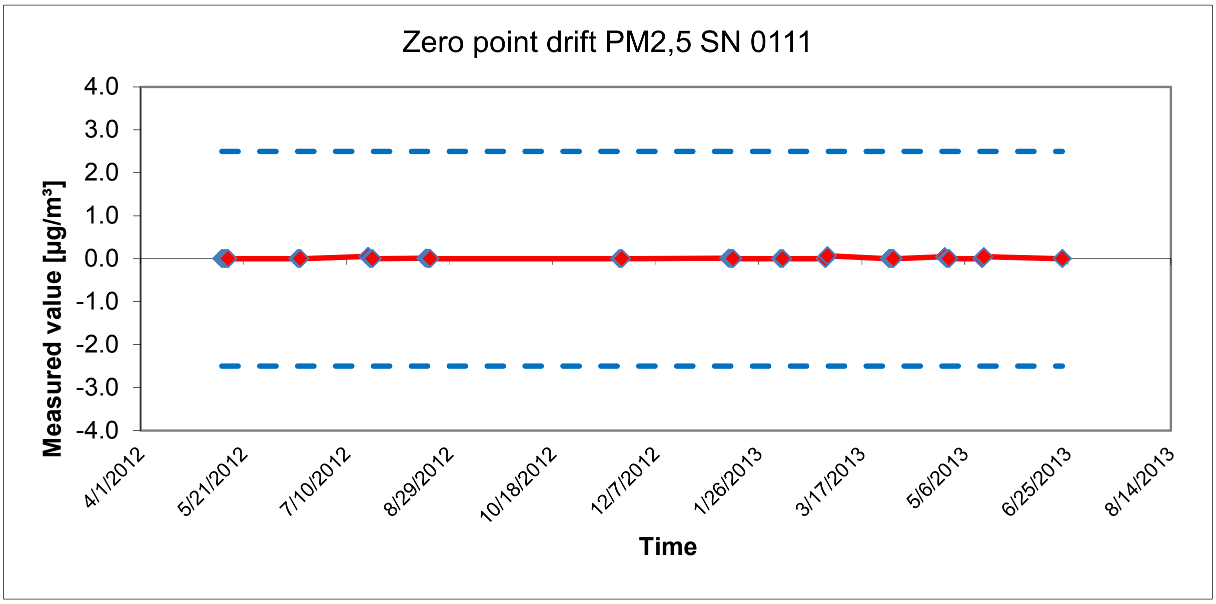


Figure 39: Zero point drift SN 0111, measured component $PM_{2.5}$

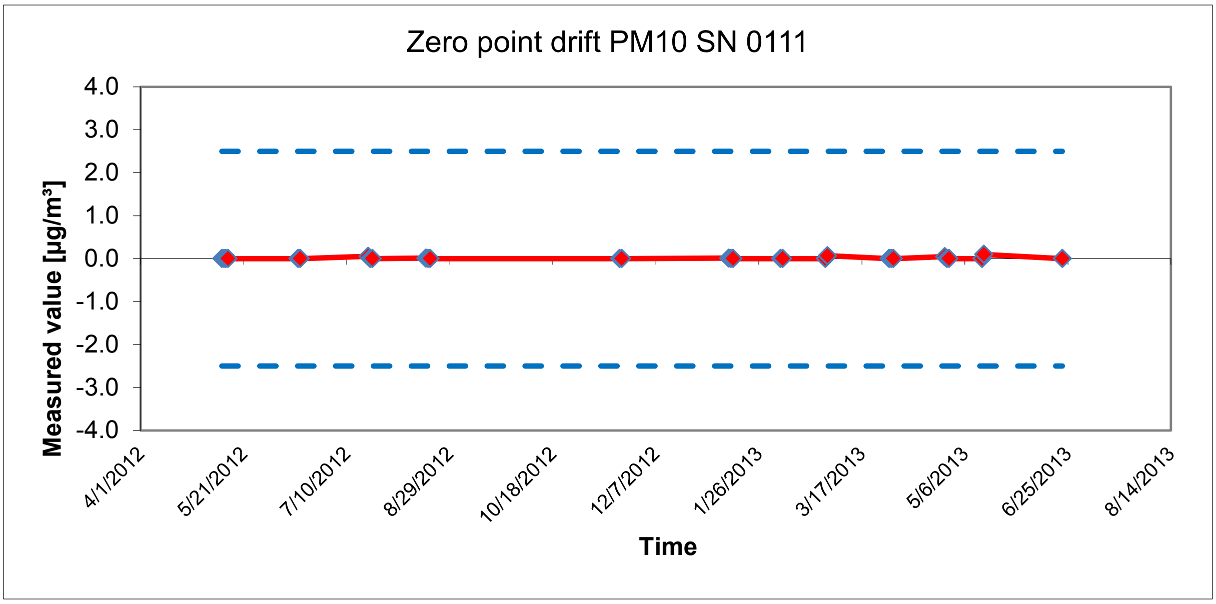


Figure 40: Zero point drift SN 0111, measured component PM_{10}

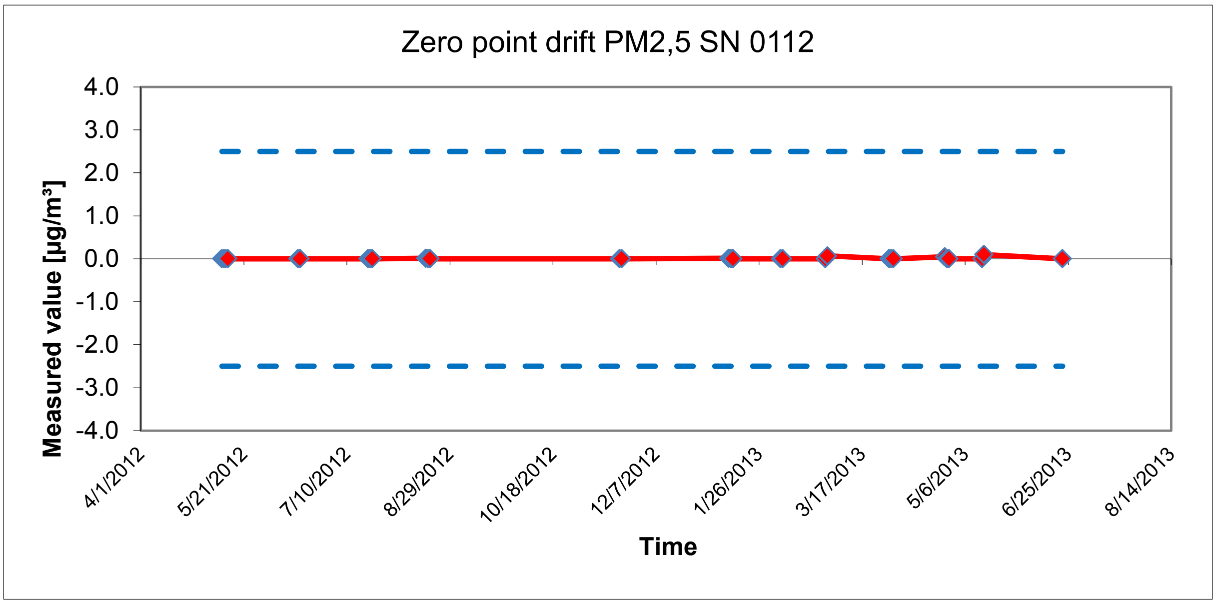


Figure 41: Zero point drift SN 0112, measured component $PM_{2.5}$

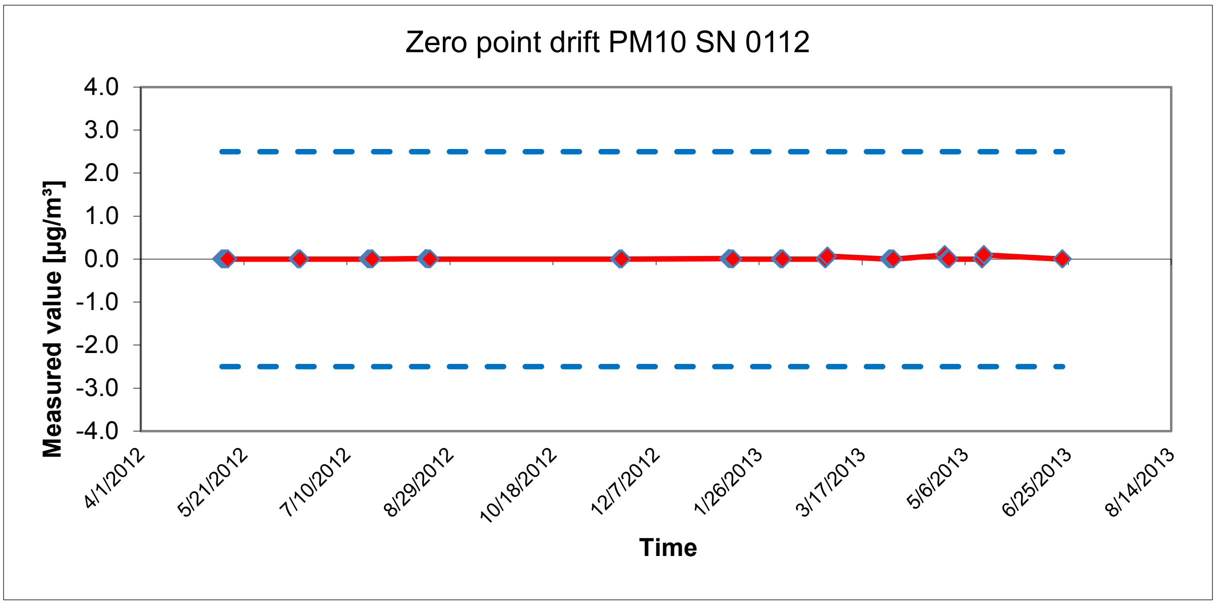


Figure 42: Zero point drift SN 0112, measured component PM_{10}

Table 30: Sensitivity drift SN 0111 & SN 0112, PM_{10}

Date	SN 0111			Date	SN 0112		
	Measured Value	Deviation from previous value	Deviation from start value		Measured Value	Deviation from previous value	Deviation from start value
		%	%			%	%
5/9/2012	40.0	-	-	5/9/2012	40.0	-	-
9/4/2012	39.5	-1.2	-1.2	9/4/2012	37,8*	-5.4	-5.4
11/22/2012	38.5	-2.5	-3.6	11/22/2012	37,8*	0.0	-5.4
2/5/2013	38,1*	-1.1	-4.7	2/5/2013	38.8	2.4	-3.1
2/26/2013	38.8	1.6	-3.1	2/26/2013	36,7**	-5.2	-8.1
5/2/2013	41,6*	7.3	4.0	5/2/2013	39.5	7.6	-1.2
6/13/2013	39.5	-4.9	-1.2	6/13/2013	40.8	3.2	2.0
7/11/2013	40.2	1.7	0.5	7/11/2013	37,8*	-7.2	-5.4

* Adjustment to channel 130
** Deviation larger than 3 channels. Adjustment to channel 130

Table 31: Sensitivity drift SN 0111 & SN 0112, $PM_{2.5}$

Date	SN 0111			Date	SN 0112		
	Measured Value	Deviation from previous value	Deviation from start value		Measured Value	Deviation from previous value	Deviation from start value
		%	%			%	%
5/9/2012	25.0	-	-	5/9/2012	25.0	-	-
9/4/2012	24.7	-1.2	-1.2	9/4/2012	23,7*	-5.4	-5.4
11/22/2012	24.1	-2.5	-3.6	11/22/2012	23,7*	0.0	-5.4
2/5/2013	23,8*	-1.1	-4.7	2/5/2013	24.2	2.4	-3.1
2/26/2013	24.2	1.6	-3.1	2/26/2013	23**	-5.0	-8.0
5/2/2013	26,1*	7.7	4.3	5/2/2013	24.7	7.4	-1.2
6/13/2013	24.7	-5.3	-1.2	6/13/2013	25.6	3.4	2.2
7/11/2013	25.1	1.7	0.5	7/11/2013	23,7*	-7.5	-5.4

* Adjustment to channel 130
** Deviation larger than 3 channels. Adjustment to channel 130

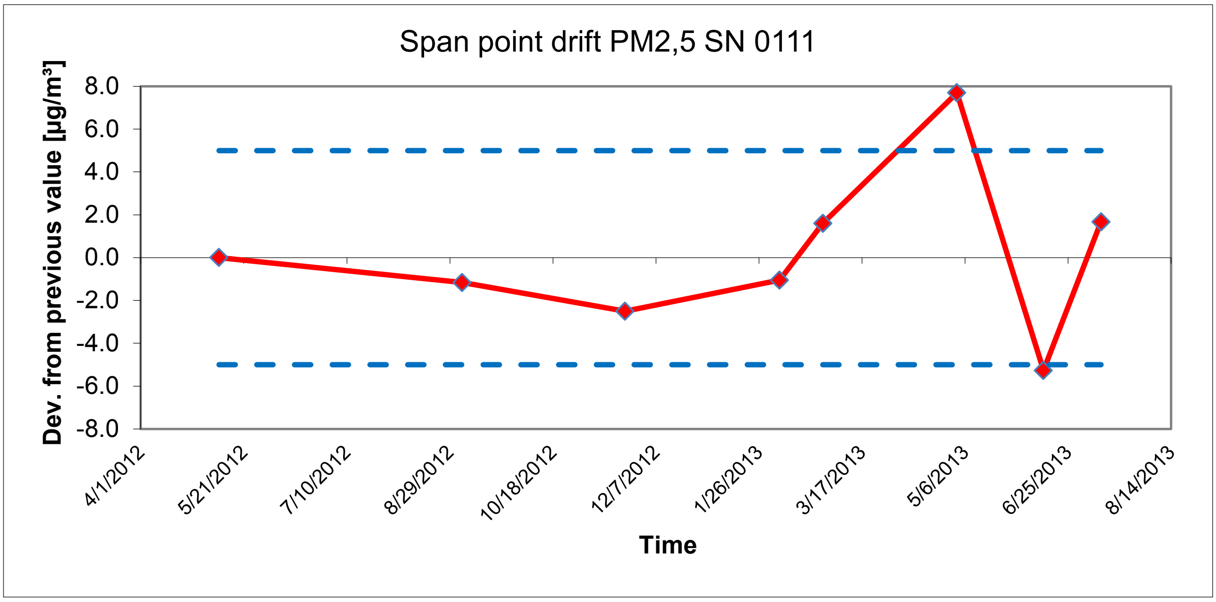


Figure 43: Drift of the measured value SN 0111, measured component $PM_{2.5}$

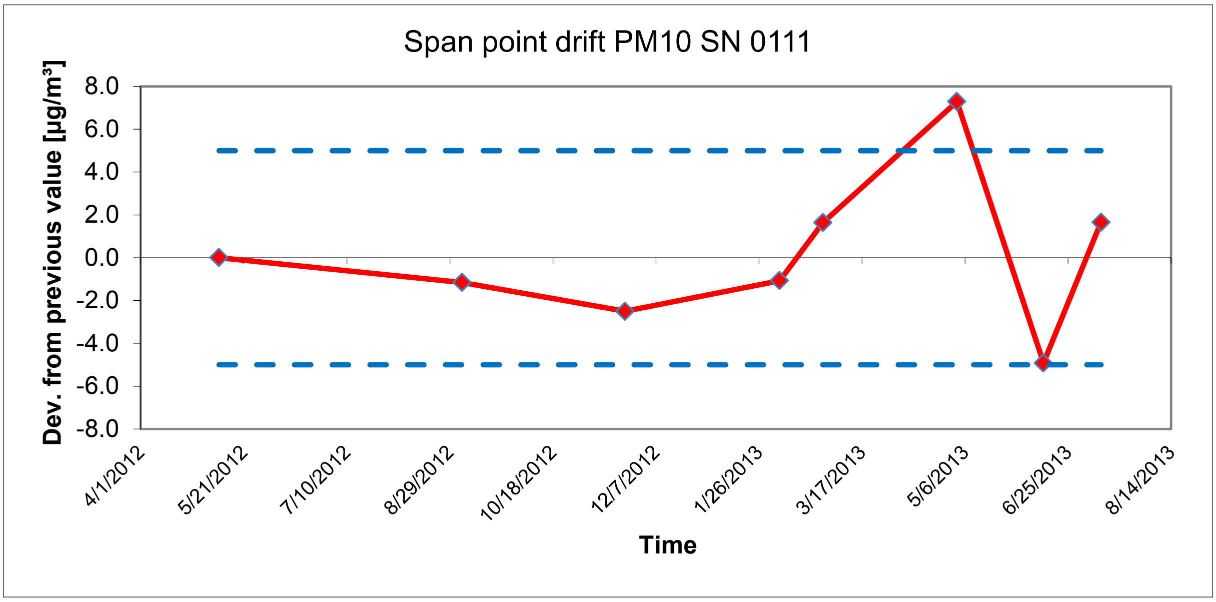


Figure 44: Drift of the measured value SN 0111, measured component PM_{10}

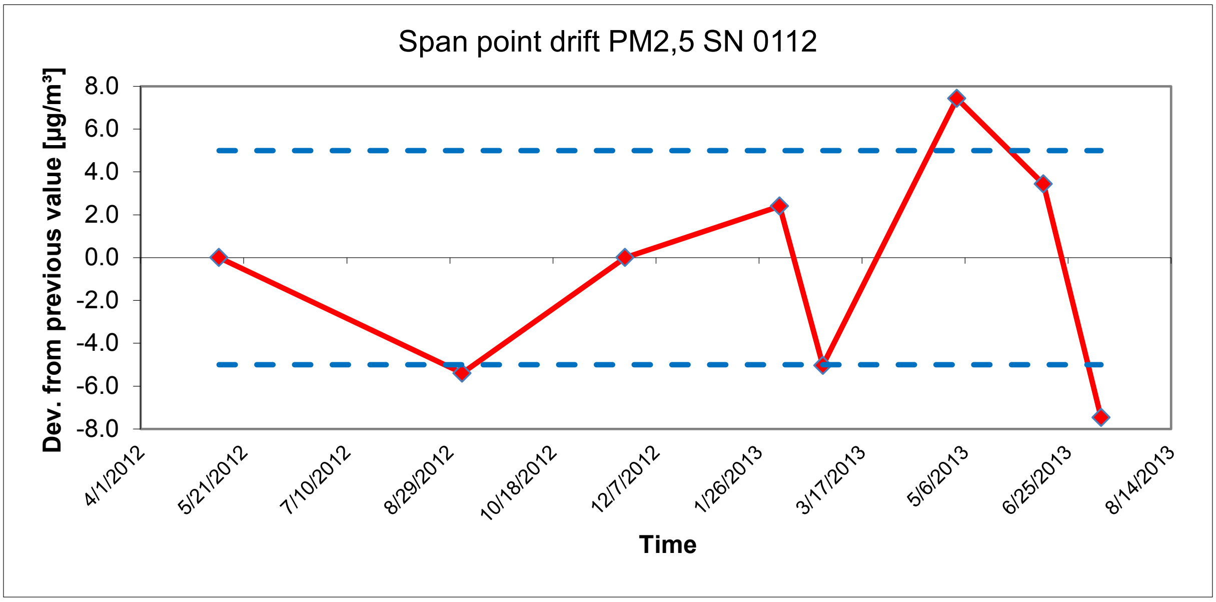


Figure 45: Drift of the measured value SN 0112, measured component $PM_{2.5}$

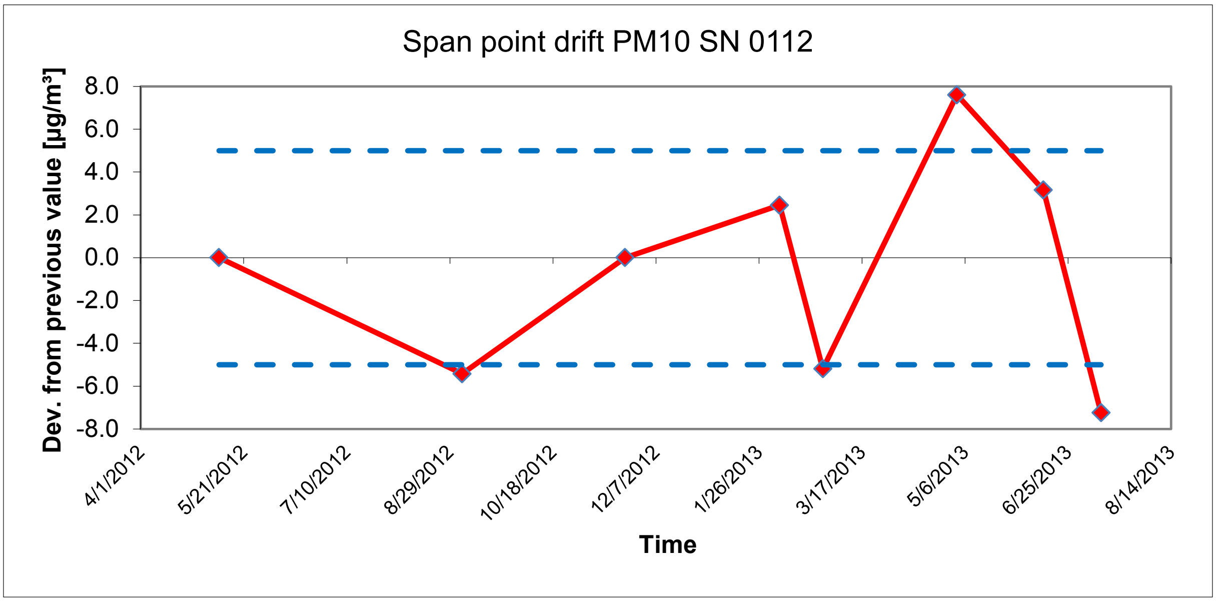


Figure 46: Drift of the measured value SN 0112, measured component PM_{10}

6.1 5.3.13 Short-term drift

The short-term drift at zero point and reference point shall not exceed the requirements of Table 2 (VDI Standard 4202, Sheet 1; September 2010) within 12 h (for benzene 24 h) in the laboratory test and within 24 h in the field test. A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.14 Response time

The response time (rise) of the measuring system shall not exceed 180 s.

The response time (fall) of the measuring system shall not exceed 180 s.

The difference between the response time (rise) and the response time (fall) of the measuring system shall not exceed 10 % of response time (rise) or 10 s, whatever value is larger.

Note:

This test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.15 Difference between sample and calibration port

The difference between the measured values obtained by feeding gas at the sample and calibration port shall not exceed the requirements of Table 2 of VDI Standard 4202, Sheet 1 (September 2010). A value c_t at 70 % to 80 % of the upper limit of the certification range shall be used as reference point.

Note:

This test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.16 Converter efficiency

In case of measuring systems with a converter, the converter efficiency shall be at least 98 %.

Note:

This test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.17 Increase of NO_2 concentration due to residence in the AMS

In case of NO_x measuring systems the increase of NO_2 due to residence in the measuring system shall not exceed the requirements of Table 2 of VDI Standard 4202, Sheet 1 (September 2010).

The requirements of Table 2 of VDI Standard 4202, Sheet 1 apply to certification ranges according to Table 1 of VDI Standard 4202, Sheet 1 (September 2010). For deviating certification ranges the requirements shall be proportionally converted.

Note:

This test item is irrelevant to particulate measuring systems.

6.2 Equipment

Not applicable.

6.3 Method

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

6.1 5.3.18 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 applicable EU Directives on air quality listed in Annex A, Table A 1 of VDI Standard 4202, Sheet 1 (September 2010).

Note:

By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems. Please refer to module 5.4.10.

6.2 Equipment

By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems. Please refer to module 5.4.10.

6.3 Method

By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems. Please refer to module 5.4.10.

6.4 Evaluation

By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems. Please refer to module 5.4.10.

6.5 Assessment

By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems. Please refer to module 5.4.10.

Performance criterion met? -

6.6 Detailed presentation of test results

By resolution of the competent body in Germany (see module 5.3.1), this test item is irrelevant to particulate measuring systems. Please refer to module 5.4.10.

6.1 5.4.1 General

The testing of particulate measuring systems shall be carried out according to the minimum requirements set out in Table 5 of VDI Standard 4202, Sheet 1 (September 2010). Particle mass concentrations shall be related to a defined volume. The relation to volume with respect to pressure and temperature shall be comprehensively described.

6.2 Equipment

No equipment is necessary to test this performance criterion.

6.3 Method

The test was carried out according to the minimum requirements set out in Table 5 of VDI Standard 4202, Sheet 1 (September 2010).

To determine whether the measured particle mass concentrations are related to a defined volume was the objective of the test.

6.4 Evaluation

The test was carried out according to the minimum requirements set out in Table 5 of VDI Standard 4202, Sheet 1 (September 2010).

The Fidas® 200 S measuring system is an optical measuring system which first determines the number and size of particles within a defined volume and then converts the obtained data to mass values by means of an algorithm. After that, the particle mass concentration is determined by relating the calculated mass to a sample volume.

6.5 Assessment

The test was carried out according to the minimum requirements set out in Table 5 of VDI Standard 4202, Sheet 1 (September 2010).

The Fidas® 200 S measuring system is an optical measuring system which first determines the number and size of particles within a defined volume and then converts the obtained data to mass values by means of an algorithm. After that, the particle mass concentration is determined by relating the calculated mass to a sample volume.

Performance criterion met? yes

6.6 Detailed presentation of test results

No equipment is necessary to test this performance criterion.

6.1 5.4.2 Equivalency of the sampling system

The equivalency between the PM_{10} sampling system and the reference method according to Standard EN 12341 [T5] shall be demonstrated.

Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.10 in this report.

6.2 Equipment

The performance criterion was tested with the additional equipment described in chapter 5 of this report.

6.3 Method

As described in chapter 4 of this report, the test was carried out at various sites during the field test. Different seasons as well as different PM_{10} concentrations were taken into account.

At least 15 valid data pairs were obtained at each test site.

6.4 Evaluation

Requirement according to Standard EN 12341:

The calculated functional correlation y = f(x) between the candidate (y) and the concentration values measured by the reference device (x) shall be limited by a two sided acceptance envelope. This acceptance envelope is defined by:

y = (x ± 10) µg/m³ for concentration mean values ≤ 100 µg/m³ and

y = 0.9x µg/m³ or 1.1x µg/m³ for concentration mean values > 100 µg/m³

Furthermore, the variation coefficient R^2 of the calculated reference-equivalence function shall not fall below the value of 0.95.

The test is directed towards the functional correlation between the concentration values obtained from paired determinations between the candidate and the reference device. Ideally, both systems measure the same mass fraction of suspended particulate matter so that y = x. The evaluation procedure is as follows:

A linear regression analysis was carried out for the measured values obtained at all four test sites individually and as a whole.

A reference equivalence function corresponding to the equation below is determined for each measured value y_i of the respective candidate and of the reference device x (both in µg/m³).

$$y_i = m \cdot x + b$$ with i = candidate Fidas® 200 S

6.5 Assessment

The reference equivalence functions for the (uncorrected) datasets lie within the limits of the respective acceptance envelope for all test sites. Moreover, the variation coefficient R^2 of the calculated reference equivalence function in the concentration range concerned is ≥ 0,95 for all test sites with the exception of Cologne (summer; only for SN 0112). Nevertheless, the instruments passed the equivalence test according to 6.1 5.4.10 Calculation of expanded uncertainty between candidates at all test sites.

Performance criterion met? no

6.6 Detailed presentation of test results

Table 32 and Table 33 present a summary of the results of the regression analyses. Figure 47 to Figure 56 provide graphical representations which illustrate these findings. In addition to the regression lines of both candidates, the diagrams show the curve y = x, which is considered ideal and the two-sided acceptance envelope All individual values for the candidates as well as for the reference devices are listed separately for each test site in annex 5 of the appendix.

Table 32: Results of the linear regression analysis of measurements with both candidates SN 0111 and SN 0112 at all four sites, raw data

SN 0111	**Number of paired values N**	**Slope m**	**Intercept b**	**R²**
Cologne, summer	81	1.016	-1.226	0.95
Cologne, winter	51	1.056	-1.071	0.99
Bonn, winter	50	1.024	0.455	0.97
Bornheim, summer	45	1.094	-1.481	0.95
SN 0112	**Number of paired values N**	**Slope m**	**Intercept b**	**R²**
Cologne, summer	82	0.998	-1.116	0.94
Cologne, winter	50	1.019	-1.102	0.99
Bonn, winter	50	0.984	0.651	0.96
Bornheim, summer	45	1.050	0.945	0.95

Table 33: Results of the linear regression analysis of measurements with both candidates SN 0111 and SN 0112 (total), raw data

Candidate	**Number of paired values N**	**Slope m**	**Intercept b**	**R²**
SN 0111	227	1.061	-1.295	0.97
SN 0112	227	1.025	-1.195	0.97

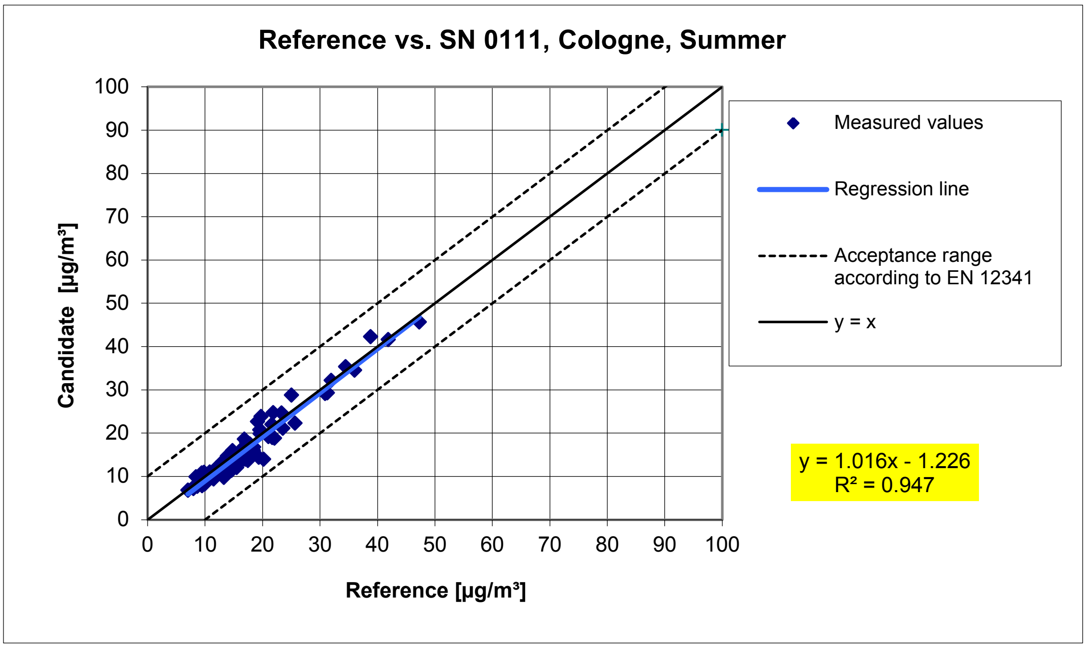


Figure 47: Reference equivalence function SN 0111, test site Cologne, summer

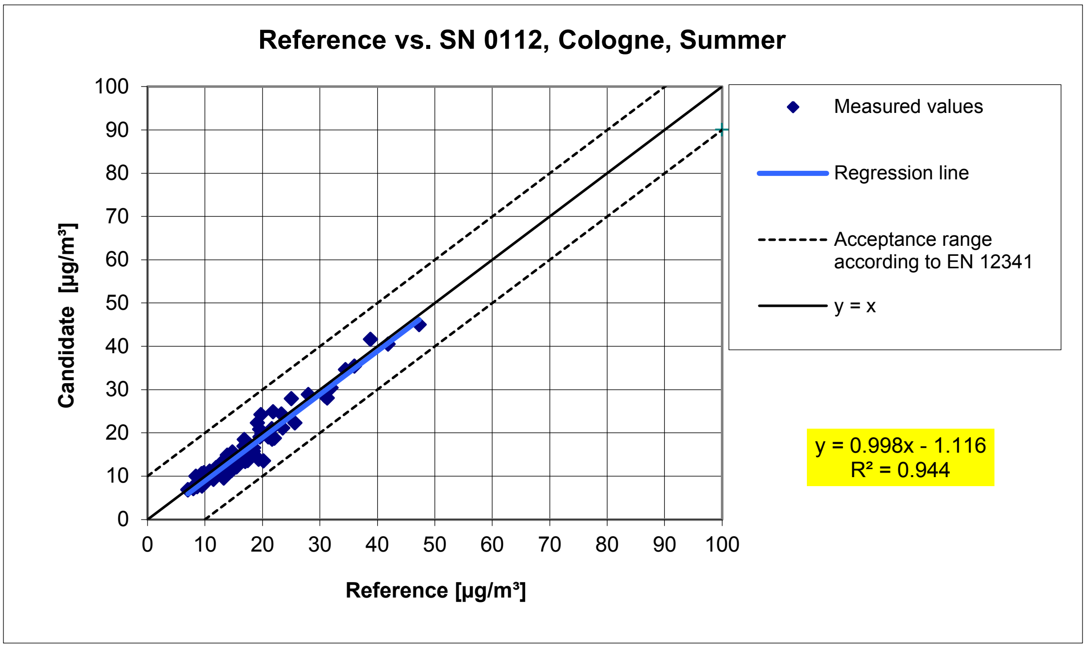


Figure 48: Reference equivalence function SN 0112, test site Cologne, summer

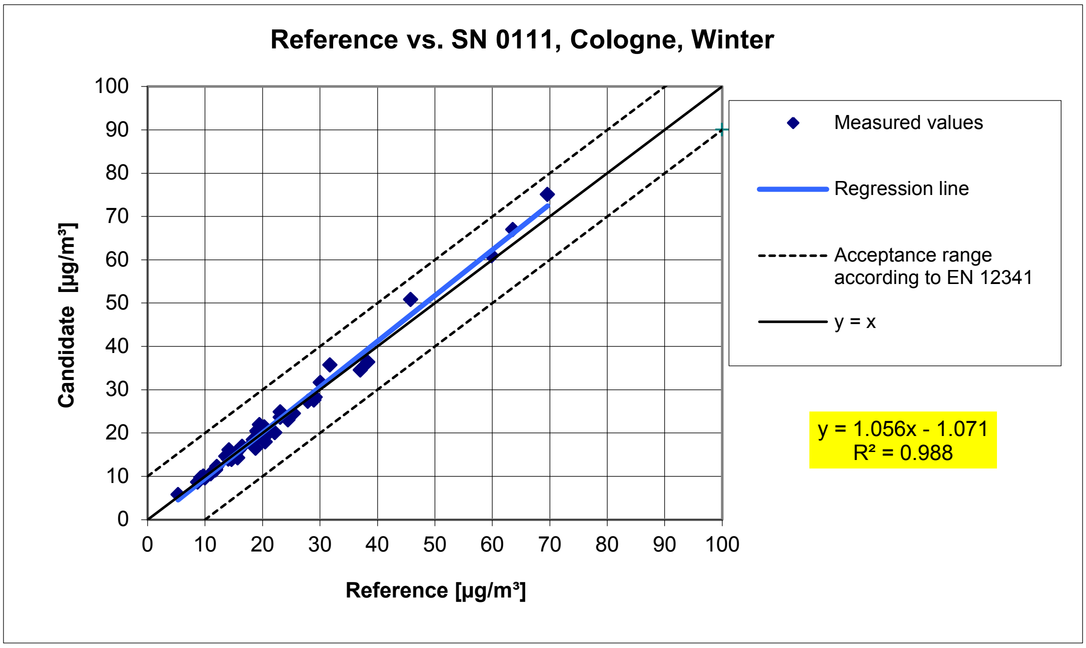


Figure 49: Reference equivalence function SN 0111, test site Cologne, winter

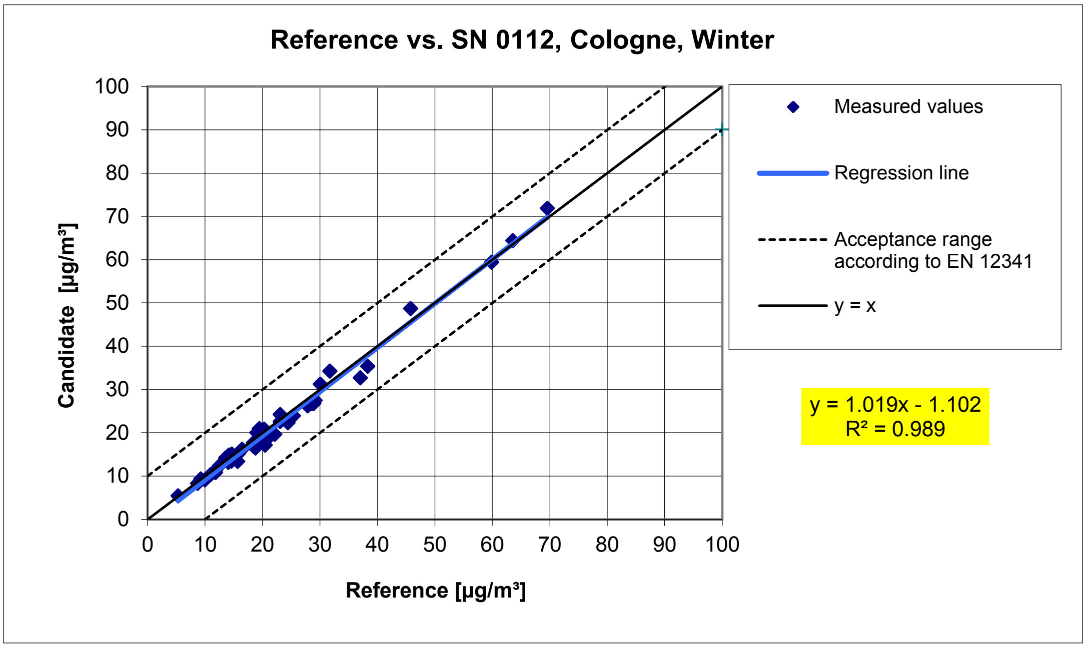


Figure 50: Reference equivalence function SN 0112, test site Cologne, winter

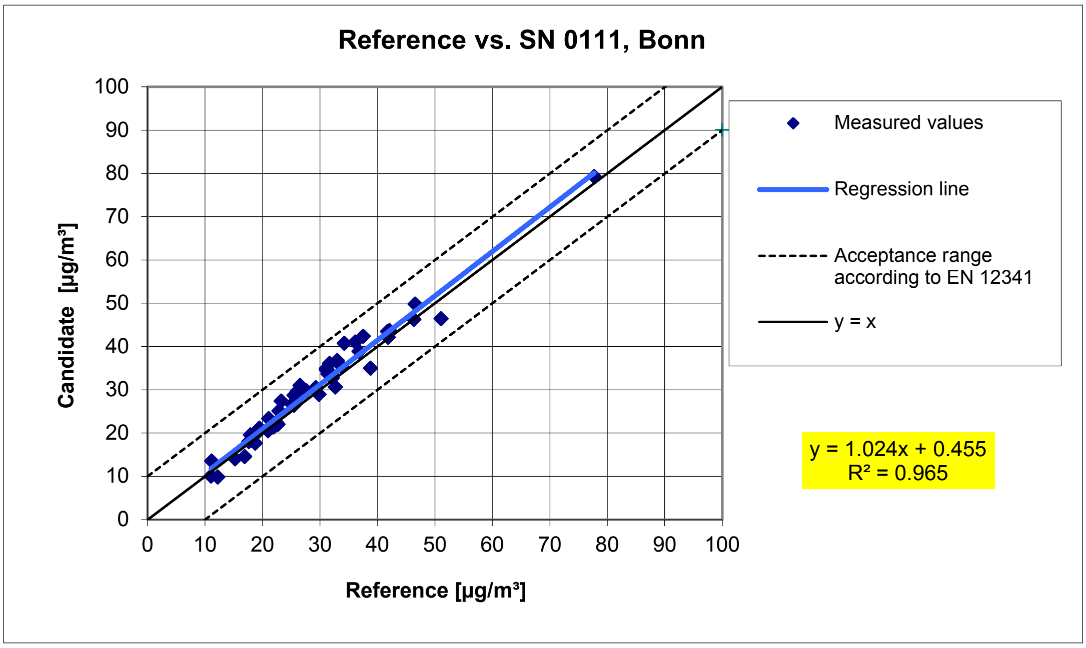


Figure 51: Reference equivalence function SN 0111, test site Bonn, winter

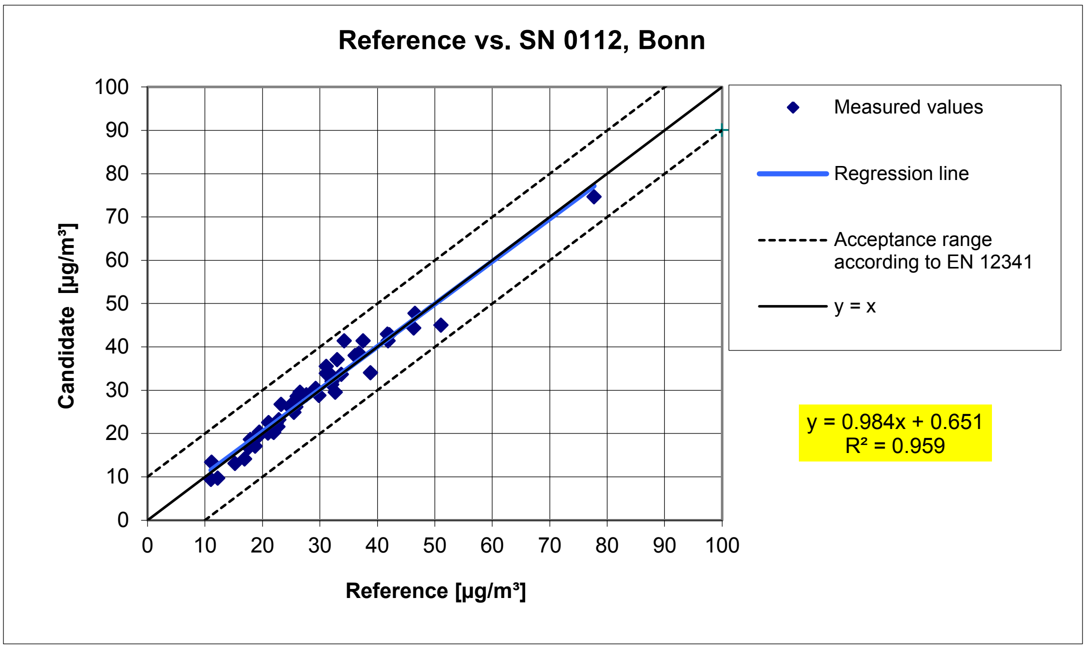


Figure 52: Reference equivalence function SN 0112, test site Bonn, winter

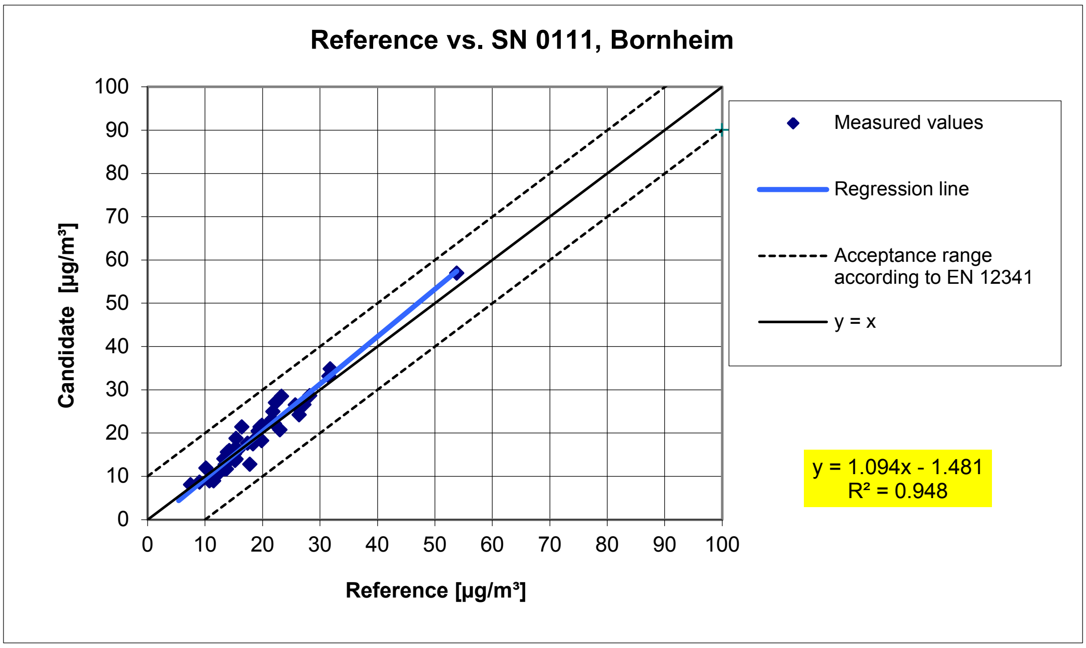


Figure 53: Reference equivalence function SN 0111, test site Bornheim, summer

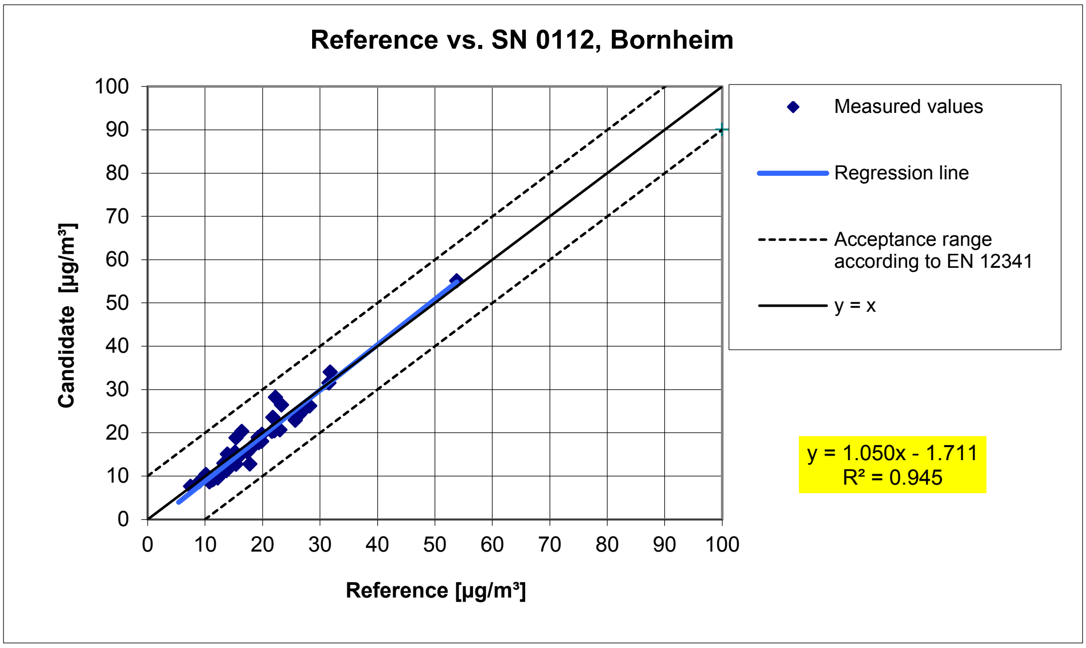


Figure 54: Reference equivalence function SN 0112, test site Bornheim, summer

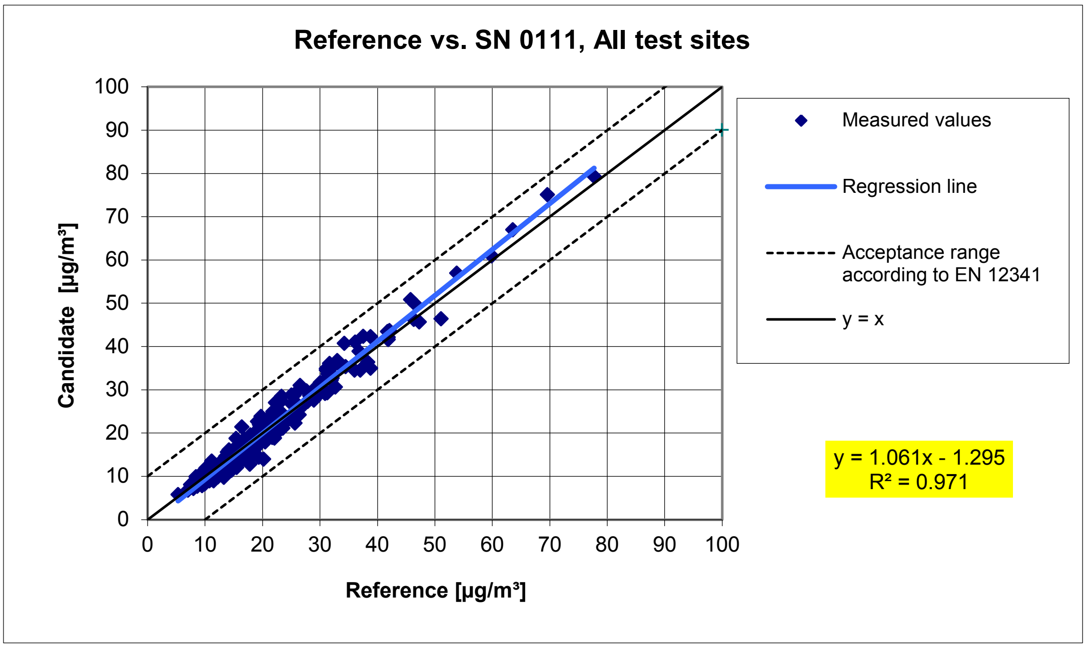


Figure 55: Reference equivalence function SN 0111, all sites

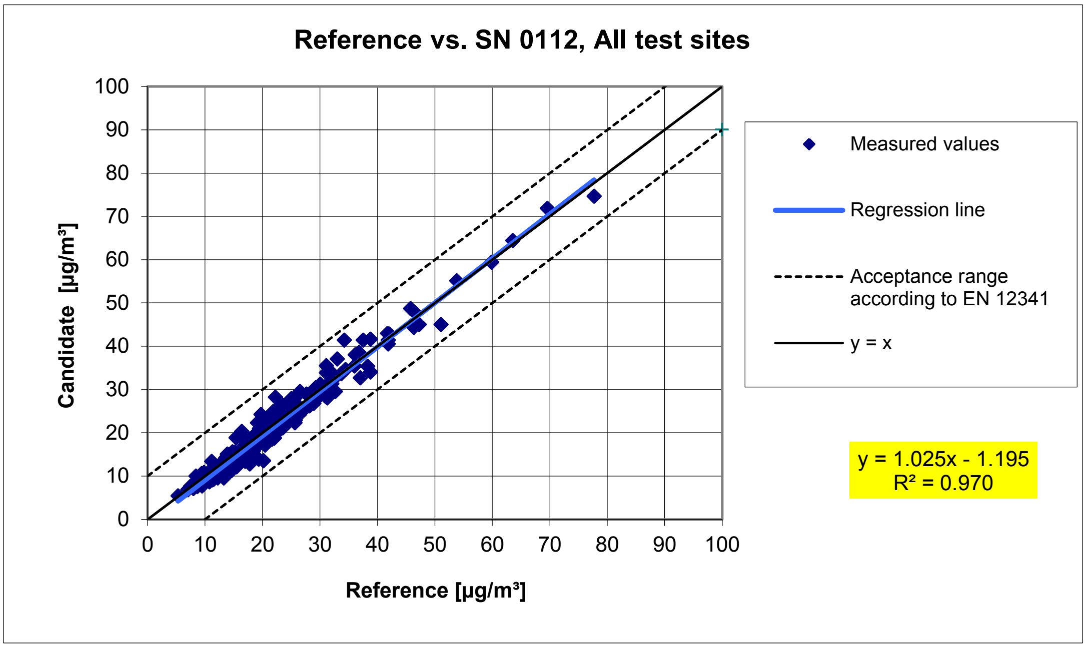


Figure 56: Reference equivalence function SN 0112, all sites

6.1 5.4.3 Reproducibility of the sampling systems

The PM_{10} sampling systems of two identical candidates shall be reproducible among themselves according to Standard EN 12341 [T5]. This shall be demonstrated in the field test.

Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.10 in this report.

6.2 Equipment

No equipment is necessary to test this performance criterion.

6.3 Method

The test was carried out at various test sites according to item 4 in this report. Different seasons as well as different PM_{10} concentrations were taken into account.

At least 15 valid data pairs were obtained per site.

6.4 Evaluation

The two-sided confidence interval CI_{95} calculated from the concentration mean values measured by the candidates shall not exceed 5 µg/m³ if the average concentration is ≤ 100 µg/m³. If the average concentration is > 100 µg/m³, the confidence interval shall not exceed 0.05.

The demonstration of the reproducibility of the candidates focuses on the differences D_i between the concentration values Y_i measured by the candidates. Ideally, both candidates are identical and therefore measure the same mass fraction of suspended particulate matter so that $D_i = 0$. The evaluation procedure is as follows:

First, the concentration mean values Y_i are calculated from the concentration values measured simultaneously by both candidates. Then the concentration mean values Y_i are split into two separate datasets:

a) Dataset with $Y_i \leq 100$ µg/m³ with number of data pairs $n_{\leq}$ and
b) Dataset with $Y_i > 100$ µg/m³ with number of data pairs $n_{>}$

With respect to a):

The data pairs of the dataset with $Y_i \leq 100$ µg/m³ are used to calculate the absolute standard deviation s_a:

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

The Student's factor $t_{f_{\leq};0,975}$, which is defined as the 0.975 quantile of the two-sided 95% confidence interval of the Student's t-distribution with $f_{\leq} = n_{\leq} - 2$ degrees of freedom, is applied.

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

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

With respect to b):

The relative standard deviation s_r is calculated from the data pairs of the dataset with Y_i > 100 µg/m³:

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

Again, the Student's factor $t_{f_{>};0,975}$ defined as 0.975 quantile of the two-sided 95 % confidence interval of the Student's t-distribution with $f_{>} = n_{>} - 2$ degrees of freedom is applied.

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

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

During the field tests, no concentration values > 100 µg/m³ were observed. For that reason, a statistical evaluation is not possible. Hence, consideration according to b) is not required.

6.5 Assessment

The following is applicable to all field test sites:

The two-sided confidence interval CI_{95} of max. 1.88 µg/m³ is far below the permissible limit of 5 µg/m³.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 34 lists the calculated values of the standard deviation s_a and the two-sided confidence interval CI_{95}. Figure 57 to Figure 61 provide the graphical representation. Aside from the regression line of both candidates (calculated by means of linear regression analysis), the diagram shows the y = x curve, which is considered ideal, and the two-sided acceptance envelope. All single values for the candidates are provided in annex 5.

Table 34: Two-sided 95 % confidence interval CI_{95} for the tested devices SN 0111 and SN 0112

Candidates	**Test site**	**Number of values**	**Standard deviation s_a**	**Student's-factor t_f**	**Confidence interval CI_{95}**
SN			µg/m³		µg/m³
0111/0112	Cologne, summer	101	0.30	1.984	0.59
0111/0112	Cologne, winter	66	0.69	1.998	1.38
0111/0112	Bonn, winter	60	0.94	2.002	1.88
0111/0112	Bornheim, summer	58	0.94	2.003	1.87
0111/0112	Total	285	0.71	1.968	1.40

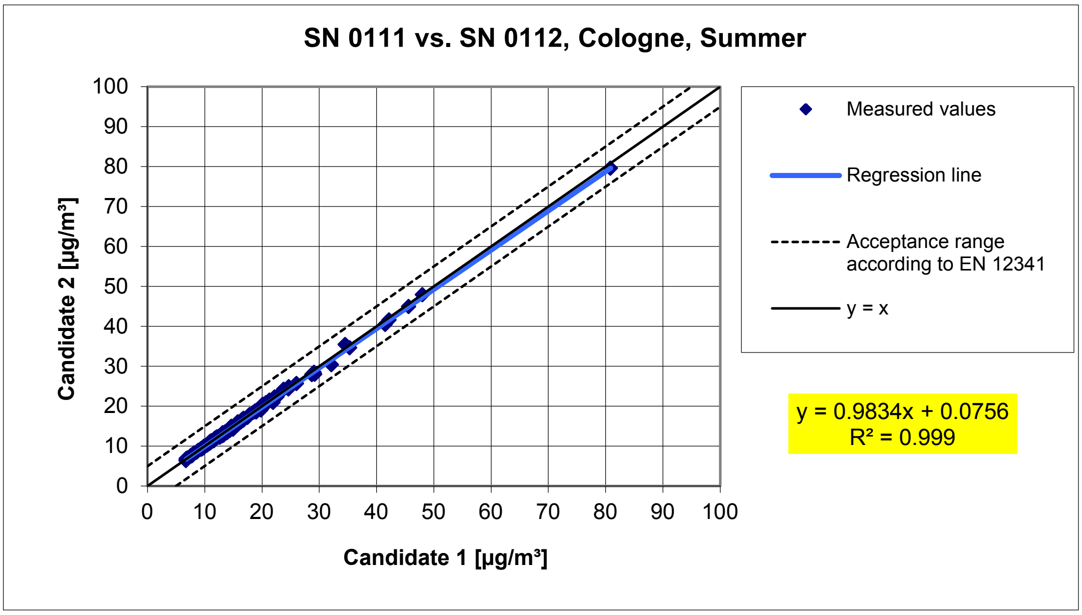


Figure 57: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Cologne, summer

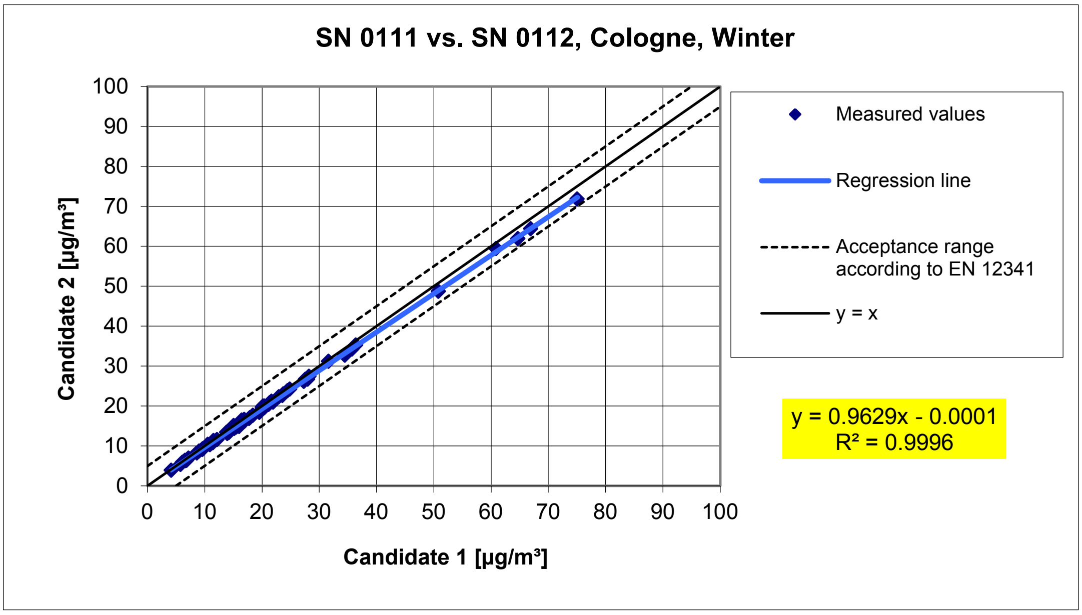


Figure 58: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Cologne, winter

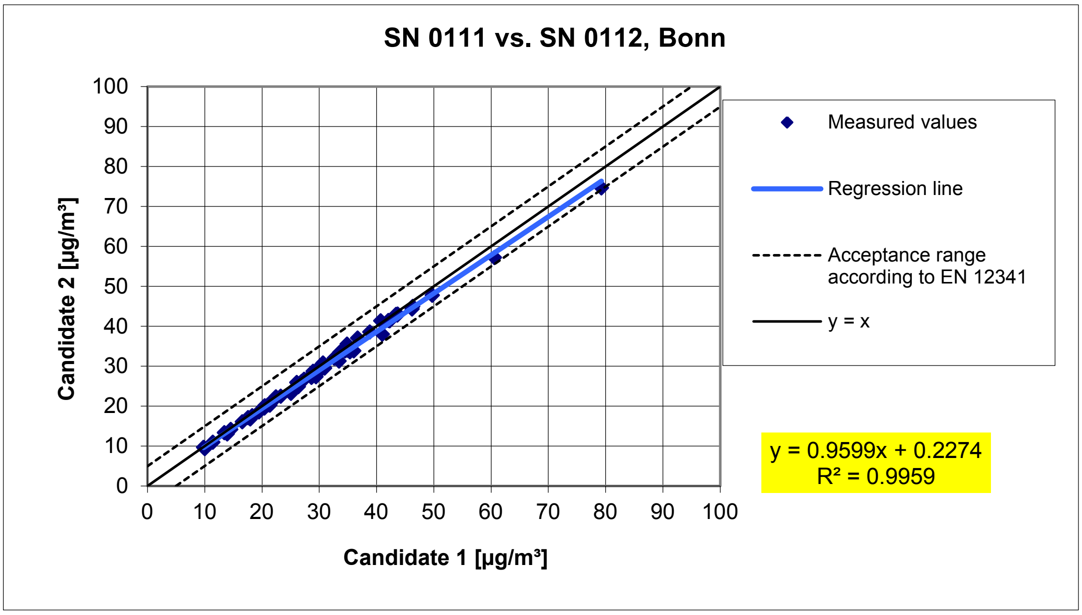


Figure 59: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Bonn, winter

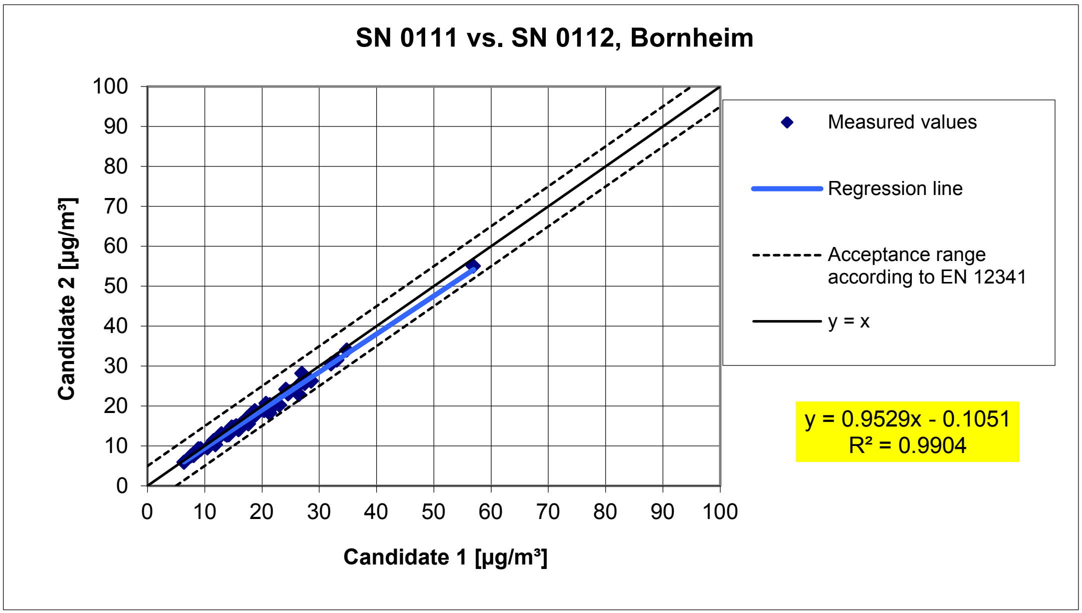


Figure 60: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Bornheim, summer

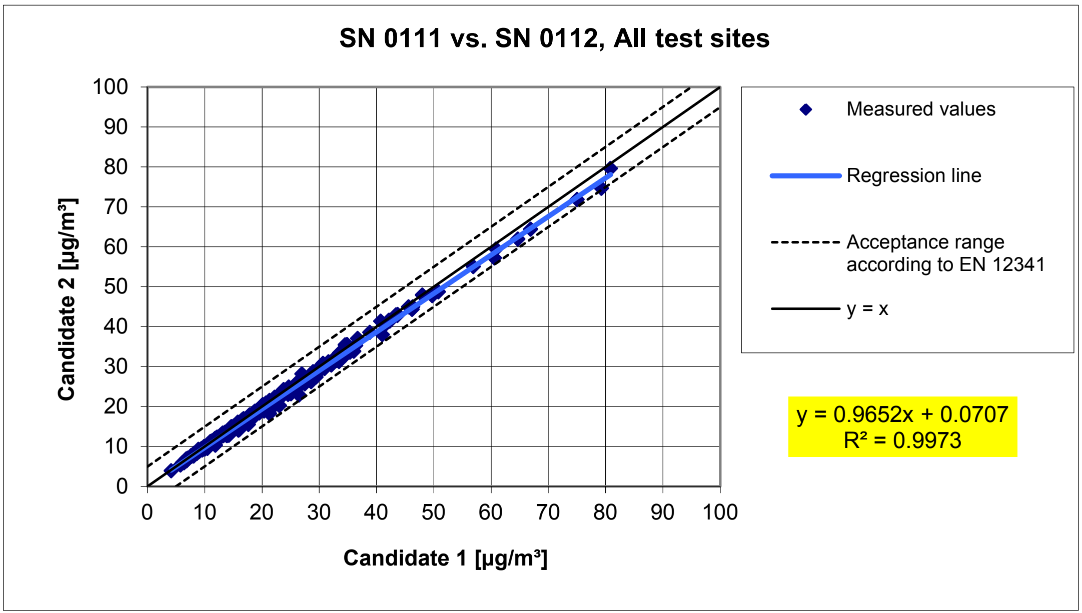


Figure 61: Results of parallel measurements with the tested devices SN 0111 / SN 0112, all test sites

6.1 5.4.4 Calibration

The candidates shall be calibrated in the field test by comparison measurements with the reference method according to Standard EN 12341 respectively EN 14907. Here, the relationship between the output signal and the gravimetrically determined reference concentration shall be determined as a steady function.

6.2 Equipment

Refer to module 5.4.2. or module 5.4.10

6.3 Method

For PM_{10}:

The reproducibility of the measuring systems was proven during testing (refer to module 5.4.2).

In order to determine the calibration function and the analytical function, the complete dataset was used (227 valid data pairs (SN 0111) and 227 valid data pairs (SN 0112)).

The quantities of the calibration function

$$y = m * x + b$$

were determined by means of linear regression. The analytical function is the inverse of the calibration function. It is:

$$x = 1/m * y – b/m$$

The slope m of the regression line describes the sensitivity of the measuring system; the y-intercept b describes the zero point.

The resulting quantities are given in Table 35.

Table 35: Results of the calibration function and analytical function, measured component PM_{10}

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
System 1 (SN 0111)	1.061	-1.295	0.943	-1.221
System 2 (SN 0112)	1.025	-1.195	0.976	-1.166

For $PM_{2.5}$:

The reproducibility of the measuring systems as per module 5.4.10 was proven during testing.

In order to determine the calibration function and the analytical function, the complete dataset was used (227 valid data pairs (SN 0111) and 227 valid data pairs (SN 0112)).

The quantities of the calibration function

$$y = m * x + b$$

were determined by means of orthogonal regression. The analytical function is the inverse of the calibration function. It is:

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

The slope m of the regression line describes the sensitivity of the measuring system, the y-intercept b describes the zero point.

The resulting quantities are given in Table 36.

Table 36: Results of the calibration function and analytical function, measured component $PM_{2.5}$

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
System 1 (SN 0111)	1.096	-0.408	0.912	-0.372
System 2 (SN 0112)	1.056	-0.234	0.947	-0.222

6.4 Evaluation

Refer to 6.3.

6.5 Assessment

A statistical correlation between the reference measuring method and the output signal could be demonstrated.

Performance criterion met? yes

6.6 Detailed presentation of test results

Refer to modules 5.4.2. and 5.4.10.

6.1 5.4.5 Cross sensitivity

The interference caused by moisture in the sample may not exceed 10 % of the limit value in the range of the limit value.

6.2 Equipment

Not required here.

6.3 Method

The interference caused by moisture in the sample was determined under field conditions.

Using the data from field test days with a relative humidity of > 70 % the difference between the obtained reference value (= nominal value) and the measured values of each candidate was calculated and the mean difference was applied as a conservative estimate for the interference caused by moisture in the sample.

In addition to that, reference/equivalence functions were determined for both devices using the data from field test days with a relative humidity of > 70 %.

6.4 Evaluation

Using the data from field test days with a relative humidity of > 70 %, the mean difference between the calculated reference value (= nominal value) and the measured value of the respective candidate was calculated and the relative deviation from the mean concentration was determined.

Annual limit value $PM_{2.5}$ = 25 µg/m³ 10 % of the annual limit value = 2.5 µg/m³

Annual limit value PM_{10} = 40 µg/m³ 10 % of the annual limit value = 4 µg/m

It was also examined whether the reproducibility of the measuring candidates using the reference method according to Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods” [5] can be ensured even if the measured values were obtained on days with a relative humidity of > 70 %.

6.5 Assessment

No deviation of the measured signal from the nominal value > 0.5 µg/m³ caused by interference due to moisture in the sample could be observed for $PM_{2.5.}$ For PM_{10}, no deviation of the measured signal from the nominal value > -1.1 µg/m³ caused by interference due to moisture in the sample could be observed The reproducibility of the candidates using the reference method according to the Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods” [5] is ensured even for days with a relative humidity of > 70 %.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 37 and Table 38 provide summaries of the results.

Table 37: Deviation between reference measurement and candidate on days with a relative humidity of > 70 %, measured component $PM_{2.5}$

Field test, days with rel. humidity >70 %				
		Reference	SN 0111	SN 0112
Mean value	µg/m³	13.8	14.3	14.0
Dev. to mean value of referenve in µg/m³	µg/m³	-	0.5	0.2
Dev. in % of mean value reference	%	-	3.9	1.2
Deviation in % of annual LV	%	-	2.2	0.7

Table 38: Deviation between reference measurement and candidate on days with a relative humidity of > 70 %, measured component PM_{10}

Field test, days with rel. humidity >70 %				
		Reference	SN 0111	SN 0112
Mean value	µg/m³	20.2	19.7	19.1
Dev. to mean value of referenve in µg/m³	µg/m³	-	-0.5	-1.1
Dev. in % of mean value reference	%	-	-2.4	-5.2
Deviation in % of annual LV	%	-	-1.2	-2.6

Single values are provided in annexes 5 and 6.

The measurement uncertainties W_{CM} on days with a relative humidity of > 70 % are presented in Table 39 and Table 40. Single values are provided in annexes 5 and 6.

Table 39: Comparison of the candidates 0111 / 0112 with the reference device, rel. humidity > 70 %, all test sites, measured component $PM_{2.5}$

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200		SN	SN 0111 & SN 0112	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All test sites, rH>70%					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.52**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**114**			**113**	
Slope b	**1.059**			**1.016**	
Uncertainty of b	**0.012**			**0.012**	
Ordinate intercept a	**0.468**			**0.615**	
Uncertainty of a	**0.237**			**0.240**	
Expanded meas. uncertainty W_{CM}	**17.93**	**%**		**12.36**	**%**

Table 40: Comparison of the candidates 0111 / 0112 with the reference device, rel. humidity > 70 %, all test sites, measured component PM_{10}

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200		SN	SN 0111 & SN 0112	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All test sites, rH>70%					
Uncertainty between Reference	**0.60**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**117**			**116**	
Slope b	**1.045**			**1.004**	
Uncertainty of b	**0.012**			**0.012**	
Ordinate intercept a	**-0.848**			**-0.735**	
Uncertainty of a	**0.296**			**0.291**	
Expanded measured uncertainty W_{CM}	**8.44**	**%**		**6.51**	**%**

6.1 5.4.6 Averaging effect

The measuring system shall allow the formation of 24 h mean values.

The time of the sum of all filter changes within 24 h shall not exceed 1 % of this averaging time.

6.2 Equipment

Additionally a timer was used.

6.3 Method

It was tested, whether the AMS allows the formation of daily mean values.

6.4 Evaluation

The Fidas® 200 S measuring system uses the measurement principle of optical light scattering and determines the mass concentrations continuously and on-line. Filter changes and other cyclical interruptions of the measuring operation do not occur.

Thus, the formation of daily mean values can be guaranteed.

6.5 Assessment

The measuring system allows the formation of daily mean values.

Performance criterion met? yes

6.6 Detailed presentation of test results

Not required here.

6.1 5.4.7 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

As indicated in chapter 4, a flow meter was used in the testing of this performance criterion.

6.3 Method

The sample volumetric flow was calibrated before testing at the first field test site. Before testing at the other field test sites it was checked for correctness with a mass flow meter and readjusted if necessary.

The Fidas® 200 S measuring system operates with a flow rate of 4.8 ± 0.15 l/min @ 25 °C and 1013 hPa.

In order to determine the constancy of sample volumetric flow, the flow rate was recorded over 24 h by means of a mass flow meter and evaluated according to the relevant upcoming test item 7.4.5 “Constancy of sample flow rate” of Technical Specification EN/TS 16450 (May 2013) [9].

6.4 Evaluation

The obtained measured values for the flow rate were used to calculate mean value, standard deviation as well as maximum and minimum value.

6.5 Assessment

The results of the flow rate checks carried out at each field test site are given in Table 41.

Table 41: Results of flow rate checks

Flow rate check before testing at Test site:	SN 0111		SN 0112	
	[l/min]	Deviation from nominal value [%]	[l/min]	Deviation from nominal value [%]
Cologne, summer	4.87	1.5	4.88	1.7
Cologne, winter	4.78	-0.4	4.80	0.0
Bonn, winter	4.77	-0.6	4.77	-0.6
Bornheim, summer	4.91	2.3	4.89	1.9

The graphical representations of flow rate constancy show that none of the values obtained during sampling deviates from the respective nominal value by more than ±5 %. The 24 h mean values for the total flow rate of 4.8 ± 0.15 l/min @ 25 °C and 1013 hPa also deviate significantly less than the permissible ±3 % from the nominal value.

All determined daily mean values deviate less than ± 3 % from the rated value and all instantaneous values deviate less than ± 5 %.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 42 shows the parameters determined for the flow. Figure 62 and Figure 63 present a graphic representation of the flow measurements of the two candidates SN 0111 and SN 0112.

Table 42: Parameters for total flow measurement (24 h mean), SN 0111 & SN 0112

	Mean [l/min]	Dev. from nominal [%]	Std. dev. [l/min]	Max [l/min]	Min [l/min]
SN 0111	4.81	0.29	0.05	5.00	4.60
SN 0112	4.80	0.00	0.01	5.00	4.60

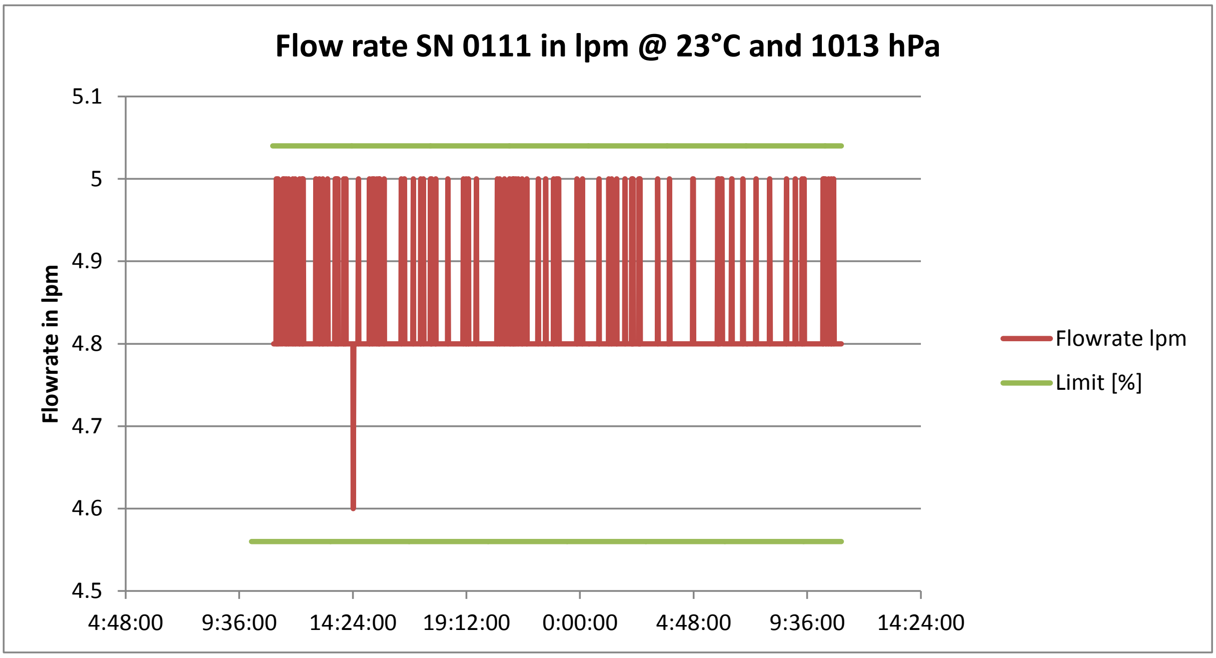


Figure 62: Flow rate of device SN 0111

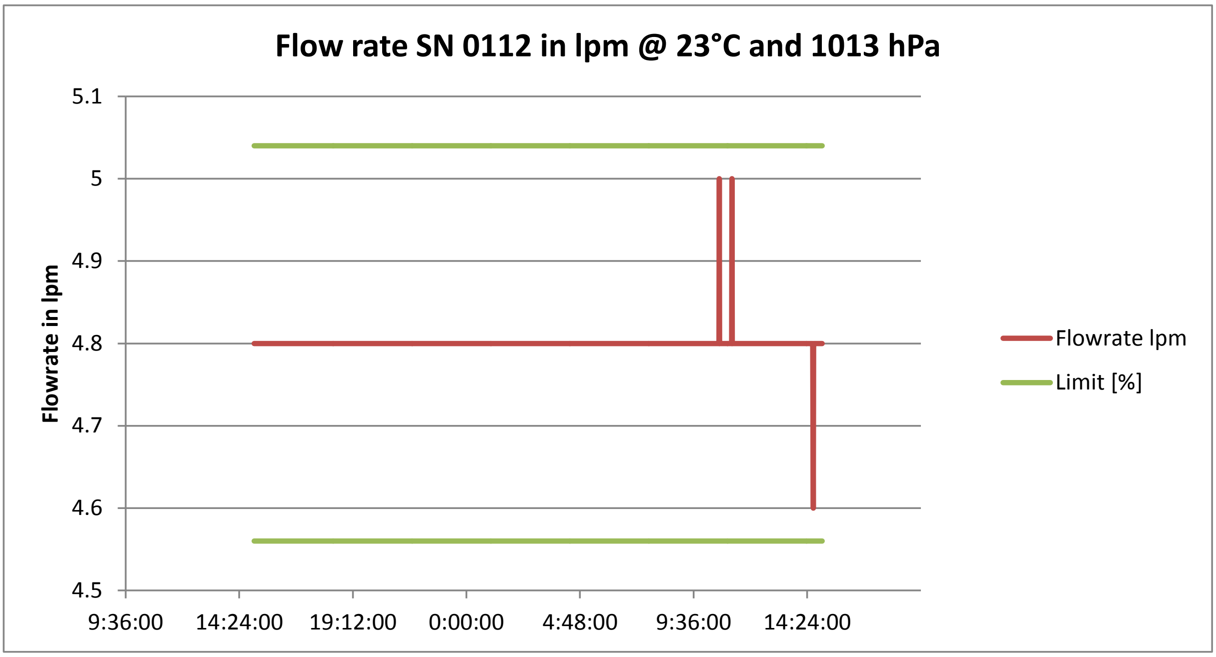


Figure 63: Flow rate of device SN 0112

6.1 5.4.8 Tightness of the measuring system

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

6.2 Equipment

Not required here.

6.3 Method

The flow meter of the Fidas® 200 S measuring system is located directly upstream the pump. To determine the leak rate of the AMS, the measuring system is switched to calibration mode and the instrument inlet is sealed (for instance by thumb or with a plug) according to chapter 3.1 of the operator's manual. As specified by the manufacturer, the flow rate measured by the instrument shall then drop to 0 ± 0.1 l/min.

This procedure was carried out every time the AMS was installed at a new field test site.

It is recommended to check the tightness of the measuring system by means of the aforementioned procedure every three months.

6.4 Evaluation

Leakage testing was performed right after the AMS was installed at a new field test site.

The criterion for passing the leakage test, which has been proposed by the manufacturer (maximum flow at blocked inlet 0 ± 0.1 l/min) proved to be an appropriate parameter for monitoring instrument tightness.

The detected maximum leak rate of 0.04 l/min is less than 1 % of the nominal flow rate which is 4.8 l/min.

6.5 Assessment

The criterion for passing the leakage test, which has been specified by the manufacturer, (flow at blocked inlet max. 0 ± 0.1 l/min) proved to be an appropriate parameter for monitoring instrument tightness. The detected maximum leak rate of 0.04 l/min is less than 1 % of the nominal flow rate which is 4.8 l/min.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 43 lists the values obtained in leakage testing.

Table 43: Results from leakage testing during the field tests

Test site	Date	SN 0111	SN 0112	Max. permissible leak rate in l/min
		Leak rate in l/min	Leak rate in l/min	
Cologne, summer	09.05.2012	0.03	0.03	0 ± 0.1
Cologne, winter	22.11.2012	0.04	0.04	0 ± 0.1
Bonn, winter	26.02.2013	0.03	0.04	0 ± 0.1
Bornheim, summer	13.05.2013	0.02	0.03	0 ± 0.1

6.1 Methodology of the equivalence check (modules 5.4.9 – 5.4.11)

According to the January 2010 version of the Guide [5], the following 5 criteria shall be met in order to prove equivalence:

1. At least 20 % of the concentration values from the complete dataset (determined by means of reference method) shall exceed the upper assessment threshold for annual limit values determined in 2008/50/EC [8], i.e. 28 µg/m³ for PM_{10} and 17 µg/m³ for $PM_{2.5}$. If this requirement cannot be met due to overall low concentration levels,a minimum number of 32 data pairs is considered a sufficient (WG15 January 2015).
2. The uncertainty between the candidates 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 uncertainty between the reference devices 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 candidate against the mean value of the reference method. In each of the following cases, the expanded uncertainty shall not exceed 25 %:
   - Complete dataset;
   - Dataset with PM concentrations greater/equal 30 µg/m³ for PM_{10} or greater/equal 18 µg/m³ for $PM_{2.5}$, provided that the dataset contains 40 or more valid data pairs;
   - Datasets for each field test site.
5. For the complete dataset to be accepted it is required that the slope b differs insignificantly from 1: $|b-1| \leq 2 \cdot u(b)$ and that the intercept a differs insignificantly from 0: $|a| \leq 2 \cdot u(a)$. Should these requirements not be met, the candidates may be calibrated using the values for slope and/or intercept from the complete dataset.

In the following 5 chapters, compliance with the 5 criteria is tested:

In chapter 6.1 5.4.9 Determination of uncertainty between candidates u_{bs} criteria 1 and 2 will be checked.

In chapter 6.1 5.4.10 Calculation of expanded uncertainty between candidates criteria 3, 4, and 5 will be checked.

In chapter 6.1 5.4.11 Application of correction factors and terms there is an exemplary evaluation for the event that criterion 5 cannot be met without application of correction factors or terms.

6.1 5.4.9 Determination of uncertainty between candidates u_{bs}

For the test of $PM_{2.5}$ measuring systems the uncertainty between the candidates shall be determined according to chapter 9.5.3.1 of the Guide "Demonstration of equivalence of Ambient Air Monitoring Methods" in the field test at least at four sampling sites representative of the future application.

The tests were also carried out for the component PM_{10}.

6.2 Equipment

No equipment is necessary to test this performance criterion.

6.3 Method

The test was carried out at four different comparisons during the field test. Different seasons and varying concentrations for $PM_{2.5}$ and PM_{10} were taken into consideration.

At least 20 % of the concentration values from the complete dataset determined with the reference method shall exceed the upper assessment threshold according to 2008/50/EC [8]. The upper assessment threshold is 17 µg/m³ for $PM_{2.5}$ and 28 µg/m³ for PM_{10}.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (4 test sites, PM_{10}: 229 valid data pairs for SN 0111 and 229 valid data pairs for SN 0112; $PM_{2.5}$: 227 valid data pairs for SN 0111 and 227 valid data pairs for SN 0112), 27.1 % of the measured values exceed the upper assessment threshold of 17 µg/m for $PM_{2.5}$ and a total of 20.3 % of the measured values exceed the upper assessment threshold of 28 µg/m³ for PM_{10}. The measured concentrations were brought into relation with ambient conditions.

6.4 Evaluation

According to **chapter 9.5.3.1** of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" the following applies:

The uncertainty between the candidates u_{bs} shall be ≤ 2.5 µg/m³. If the uncertainty between the candidates exceeds 2.5 µg/m³, one or both systems might not be working properly. In such a case, equivalence cannot be declared.

Uncertainty is determined for:

- All test sites/comparisons together (complete dataset)
- 1 dataset with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: mean values of reference measurement)
- 1 dataset with measured values ≥ 30 µg/m³ for PM_{10} (basis: mean values of reference measurement)

In addition to that, this report provides an evaluation of the following datasets:

- Each test site/comparison separately
- 1 dataset with measured values < 18 µg/m³ for $PM_{2.5}$ (basis: mean values of reference measurement)
- 1 dataset with measured values < 30 µg/m³ for PM_{10} (basis: mean values of reference measurement)

The uncertainty between the candidates u_{bs} is calculated from the differences of all daily mean values (24 h values) of the simultaneously operated candidates by means of 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 24 h values i

n = number of 24 h values

6.5 Assessment

The uncertainty between the candidates u_{bs} with a maximum of 0.84 µg/m³ for $PM_{2.5}$ and a maximum of 1.17 µg/m³ for PM_{10} does not exceed the required value of 2.5 µg/m³.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 44 and Table 45 list the calculated values for the uncertainty between candidates u_{bs}. Graphical representations of the results are provided in Figure 64 to Figure 77.

Table 44: Uncertainty between candidates u_{bs} for the devices SN 0111 and SN 0112, measured component $PM_{2.5}$

Device	Test site	No. of values	Uncertainty u_{bs}
SN			µg/m³
0111 / 0112	**All test sites**	**285**	**0.48**
Single test sites			
0111 / 0112	Cologne, summer	101	0.12
0111 / 0112	Cologne, winter	66	0.55
0111 / 0112	Bonn, winter	60	0.70
0111 / 0112	Bornheim, summer	58	0.50
Classification over reference value			
0111 / 0112	**Values ≥ 18 µg/m³**	**54**	**0.84**
0111 / 0112	Values < 18 µg/m³	171	0.33

Table 45: Uncertainty between candidates u_{bs} for the devices SN 0111 and SN 0112, measured component PM_{10}

Device	**Test site**	**No. of values**	**Uncertainty u_{bs}**
SN			µg/m³
0111 / 0112	**All test sites**	**285**	**0.67**
Single test sites			
0111 / 0112	Cologne, summer	101	0.27
0111 / 0112	Cologne, winter	66	0.67
0111 / 0112	Bonn, winter	60	0.90
0111 / 0112	Bornheim, summer	58	0.87
Classification over reference values			
0111 / 0112	**Values ≥ 30 µg/m³**	**54**	**1.17**
0111 / 0112	Values < 30 µg/m³	171	0.58

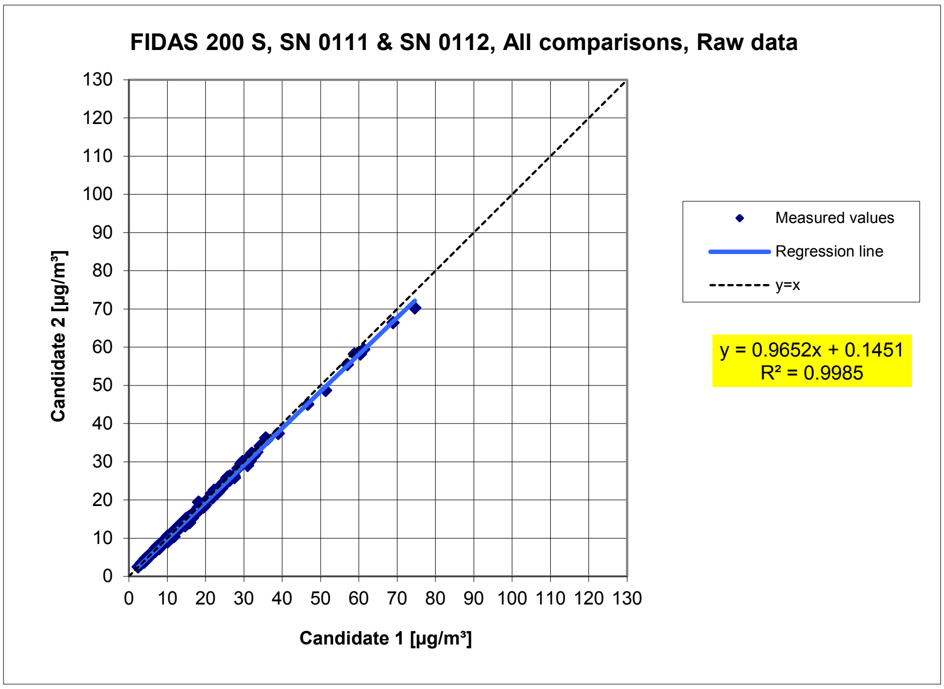


Figure 64: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites

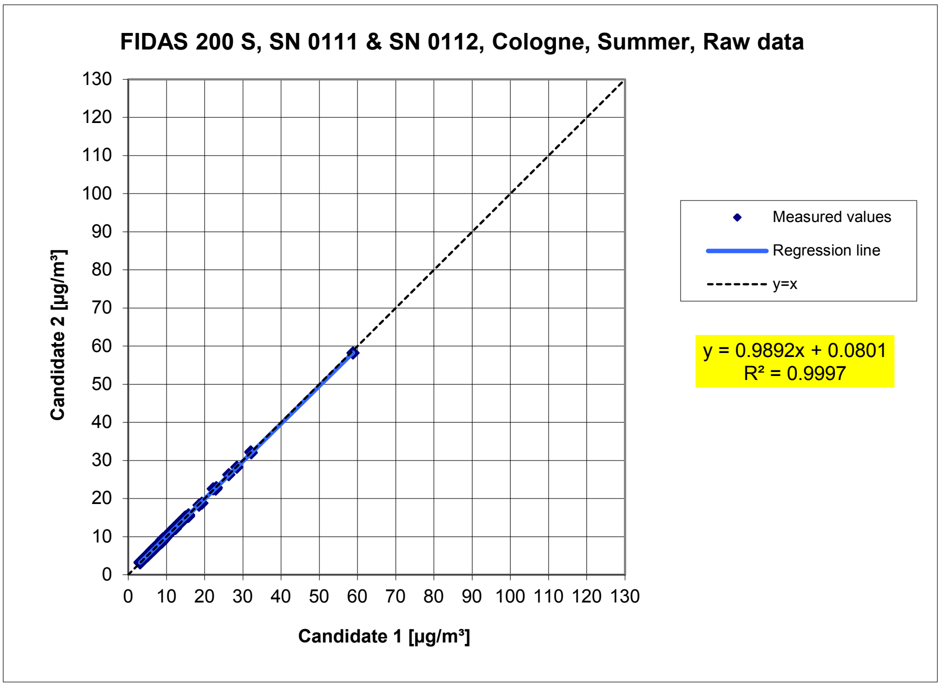


Figure 65: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Cologne, summer

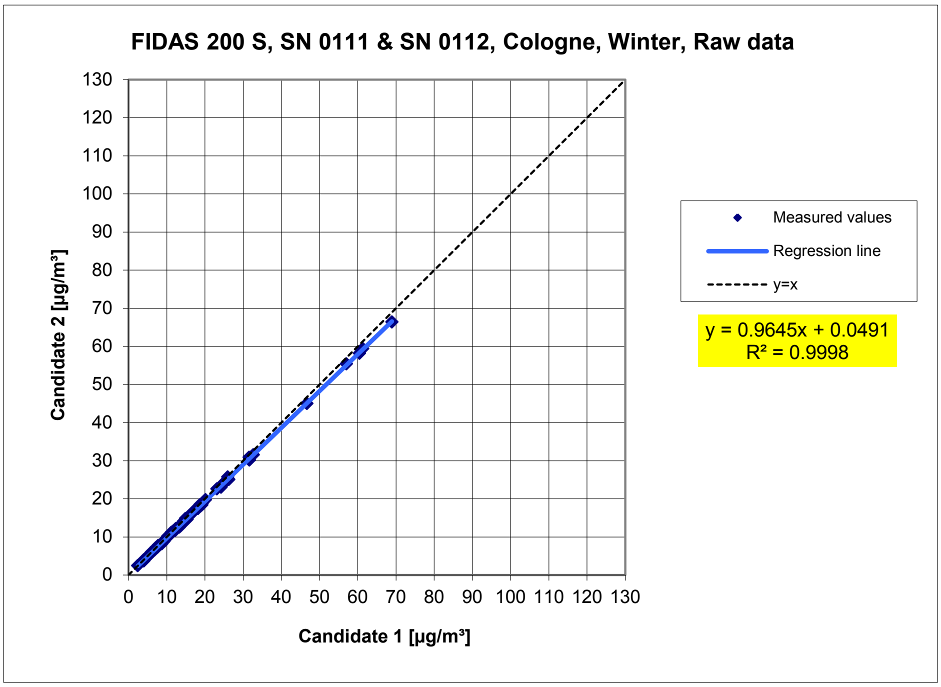


Figure 66: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Cologne, winter

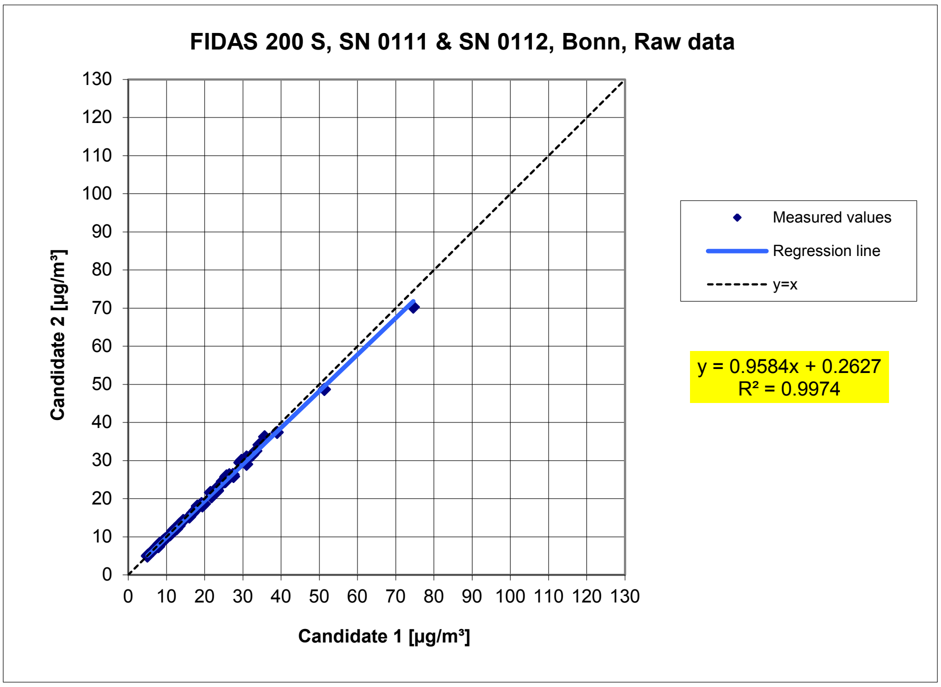


Figure 67: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Bonn, winter

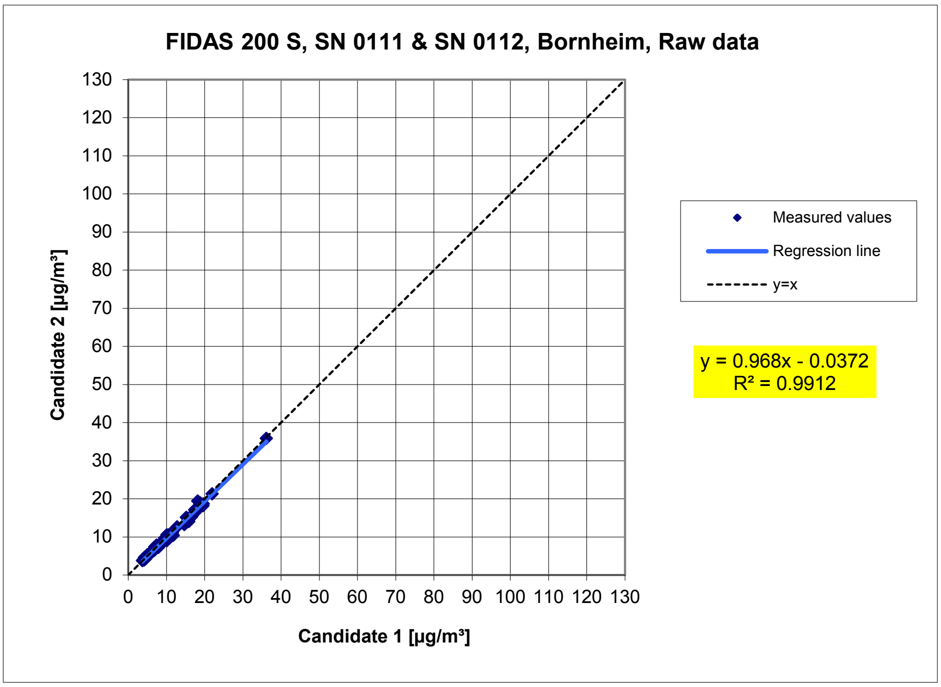


Figure 68: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Bornheim, summer

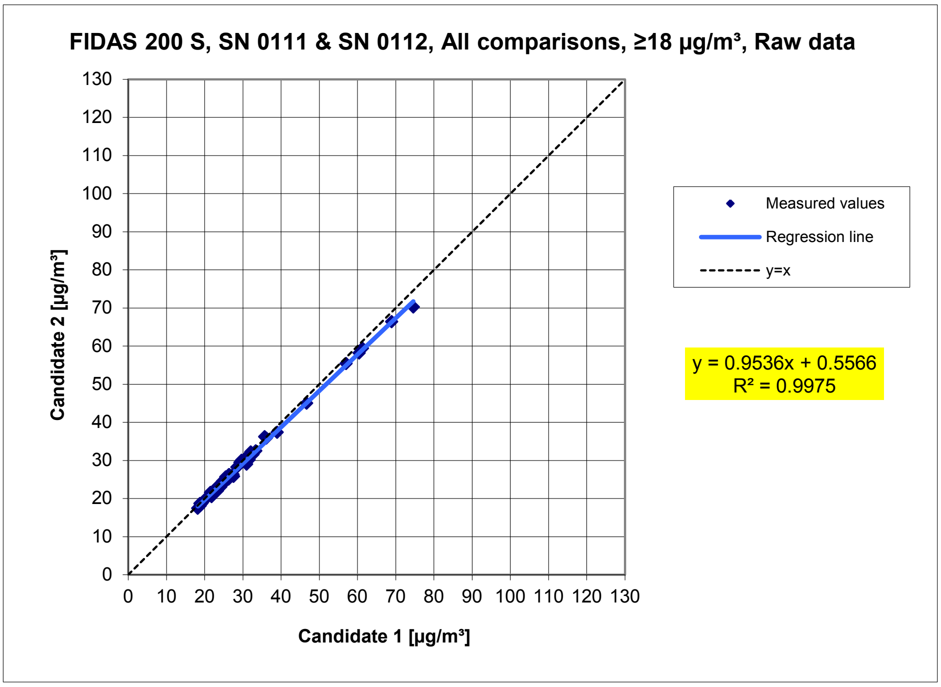


Figure 69: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites, values ≥ 18 µg/m³

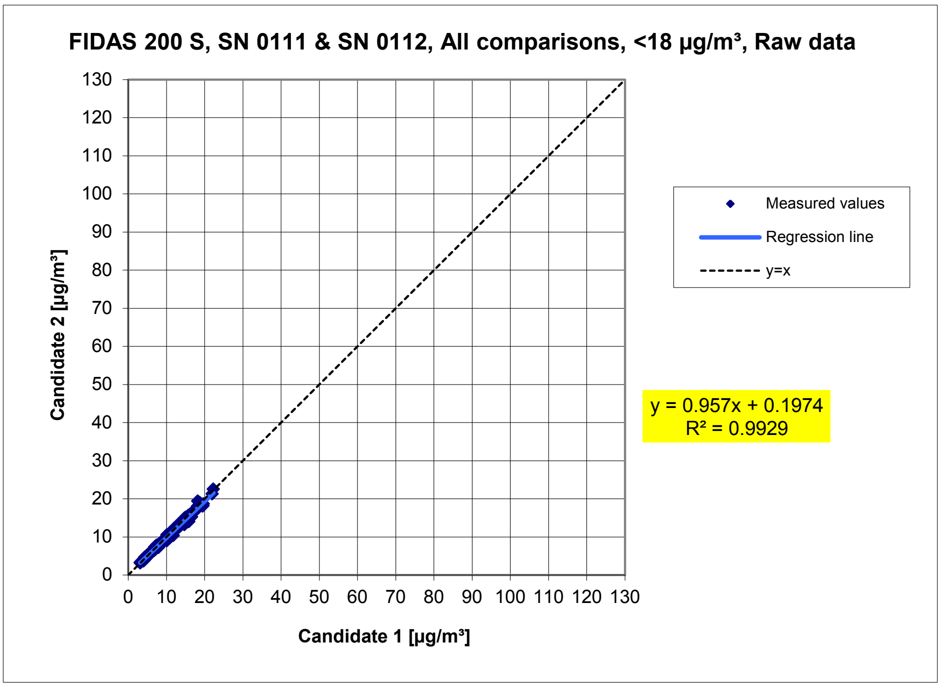


Figure 70: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites, values < 18 µg/m³

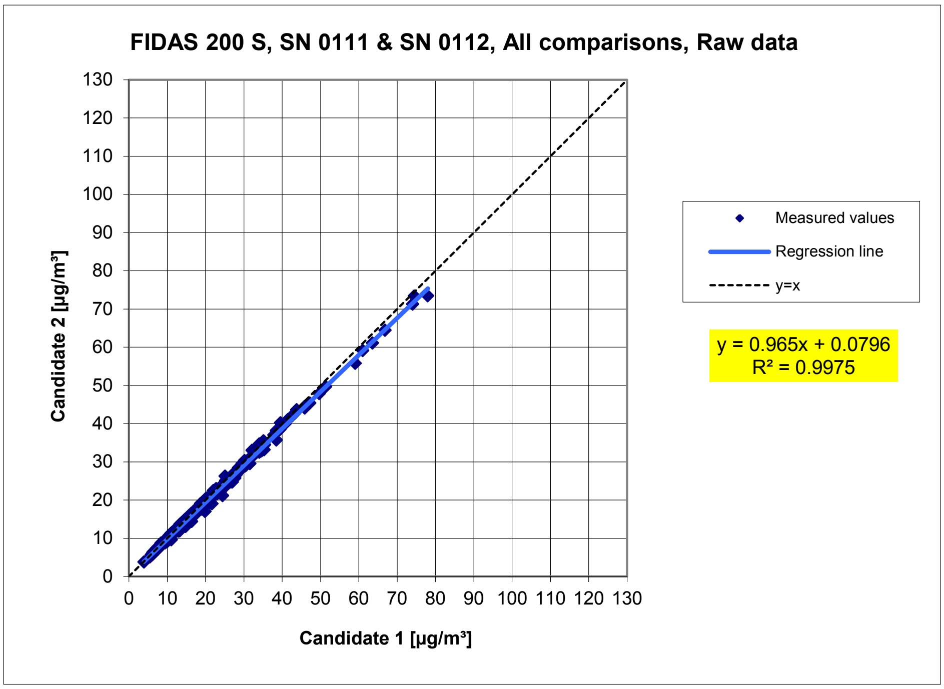


Figure 71: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, all test sites

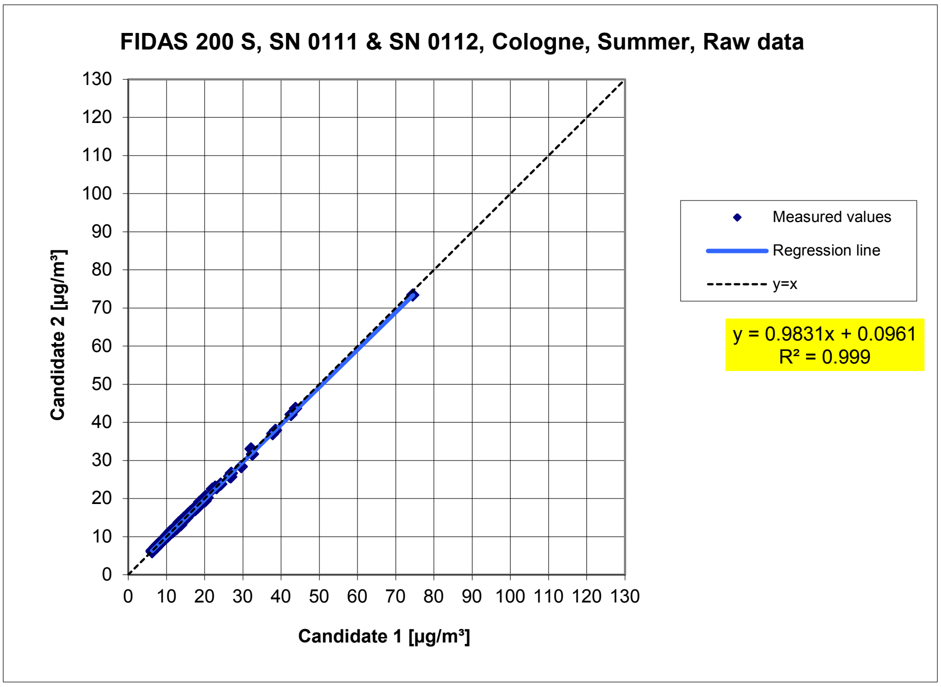


Figure 72: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, test site Cologne, summer

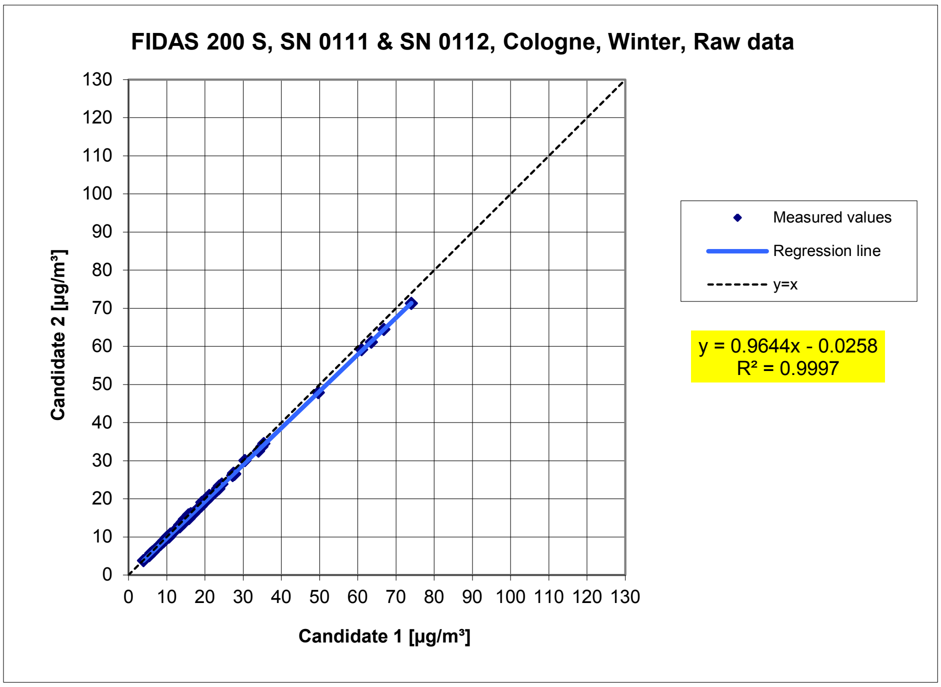


Figure 73: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, test site Cologne, winter

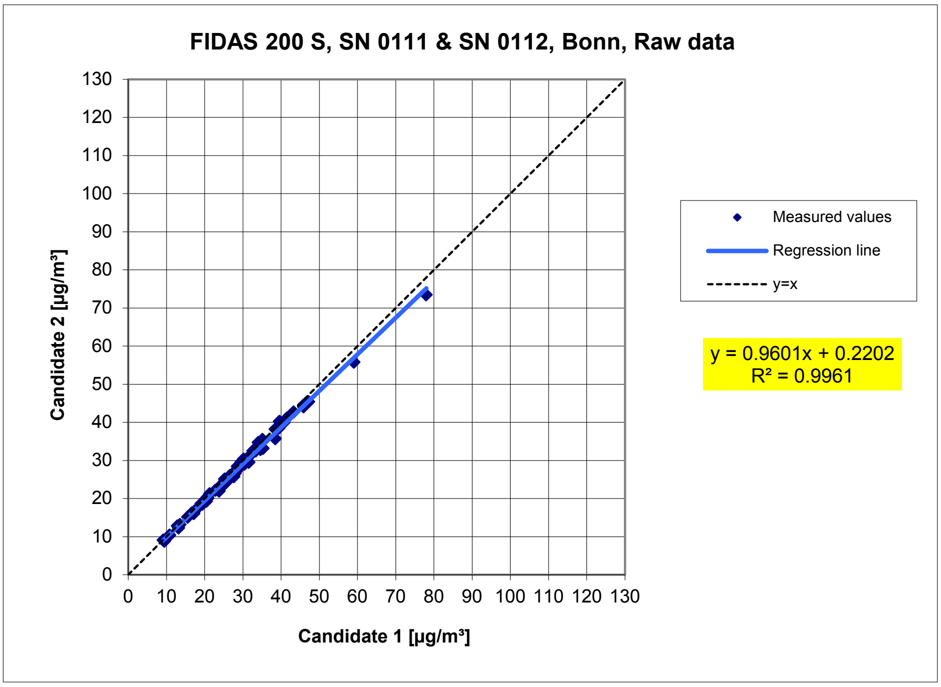


Figure 74: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, test site Bonn, winter

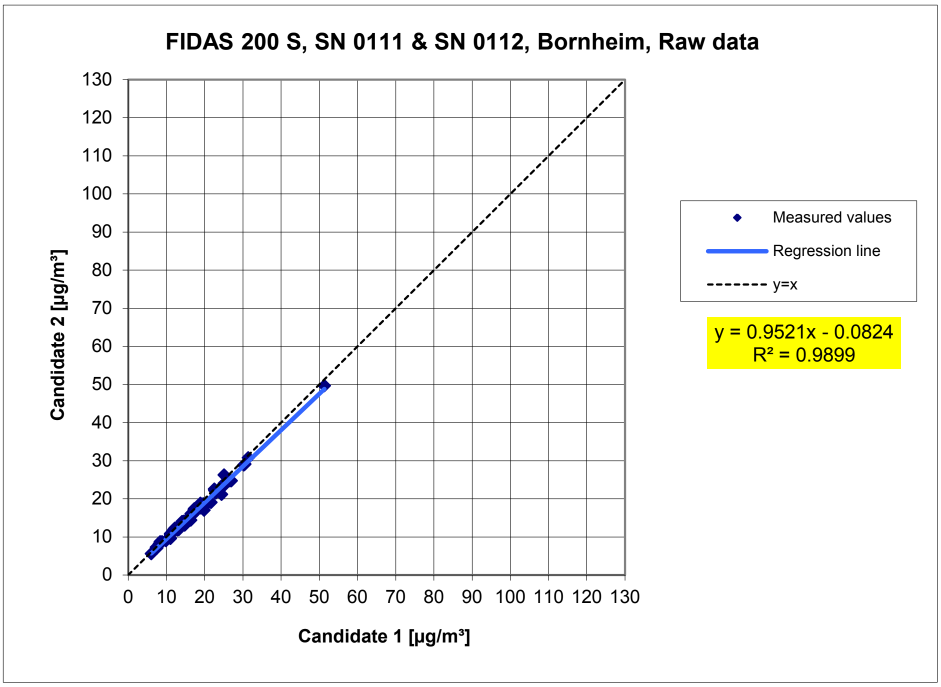


Figure 75: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, test site Bornheim, summer

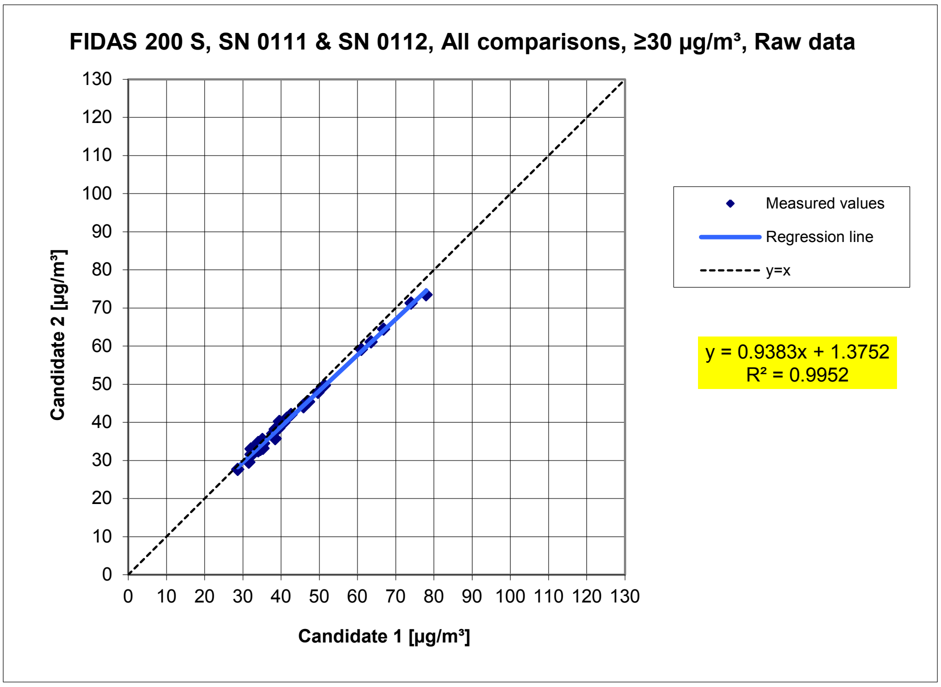


Figure 76: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, all test sites, values ≥ 30 µg/m³

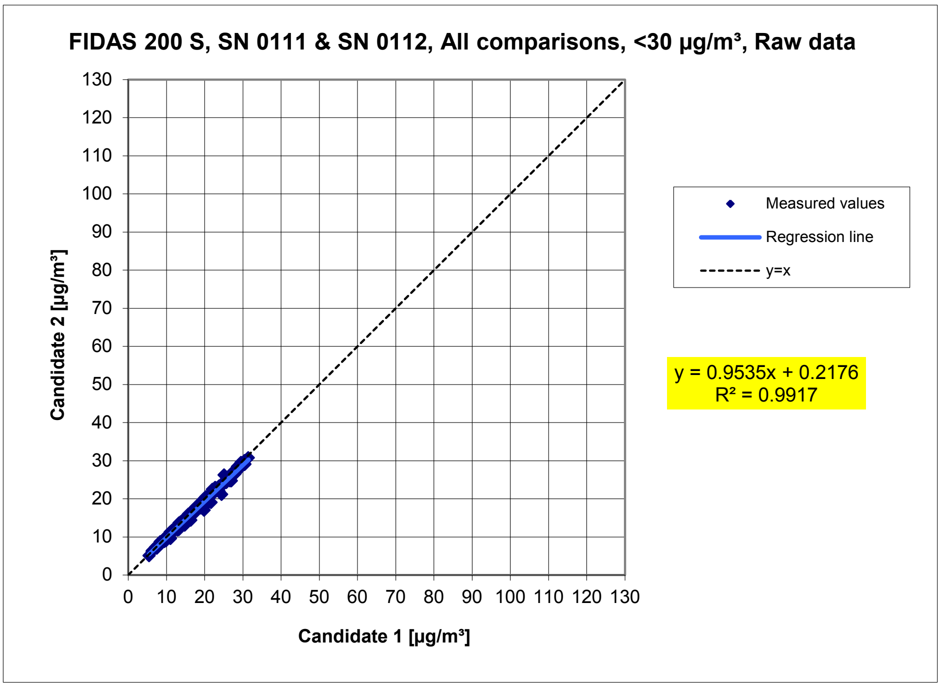


Figure 77: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, all test sites, values < 30 µg/m³

6.1 5.4.10 Calculation of expanded uncertainty between candidates

For the test of $PM_{2.5}$ measuring systems the equivalency with reference method shall be demonstrated according to chapter 9.5.3.2 to 9.6 of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" in the field test at least at four sampling sites representative of the future application. The maximum expanded uncertainty of the candidates shall be compared with data quality objectives to Annex A of VDI Standard 4202, Sheet 1 (September 2010).

The tests were also carried out for the component PM_{10}.

6.2 Equipment

Additional instruments according to item 5 of this report were used in the testing of this performance criterion.

6.3 Method

The test was carried out at four different comparisons during the field test. Different seasons and varying concentrations for $PM_{2.5}$ and PM_{10} were taken into consideration.

At least 20 % of the concentration values from the complete dataset determined with the reference method shall exceed the upper assessment threshold according to 2008/50/EC [8]. The upper assessment threshold is 17 µg/m³ for $PM_{2.5}$ and 28 µg/m³ for PM_{10}.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (4 test sites, PM_{10}: 229 valid data pairs for SN 0111 and 229 valid data pairs for SN 0112; $PM_{2.5}$: 227 valid data pairs for SN 0111 and 227 valid data pairs for SN 0112), 27.1 % of the measured values exceed the upper assessment threshold of 17 µg/m for $PM_{2.5}$ and a total of 20.3 % of the measured values exceed the upper assessment threshold of 28 µg/m³ for PM_{10}. The measured concentrations were brought into relation with ambient conditions.

6.4 Evaluation

[Item 9.5.3.2] The calculation of expanded uncertainty is preceded by an uncertainty check between the two simultaneously operated reference devices u_{ref}.

The uncertainty between the simultaneously operated reference devices is determined analogous to the uncertainty between the candidates and shall be ≤ 2 µg/m³.

The evaluated results are given in 7.6 of this test item.

In order to evaluate the comparability between the candidates y and the reference method x, a linear correlation $y_i = a + bx_i$ between the measured results obtained from both methods is assumed. The correlation between the mean values of the reference devices and the candidates, which shall be assessed individually, is established by means of orthogonal regression.

Regression is calculated for:

- All test sites/comparisons together
- Each test site/comparison separately
- 1 dataset with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: mean values of reference measurement)
- 1 dataset with measured values ≥ 30 µg/m³ for PM_{10} (basis: mean values of reference measurement)

For further evaluation, the results of the uncertainty u_{c_s} of the candidates compared with the reference method is described in the following equation, which describes u_{CR} as a function of the OM 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 the value u_{bs}, which is calculated for using the candidates, can be used in this test (refer to item 6.1 5.4.9 Determination of uncertainty between candidates ubs)

Algorithms for the calculation of intercept a as well as slope b and its variances by means of orthogonal regression are specified in Annex B of [5].

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

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

Uncertainty u_{CR} is calculated for:

- All test sites/comparisons together
- Each test site/comparison separately
- 1 dataset with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: mean values of reference measurement)
- 1 dataset with measured values ≥ 30 µg/m³ for PM_{10} (basis: mean values of reference measurement)

According to the Guide, preconditions for acceptance of the complete dataset are that:

- the slope b differs insignificantly from 1: $|b-1| \leq 2 \cdot u(b)$

and that

- the intercept a differs insignificantly from 0: $|a| \leq 2 \cdot u(a)$

with u(b) and u(a) being the standard uncertainties of slope and intercept, each calculated as the square root of their variances. If these preconditions are not met, the candidates may be calibrated according to item 9.7 of the guideline (refer to 6.1 5.4.11 Application of correction factors and terms. The calibration shall only be applied to the complete dataset.

[Item 9.5.4] The combined uncertainty of the candidates $w_{c,CM}$ is calculated for each dataset 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 = 30 µg/m³ for $PM_{2.5}$ and at the level of y_i = 50 µg/m³ for PM_{10}.

[Item 9.5.5] The expanded relative uncertainty of the results of the candidates is calculated for each dataset by multiplying $w_{c,CM}$ with a coverage factor k according to the following equation:

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

In practice k=2 for large n

[Item 9.6] The highest resulting uncertainty W_{CM} is compared with the requirements on data quality of ambient air measurements according to EU Standard [8] and assessed. There are two possible results:

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

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 % [8].

6.5 Assessment

Without application of correction factors, the determined uncertainties W_{CM} for PM_{10} for all datasets under consideration lie below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter. With the exception of Bornheim (summer) the determined uncertainties for $PM_{2.5}$ for all datasets under consideration and without application of correction factors lie below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter. Correction factors shall be applied according to chapter 6.1 5.4.11 Application of correction factors and terms.

Performance criterion met? no

Table 46 and Table 47 provide an overview of all results from the equivalence test of the Fidas® 200 S for $PM_{2.5}$ and PM_{10}. In the event that a criterion has not been met, the respective cell is marked in red.

Table 46: Overview of equivalence test of Fidas® 200 S for $PM_{2.5}$

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.48**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**225**				
Slope b	**1.076**	**significant**			
Uncertainty of b	**0.011**				
Ordinate intercept a	**-0.339**	**not significant**			
Uncertainty of a	**0.192**				
Expanded meas. uncertainty W_{CM}	**16.84**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.63**	**µg/m³**			
Uncertainty between Candidates	**0.84**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**54**				
Slope b	**1.046**				
Uncertainty of b	**0.025**				
Ordinate intercept a	**0.458**				
Uncertainty of a	**0.769**				
Expanded meas. uncertainty W_{CM}	**18.34**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.57**	**µg/m³**			
Uncertainty between Candidates	**0.33**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**171**				
Slope b	**1.198**				
Uncertainty of b	**0.032**				
Ordinate intercept a	**-1.482**				
Uncertainty of a	**0.327**				
Expanded meas. uncertainty W_{CM}	**31.33**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010				
Candidate	FIDAS 200 S	SN	SN 0111 & SN 0112	
		Limit value	30	µg/m^3
Status of measured values	Raw data	Allowed uncertainty	25	%
Cologne, Summer				
Uncertainty between Reference	**0.66**	**µg/m^3**		
Uncertainty between Candidates	**0.12**	**µg/m^3**		
	SN 0111		**SN 0112**	
Number of data pairs	**81**		**82**	
Slope b	**1.119**		**1.116**	
Uncertainty of b	**0.034**		**0.035**	
Ordinate intercept a	**-0.925**		**-0.885**	
Uncertainty of a	**0.363**		**0.378**	
Expanded meas. uncertainty W_{CM}	**20.11**	**%**	**20.13**	**%**
Cologne, Winter				
Uncertainty between Reference	**0.54**	**µg/m^3**		
Uncertainty between Candidates	**0.55**	**µg/m^3**		
	SN 0111		**SN 0112**	
Number of data pairs	**51**		**50**	
Slope b	**1.051**		**1.014**	
Uncertainty of b	**0.014**		**0.014**	
Ordinate intercept a	**0.691**		**0.679**	
Uncertainty of a	**0.313**		**0.326**	
Expanded meas. uncertainty W_{CM}	**17.05**	**%**	**11.42**	**%**
Bonn				
Uncertainty between Reference	**0.62**	**µg/m^3**		
Uncertainty between Candidates	**0.70**	**µg/m^3**		
	SN 0111		**SN 0112**	
Number of data pairs	**50**		**50**	
Slope b	**1.114**		**1.070**	
Uncertainty of b	**0.025**		**0.027**	
Ordinate intercept a	**-0.783**		**-0.519**	
Uncertainty of a	**0.571**		**0.619**	
Expanded meas. uncertainty W_{CM}	**21.21**	**%**	**16.63**	**%**
Bornheim				
Uncertainty between Reference	**0.42**	**µg/m^3**		
Uncertainty between Candidates	**0.50**	**µg/m^3**		
	SN 0111		**SN 0112**	
Number of data pairs	**45**		**45**	
Slope b	**1.214**		**1.186**	
Uncertainty of b	**0.054**		**0.054**	
Ordinate intercept a	**-1.487**		**-1.606**	
Uncertainty of a	**0.644**		**0.643**	
Expanded meas. uncertainty W_{CM}	**35.02**	**%**	**29.11**	**%**
All comparisons, ≥18 µg/m^3				
Uncertainty between Reference	**0.63**	**µg/m^3**		
Uncertainty between Candidates	**0.84**	**µg/m^3**		
	SN 0111		**SN 0112**	
Number of data pairs	**54**		**54**	
Slope b	**1.071**		**1.022**	
Uncertainty of b	**0.025**		**0.026**	
Ordinate intercept a	**0.185**		**0.713**	
Uncertainty of a	**0.754**		**0.80**	
Expanded meas. uncertainty W_{CM}	**20.38**	**%**	**16.90**	**%**
All comparisons, <18 µg/m^3				
Uncertainty between Reference	**0.57**	**µg/m^3**		
Uncertainty between Candidates	**0.33**	**µg/m^3**		
	SN 0111		**SN 0112**	
Number of data pairs	**173**		**173**	
Slope b	**1.222**		**1.180**	
Uncertainty of b	**0.032**		**0.032**	
Ordinate intercept a	**-1.573**		**-1.399**	
Uncertainty of a	**0.328**		**0.331**	
Expanded meas. uncertainty W_{CM}	**35.28**	**%**	**28.40**	**%**
All comparisons				
Uncertainty between Reference	**0.58**	**µg/m^3**		
Uncertainty between Candidates	**0.48**	**µg/m^3**		
	SN 0111		**SN 0112**	
Number of data pairs	**227**		**227**	
Slope b	**1.096**	**significant**	**1.056**	**significant**
Uncertainty of b	**0.011**		**0.011**	
Ordinate intercept a	**-0.408**	**significant**	**-0.234**	**not significant**
Uncertainty of a	**0.190**		**0.196**	
Expanded meas. uncertainty W_{CM}	**19.55**	**%**	**14.68**	**%**

The results of the check of the five criteria given in chapter 6.1 Methodology of the equivalence check (modules 5.4.9 – 5.4.11) are as follows:

Criterion 1: More than 20 % of the data are greater than 17 µg/m³.

Criterion 2: The uncertainty between the candidates is less than 2.5 µg/m³.

Criterion 3: The uncertainty between the reference devices is less than 2.0 µg/m³.

Criterion 4: With the exception of the test site Bornheim (summer) all of the expanded uncertainties are below 25 %.

Criterion 5: The slopes used for evaluation of the complete dataset are significantly greater than the permissible values for both devices. In addition to that, the intercept used for evaluation is also significantly greater the permissible values for SN 0111.

Other: For both candidates, the total slope is 1.076 and the intercept is -0.339 at an expanded overall uncertainty of 16.84 % for the complete dataset.

Table 47: Overview of equivalence test of Fidas® 200 S for PM_{10}

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.62**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**227**				
Slope b	**1.058**	**significant**			
Uncertainty of b	**0.011**				
Ordinate intercept a	**-1.505**	**significant**			
Uncertainty of a	**0.264**				
Expanded measured uncertainty WCM	**9.11**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.67**	**µg/m³**			
Uncertainty between Candidates	**1.17**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**35**				
Slope b	**1.005**				
Uncertainty of b	**0.038**				
Ordinate intercept a	**0.746**				
Uncertainty of a	**1.619**				
Expanded measured uncertainty WCM	**11.09**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.61**	**µg/m³**			
Uncertainty between Candidates	**0.58**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**192**				
Slope b	**1.085**				
Uncertainty of b	**0.022**				
Ordinate intercept a	**-1.979**				
Uncertainty of a	**0.386**				
Expanded measured uncertainty WCM	**11.18**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne, Summer					
Uncertainty between Reference	0.80	µg/m³			
Uncertainty between Candidates	0.27	µg/m³			
	SN 0111			SN 0112	
Number of data pairs	81			82	
Slope b	1.045			1.028	
Uncertainty of b	0.028			0.028	
Ordinate intercept a	-1.637			-1.524	
Uncertainty of a	0.490			0.489	
Expanded measured uncertainty W_{CM}	6.98	%		6.56	%
Cologne, Winter					
Uncertainty between Reference	0.53	µg/m³			
Uncertainty between Candidates	0.67	µg/m³			
	SN 0111			SN 0112	
Number of data pairs	51			50	
Slope b	1.064			1.027	
Uncertainty of b	0.015			0.015	
Ordinate intercept a	-1.260			-1.284	
Uncertainty of a	0.399			0.398	
Expanded measured uncertainty W_{CM}	9.66	%		5.53	%
Bonn					
Uncertainty between Reference	0.38	µg/m³			
Uncertainty between Candidates	0.90	µg/m³			
	SN 0111			SN 0112	
Number of data pairs	50			50	
Slope b	1.043			1.004	
Uncertainty of b	0.027			0.029	
Ordinate intercept a	-0.082			0.061	
Uncertainty of a	0.821			0.865	
Expanded measured uncertainty W_{CM}	11.98	%		9.29	%
Bornheim					
Uncertainty between Reference	0.54	µg/m³			
Uncertainty between Candidates	0.87	µg/m³			
	SN 0111			SN 0112	
Number of data pairs	47			47	
Slope b	1.128			1.083	
Uncertainty of b	0.040			0.039	
Ordinate intercept a	-1.986			-2.169	
Uncertainty of a	0.733			0.720	
Expanded measured uncertainty W_{CM}	19.05	%		10.63	%
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	0.67	µg/m³			
Uncertainty between Candidates	1.17	µg/m³			
	SN 0111			SN 0112	
Number of data pairs	35			35	
Slope b	1.037			0.974	
Uncertainty of b	0.038			0.039	
Ordinate intercept a	0.054			1.391	
Uncertainty of a	1.628			1.65	
Expanded measured uncertainty W_{CM}	12.93	%		10.55	%
All comparisons, <30 µg/m³					
Uncertainty between Reference	0.61	µg/m³			
Uncertainty between Candidates	0.58	µg/m³			
	SN 0111			SN 0112	
Number of data pairs	194			194	
Slope b	1.109			1.063	
Uncertainty of b	0.022			0.021	
Ordinate intercept a	-2.089			-1.870	
Uncertainty of a	0.394			0.378	
Expanded measured uncertainty W_{CM}	14.98	%		8.17	%
All comparisons					
Uncertainty between Reference	0.62	µg/m³			
Uncertainty between Candidates	0.67	µg/m³			
	SN 0111			SN 0112	
Number of data pairs	229			229	
Slope b	1.077	significant		1.039	significant
Uncertainty of b	0.011			0.011	
Ordinate intercept a	-1.561	significant		-1.436	significant
Uncertainty of a	0.266			0.264	
Expanded measured uncertainty W_{CM}	11.74	%		7.53	%

The results of the check of the five criteria given in chapter 6.1 Methodology of the equivalence check (modules 5.4.9 – 5.4.11) are as follows:

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

Criterion 2: The uncertainty between the candidates is less than 2.5 µg/m³.

Criterion 3: The uncertainty between the reference devices is less than 2.0 µg/m³.

Criterion 4: All of the expanded uncertainties are below 25 %.

Criterion 5: The slopes as well as the intercepts used for evaluation of the complete dataset are significantly greater than the permissible values for both devices.

Other: For both candidates, the total slope is 1.058 and the intercept is -1.505 at an expanded overall uncertainty of 9.11 % for the complete dataset.

The January 2010 version of the Guide is ambiguous with respect to which slope and which intercept should be used to correct a candidate should it fail the test of equivalence. After consultation with the convenor (Mr Theo Hafkenscheid) of the EC working group responsible for setting up the Guide, it was decided that the requirements of the November 2005 version of the Guide are still valid, and that the slope and intercept from the orthogonal regression of all the paired data be used. These are stated additionally under “Other” in the above.

The 2006 UK Equivalence Report [10] has highlighted this was a flaw in the mathematics required for equivalence as per the November 2005 version of the Guide as it penalised instruments that were more accurate (Annex E Section 4.2 therein). This same flaw is copied in the January 2010 version. Hence, the Fidas® 200 S measuring system for $PM_{2.5}$ and PM_{10} is indeed being penalised by the mathematics for being accurate. It is proposed that the same pragmatic approach is taken here that was previously undertaken in earlier studies.

Therefore, according to Table 46, the slope and intercept should be corrected for $PM_{2.5}$ due to the determined uncertainties W_{CM} of “Bornheim, summer” being too high and also due to its significance. For PM_{10} as well, the slope and intercept should be corrected due to its significance according to Table 47. Nonetheless it should be noted that, even without application of correction factors, the determined uncertainties W_{CM} for PM_{10} lie below the specified expanded relative uncertainty W_{dqo} of 25 % for particulate matter for all datasets considered.

For $PM_{2.5}$:

The slope for the complete dataset is 1.076. The intercept for the complete dataset is -0.339. Thus, an additional evaluation applying the respective calibration factors to the datasets is made in chapter 6.1 5.4.11 Application of correction factors and terms.

For PM_{10}:

The slope for the complete dataset is 1.058. The intercept for the complete dataset is -1.505. An additional evaluation where the respective calibration factors are applied to the datasets is made in chapter 6.1 5.4.11 Application of correction factors and terms.

The revised January 2010 version of the Guide requires that, in order to monitor the processes in compliance with the guidelines, random checks shall be performed on a number of systems within a measuring network and that the number of measuring sites shall depend on the expanded uncertainty of the system. Either the network operator or the responsible authority of the member state is responsible for the appropriate realisation of the requirement mentioned above. However, TÜV Rheinland recommends that the expanded uncertainty for the complete dataset (here: uncorrected raw data) shall be referred to, i.e. 16.8 % for $PM_{2.5}$, which would require annual checks at 4 sites, and 9.1 %, for PM_{10}, which would require annual checks a 2 sites (Guide [5], Chapter 9.9.2, Table 6). Due to the necessary application of the corresponding calibration factors, this assessment should be made on the basis of the evaluation of the corrected datasets (refer to chapter 6.1 5.4.11 Application of correction factors and terms).

6.6 Detailed presentation of test results

Table 48 and Table 49 present an overview of the uncertainties between the reference devices u_{ref} obtained in the field tests.

Table 48: Uncertainty between reference devices u_{ref} for $PM_{2.5}$

Reference devices	**Test site**	**No. of values**	**Uncertainty u_{bs}**
No.			µg/m³
1 / 2	Cologne, summer	82	0.66
1 / 2	Cologne, winter	52	0.54
1 / 2	Bonn, winter	50	0.62
1 / 2	Bornheim, summer	47	0.42
1 / 2	All test sites	231	0.58

Table 49: Uncertainty between reference devices u_{ref} for PM_{10}

Reference devices	**Test site**	**No. of values**	**Uncertainty u_{bs}**
Nr.			µg/m³
1 / 2	Cologne, summer	82	0.80
1 / 2	Cologne, winter	52	0.53
1 / 2	Bonn, winter	50	0.38
1 / 2	Bornheim, summer	49	0.54
1 / 2	All test sites	233	0.62

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

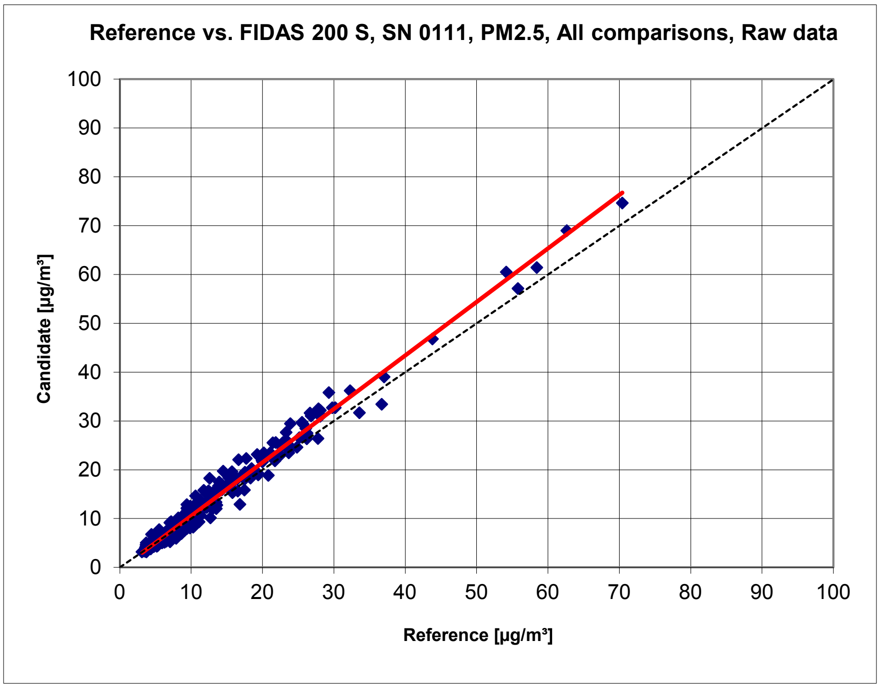


Figure 78: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, all test sites

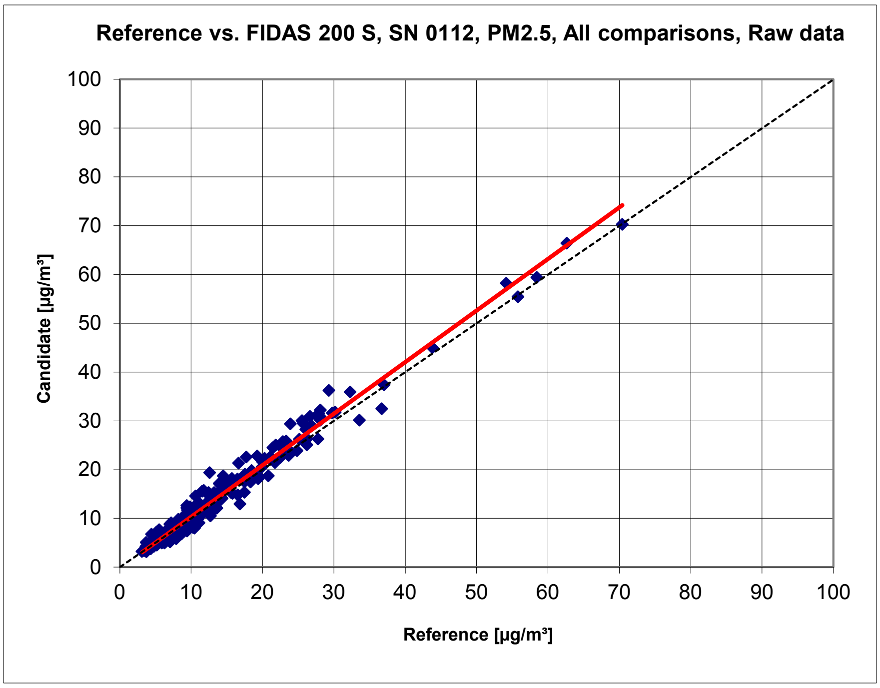


Figure 79: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, all test sites

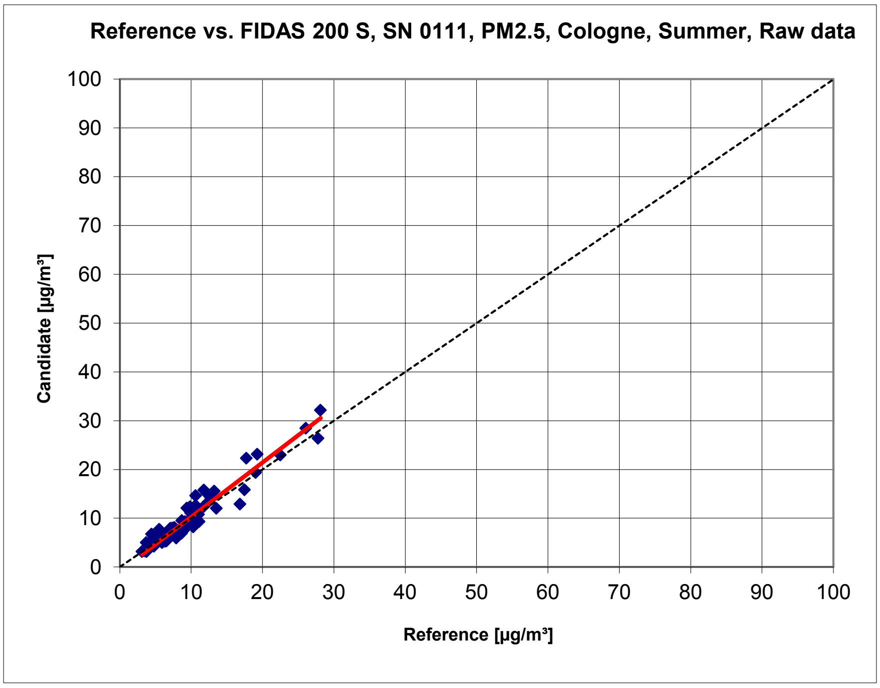


Figure 80: *Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Cologne, summer*

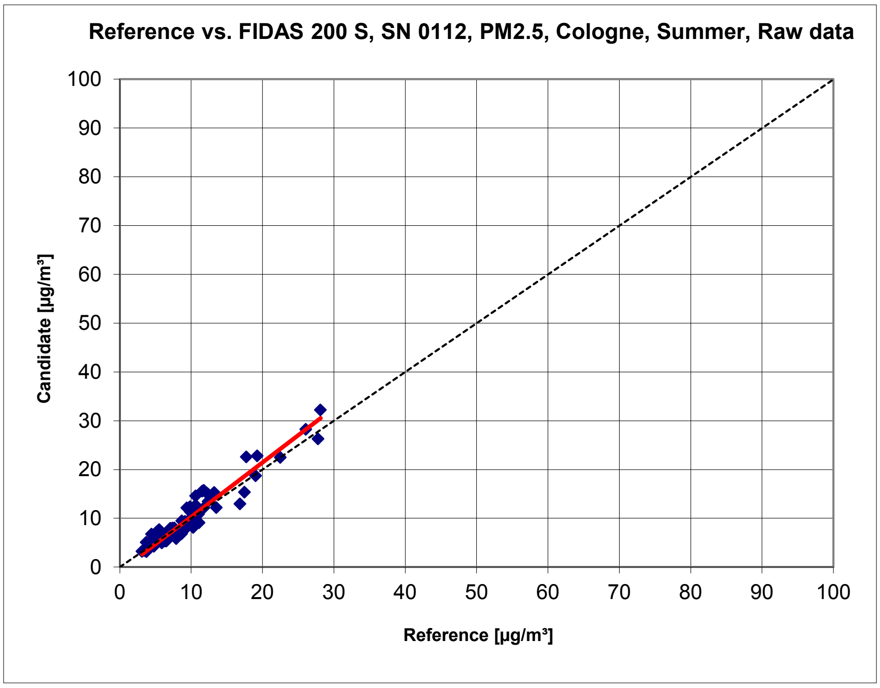


Figure 81: *Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Cologne, summer*

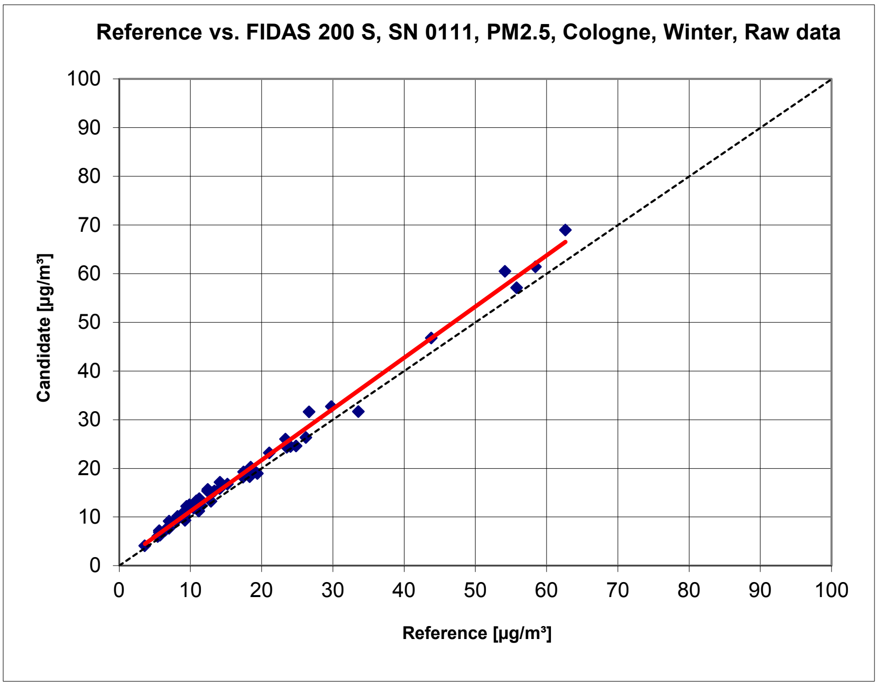


Figure 82: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Cologne, winter

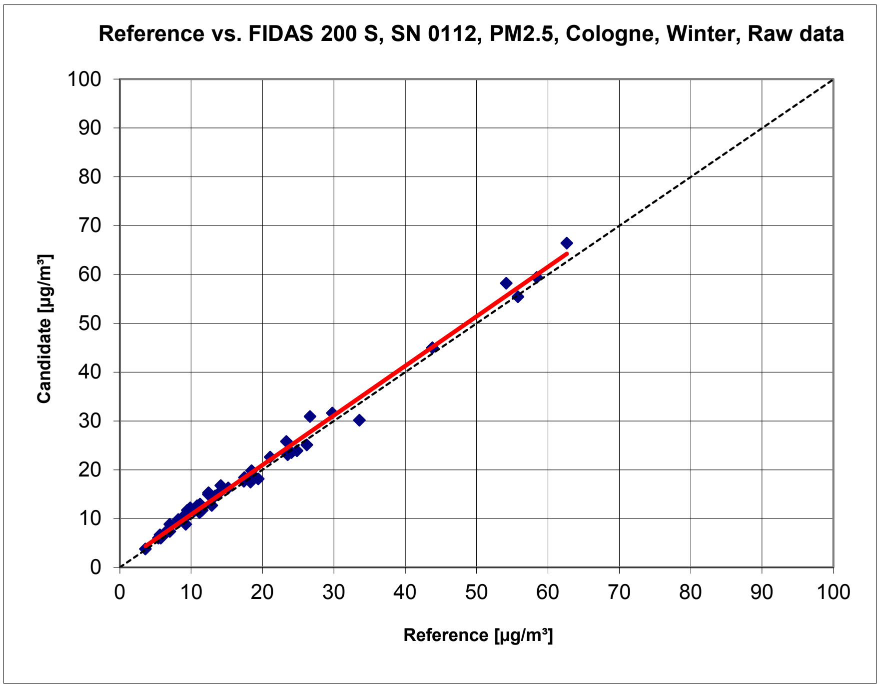


Figure 83: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Cologne, winter

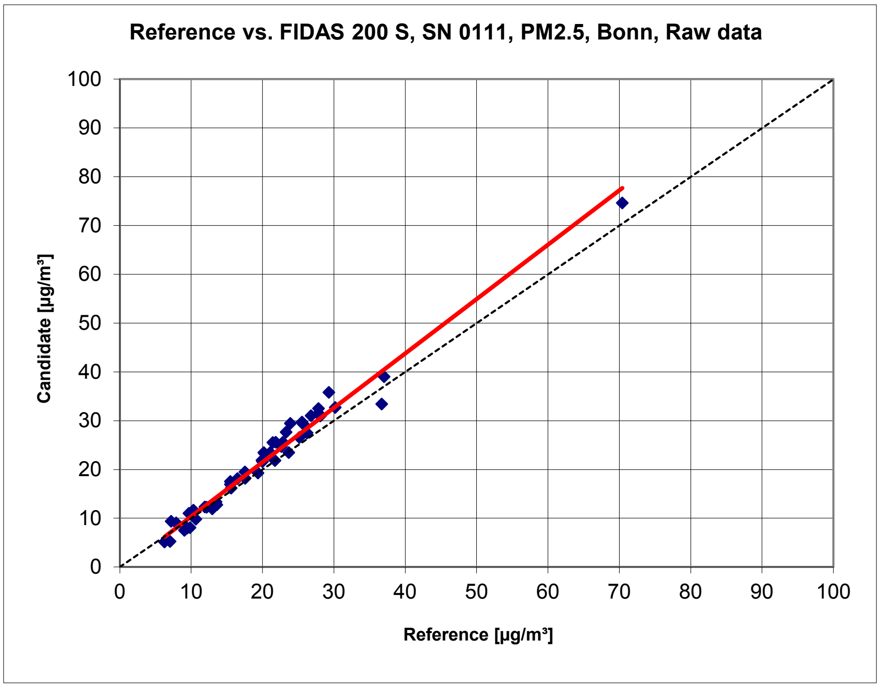


Figure 84: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Bonn, winter

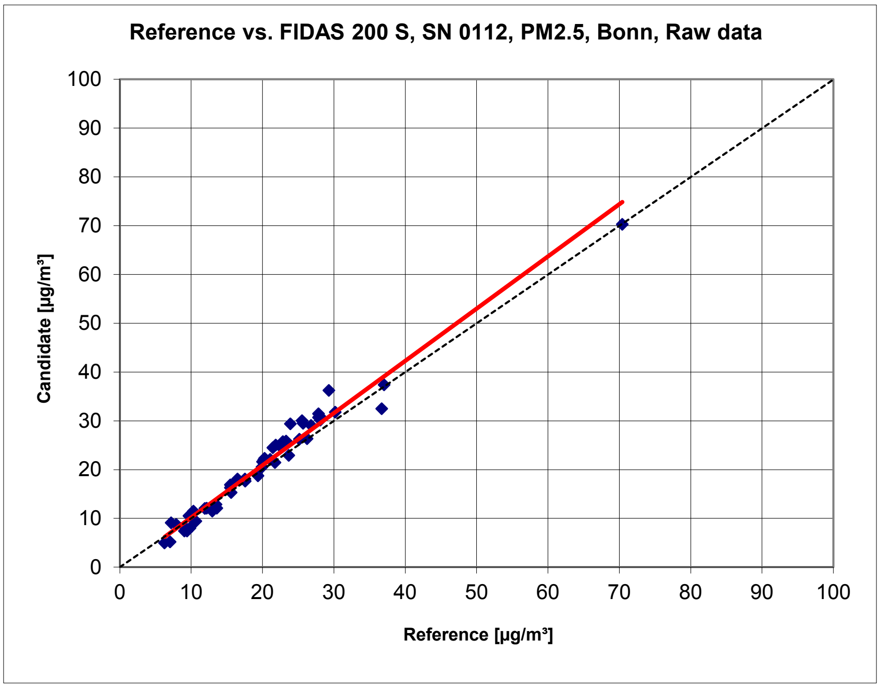


Figure 85: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Bonn, winter

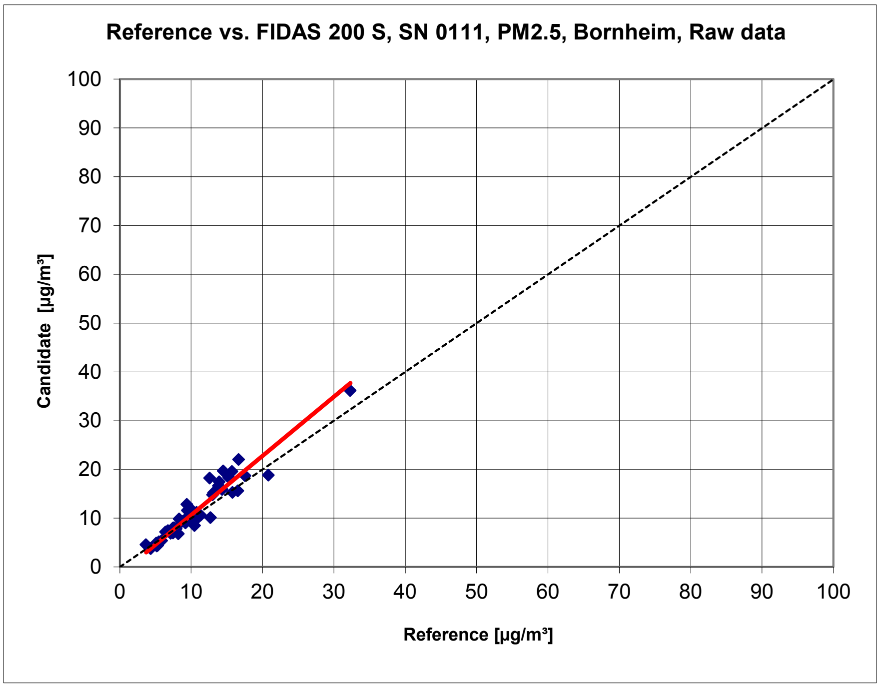


Figure 86: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Bornheim, summer

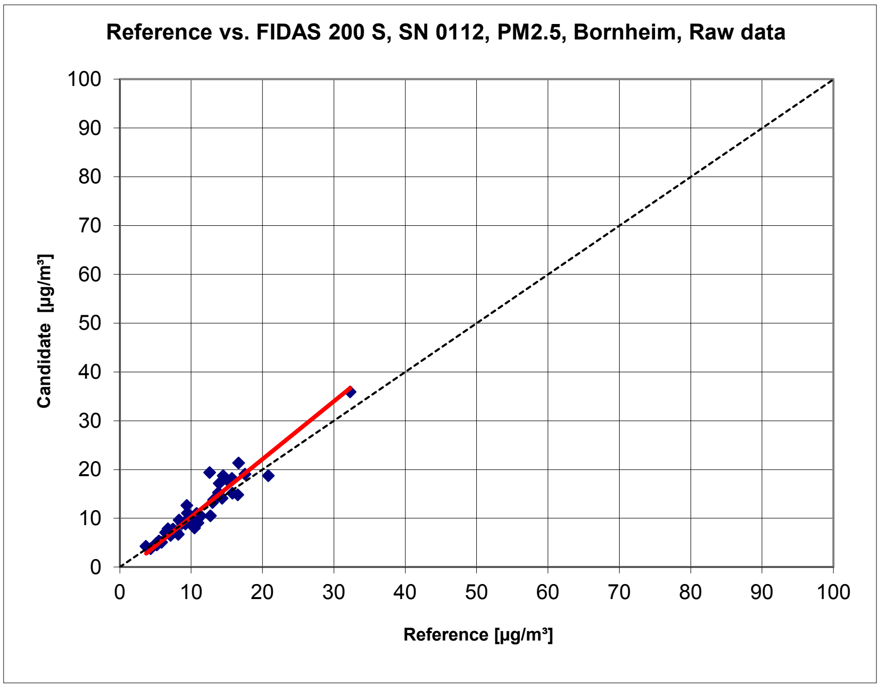


Figure 87: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Bornheim, summer

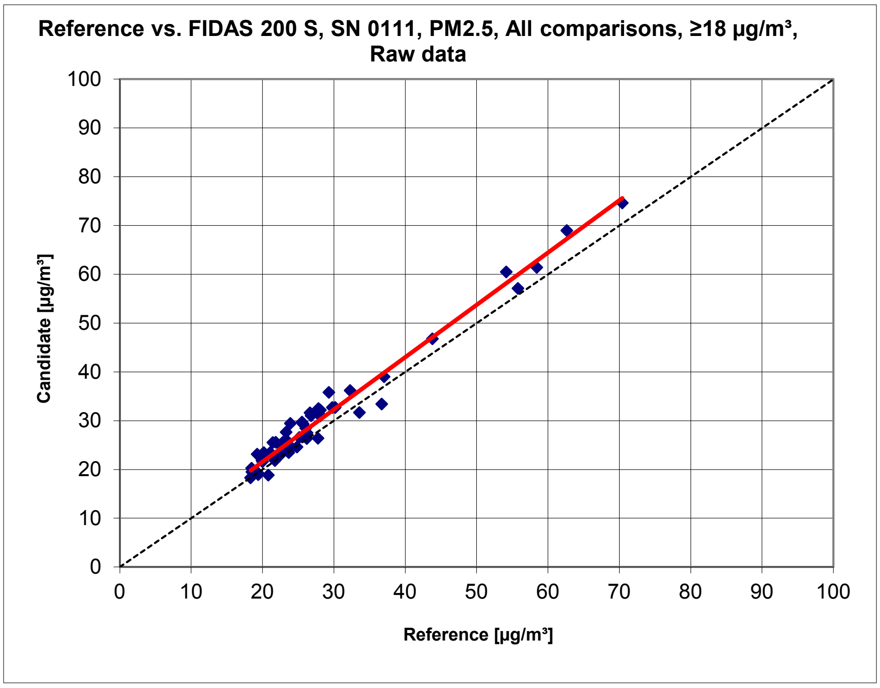


Figure 88: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, values ≥ 18 µg/m³

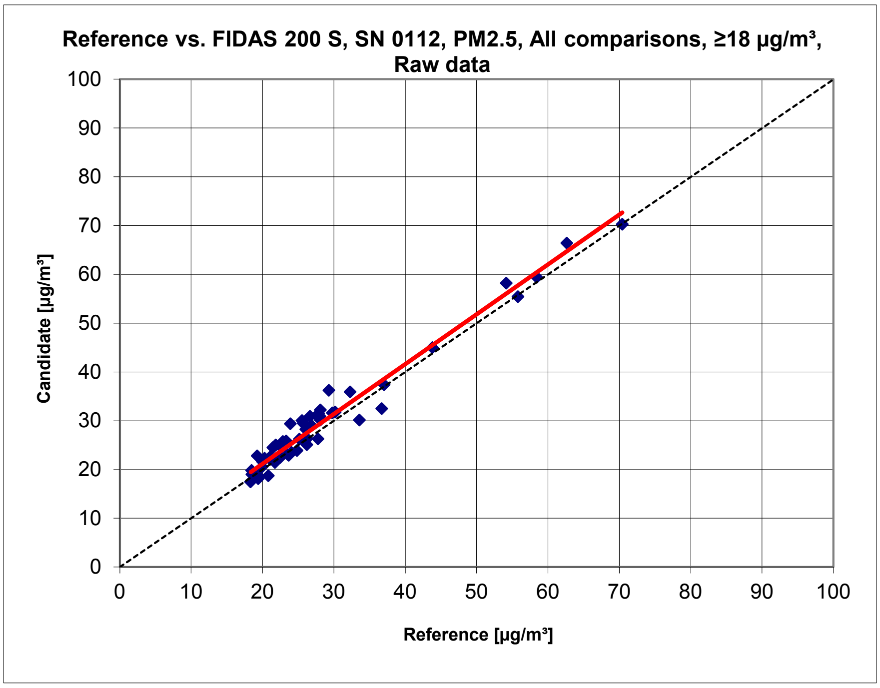


Figure 89: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, values ≥ 18 µg/m³

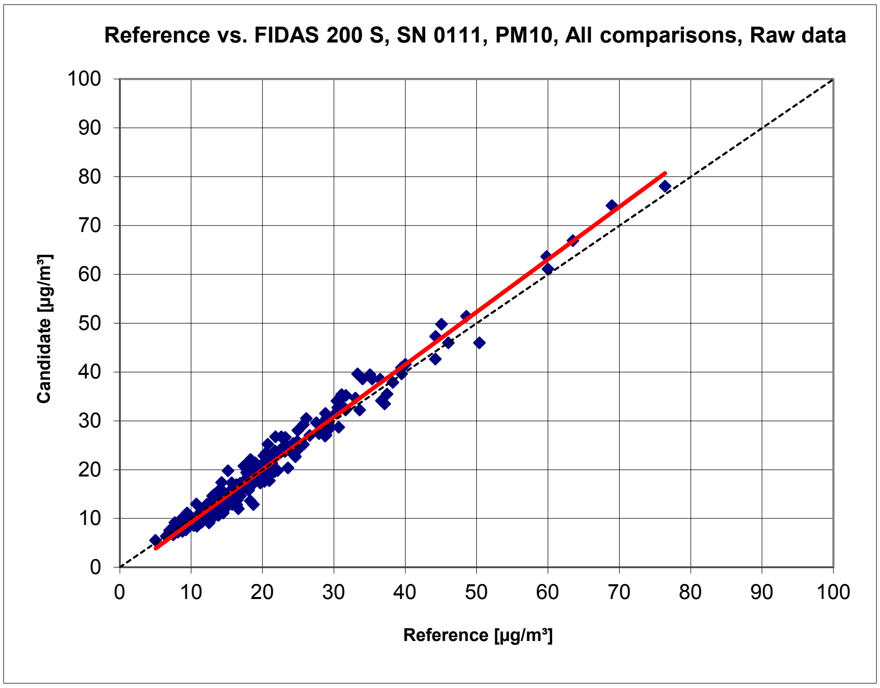


Figure 90: Reference device vs. candidate, SN 0111, measured component PM_{10}, all test sites

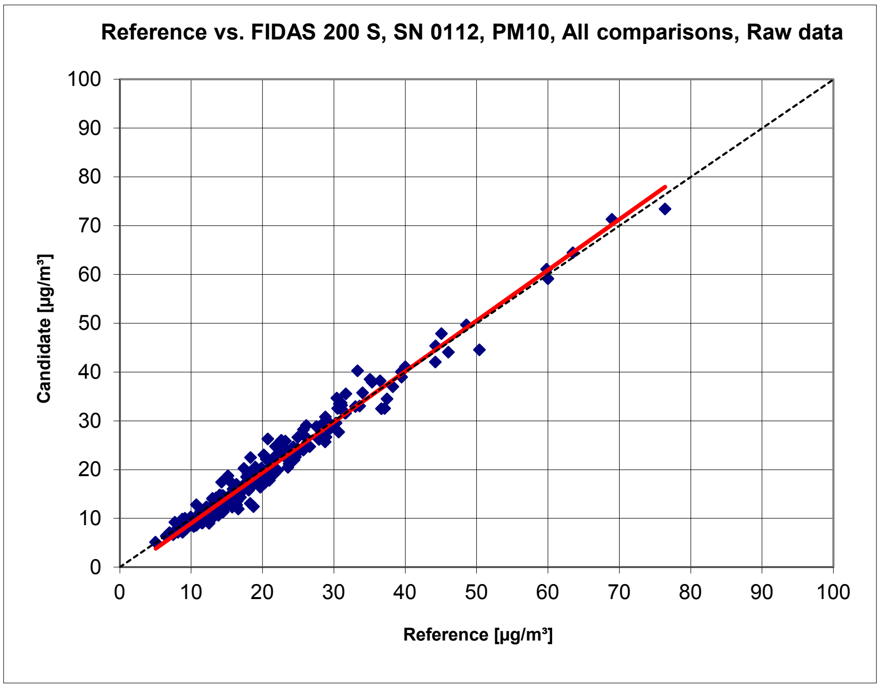


Figure 91: Reference device vs. candidate, SN 0112, measured component PM_{10}, all test sites

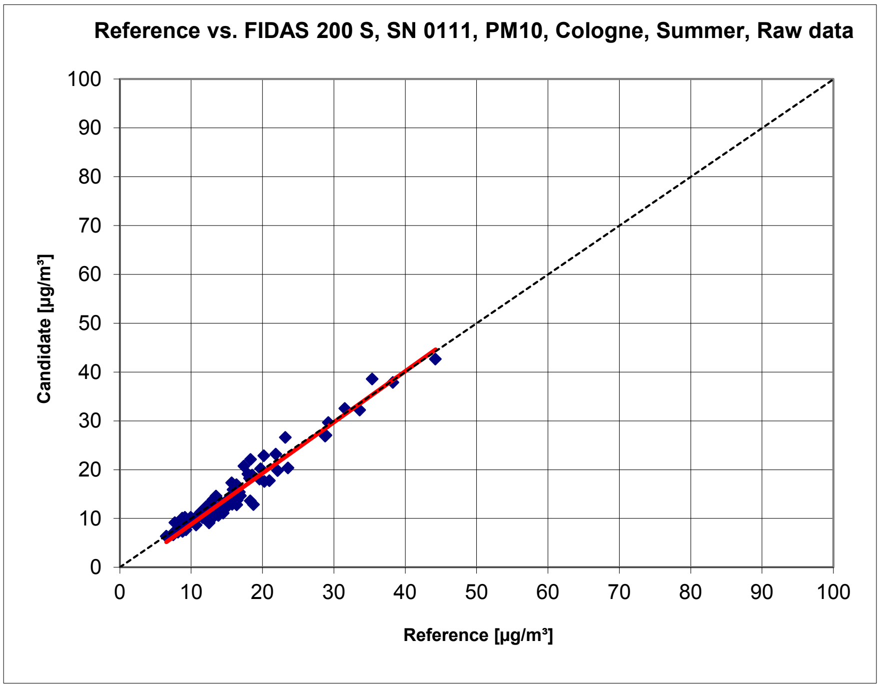


Figure 92: Reference device vs. candidate, SN 0111, measured component PM_{10}, Cologne, summer

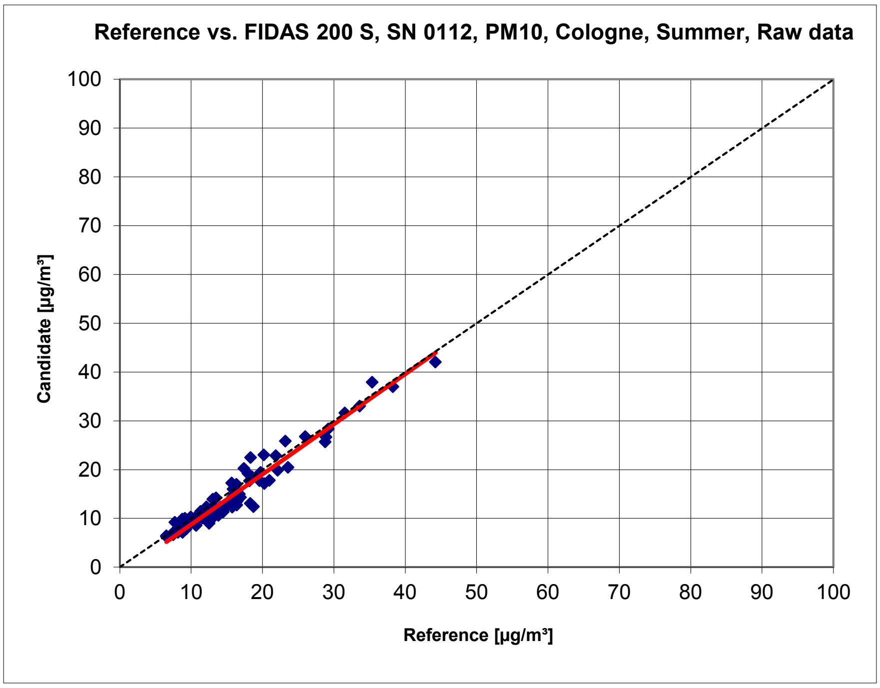


Figure 93: Reference device vs. candidate, SN 0112, measured component PM_{10}, Cologne, summer

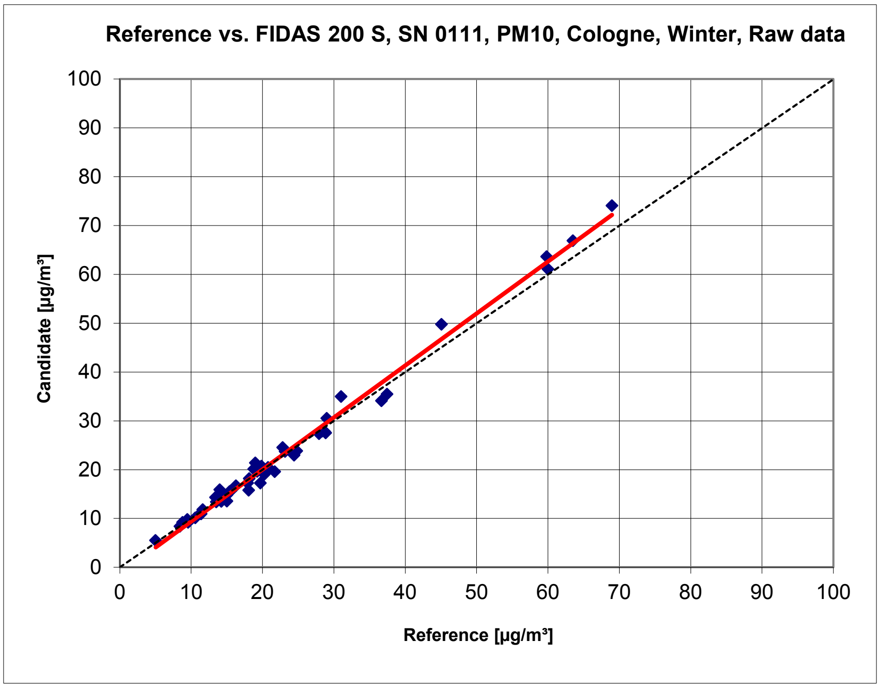


Figure 94: Reference device vs. candidate, SN 0111, measured component PM_{10}, Cologne, winter

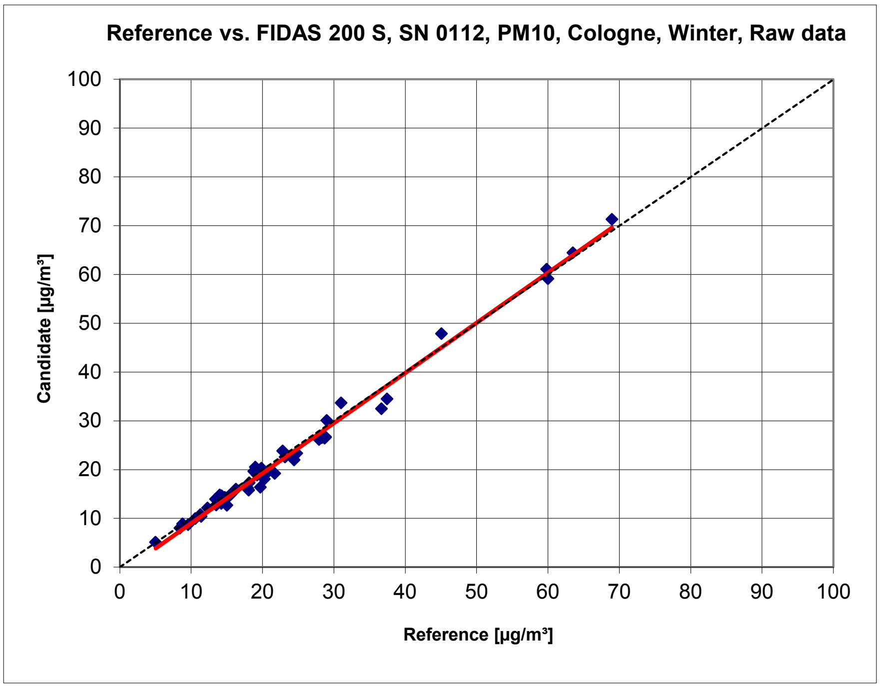


Figure 95: Reference device vs. candidate, SN 0112, measured component PM_{10}, Cologne, winter

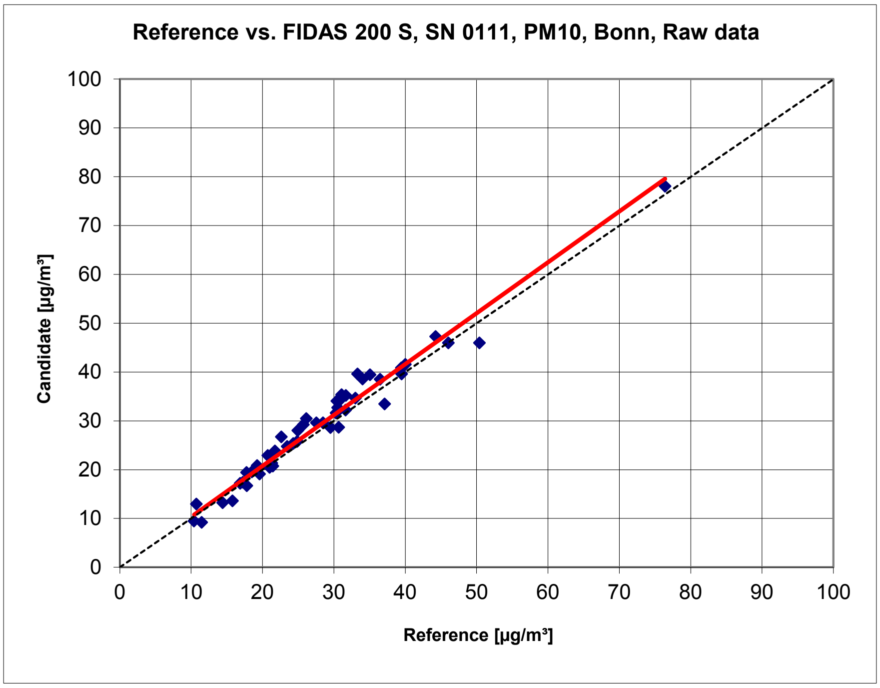


Figure 96: *Reference device vs. candidate, SN 0111, measured component PM_{10}, Bonn, winter*

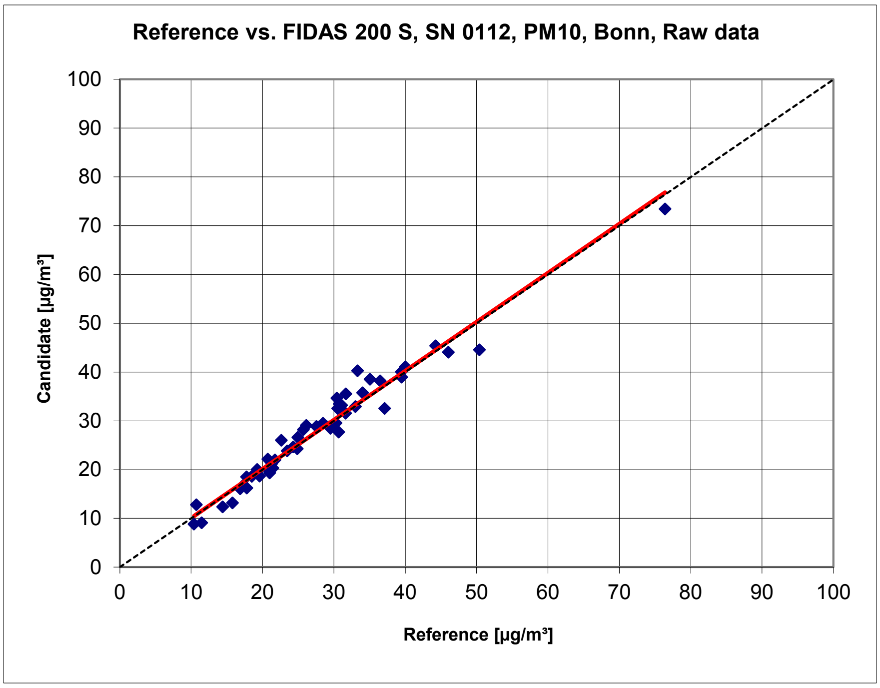


Figure 97: *Reference device vs. candidate, SN 0112, measured component PM_{10}, Bonn, winter*

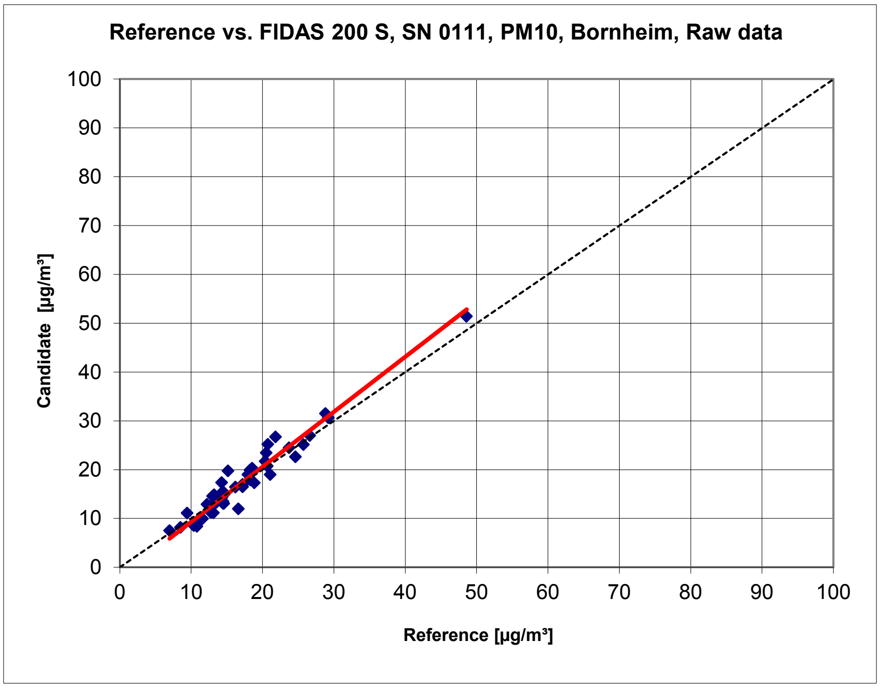


Figure 98: Reference device vs. candidate, SN 0111, measured component PM_{10}, Bornheim, summer

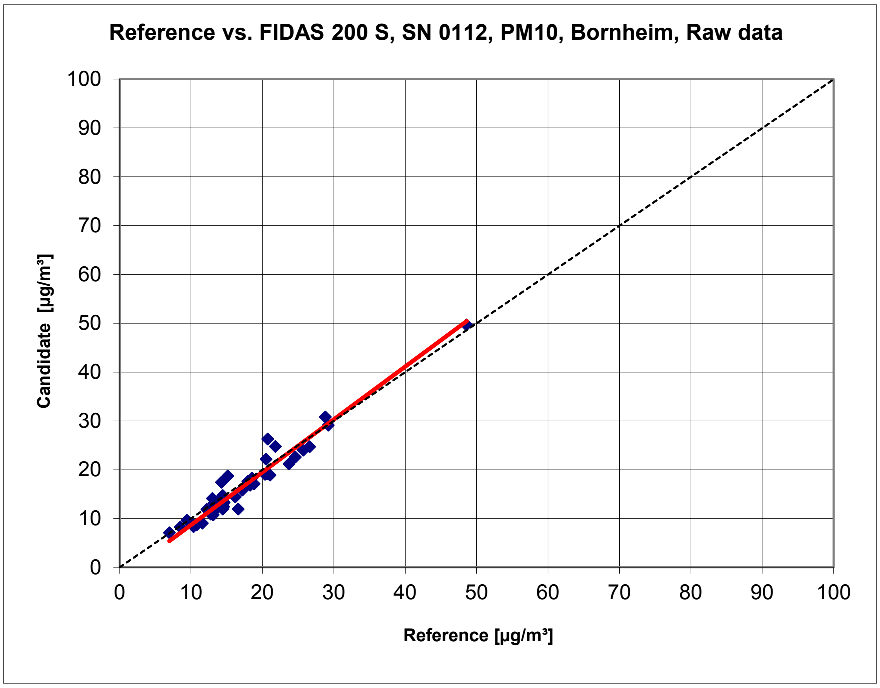


Figure 99: Reference device vs. candidate, SN 0112, measured component PM_{10}, Bornheim, summer

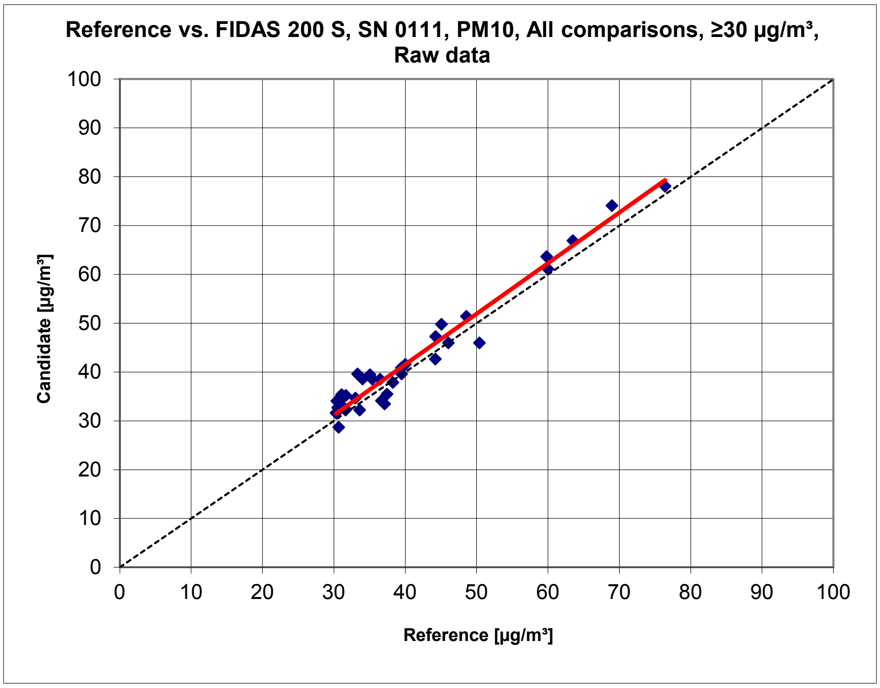


Figure 100: Reference device vs. candidate, SN 0111, measured component PM_{10}, values ≥ 30 µg/m³

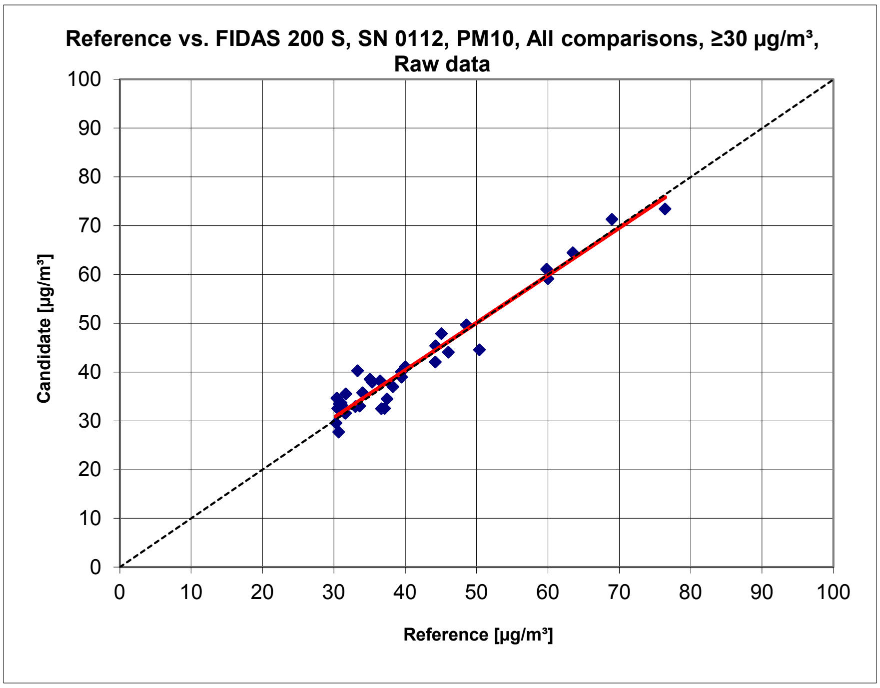


Figure 101: Reference device vs. candidate, SN 0112, measured component PM_{10}, values ≥ 30 µg/m³

6.1 5.4.11 Application of correction factors and terms

If the maximum expanded uncertainty of the candidates exceeds the data quality objectives according to Annex B of Standard VDI 4202, Sheet 1 (September 2010) for the test of $PM_{2.5}$ measuring systems, the application of factors and terms is allowed. Values corrected shall meet the requirements of chapter 9.5.3.2ff of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods".

The tests were also carried out for the component PM_{10}.

6.2 Equipment

No equipment is necessary to test this performance criterion.

6.3 Method

Refer to module 5.4.10.

6.4 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 complete dataset. The corrected values shall satisfy the requirements for all datasets 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

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

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

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in annex B of [4]. 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 term 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

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

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 [4]. 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 [5]. 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 dataset, uncertainty $w_{c,CM,corr}$ is calculated at the daily limit value by taking y_i as 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 $W_{CM,corr}$ is compared and assessed with the requirements on data quality of ambient air measurements according to EU Standard [8]. 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 % [8].

6.5 Assessment

Due to application of the correction factors, the candidates meet the requirements on data quality of ambient air quality measurements for all datasets for $PM_{2.5}$ and PM_{10}. For PM_{10}, the requirements are met even without application of correction factors. The corrections of slope and intercept nevertheless lead to an improvement of the expanded measurement uncertainties of the full data comparison.

Performance criterion met? yes

The evaluation of the complete dataset for both candidates shows a significant intercepts for the two measuring components $PM_{2.5}$ and PM_{10}.

For $PM_{2.5}$:

The slope for the complete dataset is 1.076. The intercept for the complete dataset is -0.339 (refer to Table 46).

For PM_{10}:

The slope for the complete dataset is 1.058. The intercept for the complete dataset -1.505 (refer to Table 47).

Slope and intercept were corrected for both measured components for the complete dataset. All datasets were then re-evaluated using the corrected values.

After correction, all datasets fulfil the requirements on data quality and the measurement uncertainties improve significantly at some sites.

The January 2010 version of the Guide requires that the systems are tested annually at a number of sites corresponding to the highest expanded uncertainty found during equivalence testing, if the AMS is operated within a network. The corresponding criterion for determining the number of test sites is divided into 5 % steps (Guide [4], chapter 9.9.2, Table 6). It should be noted that the highest expanded uncertainty determined for $PM_{2.5}$ lies in the range of 15 % to 20 %. For PM_{10}, the highest expanded uncertainty determined lies in the range of <10 % before as well as after the correction.

The network operator or the responsible authority of the member state is responsible for the appropriate realisation of the required regular checks in networks mentioned above. However, TÜV Rheinland recommends to use the expanded uncertainty for the complete dataset, i.e. for $PM_{2.5}$: (uncorrected dataset) and 10.2 % (dataset after slope/offset correction), which would require an annual test at 4 measurement sites (uncorrected) or 3 measurement sites (corrected); for PM_{10}: 9.1 % (uncorrected dataset) and 7.2 % (dataset after slope/offset correction), which would require an annual test at 2 measurement sites for both datasets (uncorrected and corrected).

6.6 Detailed presentation of test results

Table 50 and Table 51 present the results of the evaluations of the equivalence test after application of the correction factors for slope and intercept on the complete dataset.

Table 50: Summary of the results of the equivalence test, SN 0111 & SN 0112, measured component $PM_{2.5}$ after correction of slope / intercept

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	30	µg/m³
Status of measured values	Slope & offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.44**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**225**				
Slope b	**0.999**	**not significant**			
Uncertainty of b	**0.010**				
Ordinate intercept a	**0.012**	**not significant**			
Uncertainty of a	**0.178**				
Expanded meas. uncertainty W_{CM}	**10.17**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.63**	**µg/m³**			
Uncertainty between Candidates	**0.78**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**54**				
Slope b	**0.971**				
Uncertainty of b	**0.023**				
Ordinate intercept a	**0.771**				
Uncertainty of a	**0.715**				
Expanded meas. uncertainty W_{CM}	**12.87**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.57**	**µg/m³**			
Uncertainty between Candidates	**0.31**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**171**				
Slope b	**1.108**				
Uncertainty of b	**0.030**				
Ordinate intercept a	**-1.010**				
Uncertainty of a	**0.304**				
Expanded meas. uncertainty W_{CM}	**17.50**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	30	µg/m³
Status of measured values	Slope & offset corrected		Allowed uncertainty	25	%
Cologne, Summer					
Uncertainty between Reference	**0.66**	**µg/m³**			
Uncertainty between Candidates	**0.11**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**81**			**82**	
Slope b	**1.036**			**1.034**	
Uncertainty of b	**0.031**			**0.033**	
Ordinate intercept a	**-0.518**			**-0.478**	
Uncertainty of a	**0.337**			**0.351**	
Expanded meas. uncertainty W_{CM}	**10.06**	**%**		**10.40**	**%**
Cologne, Winter					
Uncertainty between Reference	**0.54**	**µg/m³**			
Uncertainty between Candidates	**0.51**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**51**			**50**	
Slope b	**0.976**			**0.942**	
Uncertainty of b	**0.013**			**0.013**	
Ordinate intercept a	**0.962**			**0.951**	
Uncertainty of a	**0.291**			**0.303**	
Expanded meas. uncertainty W_{CM}	**8.36**	**%**		**9.90**	**%**
Bonn					
Uncertainty between Reference	**0.62**	**µg/m³**			
Uncertainty between Candidates	**0.65**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**50**			**50**	
Slope b	**1.034**			**0.993**	
Uncertainty of b	**0.023**			**0.025**	
Ordinate intercept a	**-0.394**			**-0.144**	
Uncertainty of a	**0.531**			**0.575**	
Expanded meas. uncertainty W_{CM}	**11.94**	**%**		**12.42**	**%**
Bornheim					
Uncertainty between Reference	**0.42**	**µg/m³**			
Uncertainty between Candidates	**0.46**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**45**			**45**	
Slope b	**1.124**			**1.098**	
Uncertainty of b	**0.050**			**0.050**	
Ordinate intercept a	**-1.027**			**-1.137**	
Uncertainty of a	**0.598**			**0.598**	
Expanded meas. uncertainty W_{CM}	**21.34**	**%**		**16.63**	**%**
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.63**	**µg/m³**			
Uncertainty between Candidates	**0.78**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**54**			**54**	
Slope b	**0.994**			**0.948**	
Uncertainty of b	**0.023**			**0.024**	
Ordinate intercept a	**0.515**			**1.011**	
Uncertainty of a	**0.701**			**0.74**	
Expanded meas. uncertainty W_{CM}	**12.77**	**%**		**13.86**	**%**
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.57**	**µg/m³**			
Uncertainty between Candidates	**0.31**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**173**			**173**	
Slope b	**1.130**			**1.090**	
Uncertainty of b	**0.030**			**0.030**	
Ordinate intercept a	**-1.095**			**-0.929**	
Uncertainty of a	**0.304**			**0.308**	
Expanded meas. uncertainty W_{CM}	**20.87**	**%**		**15.14**	**%**
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.44**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**227**			**227**	
Slope b	**1.017**	**not significant**		**0.981**	**not significant**
Uncertainty of b	**0.010**			**0.010**	
Ordinate intercept a	**-0.053**	**not significant**		**0.111**	**not significant**
Uncertainty of a	**0.176**			**0.182**	
Expanded meas. uncertainty W_{CM}	**10.57**	**%**		**10.89**	**%**

Table 51: Summary of the results of the equivalence test, SN 0111 & SN 0112, measured component PM_{10} after correction of slope / intercept

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	50	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.62**	**µg/m³**			
Uncertainty between Candidates	**0.64**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**227**				
Slope b	**0.999**	**not significant**			
Uncertainty of b	**0.011**				
Ordinate intercept a	**0.015**	**not significant**			
Uncertainty of a	**0.249**				
Expanded measured uncertainty WCM	**7.22**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.67**	**µg/m³**			
Uncertainty between Candidates	**1.10**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**35**				
Slope b	**0.949**				
Uncertainty of b	**0.036**				
Ordinate intercept a	**2.181**				
Uncertainty of a	**1.530**				
Expanded measured uncertainty WCM	**10.17**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.61**	**µg/m³**			
Uncertainty between Candidates	**0.55**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**192**				
Slope b	**1.023**				
Uncertainty of b	**0.021**				
Ordinate intercept a	**-0.408**				
Uncertainty of a	**0.364**				
Expanded measured uncertainty WCM	**7.23**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	50	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
Cologne, Summer					
Uncertainty between Reference	**0.80**	**µg/m³**			
Uncertainty between Candidates	**0.26**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**81**			**82**	
Slope b	**0.986**			**0.970**	
Uncertainty of b	**0.026**			**0.026**	
Ordinate intercept a	**-0.098**			**0.009**	
Uncertainty of a	**0.463**			**0.462**	
Expanded measured uncertainty W_{CM}	**7.28**	**%**		**8.86**	**%**
Cologne, Winter					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.63**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**51**			**50**	
Slope b	**1.006**			**0.971**	
Uncertainty of b	**0.014**			**0.014**	
Ordinate intercept a	**0.238**			**0.216**	
Uncertainty of a	**0.378**			**0.377**	
Expanded measured uncertainty W_{CM}	**6.23**	**%**		**7.62**	**%**
Bonn					
Uncertainty between Reference	**0.38**	**µg/m³**			
Uncertainty between Candidates	**0.85**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**50**			**50**	
Slope b	**0.985**			**0.948**	
Uncertainty of b	**0.026**			**0.027**	
Ordinate intercept a	**1.372**			**1.510**	
Uncertainty of a	**0.776**			**0.817**	
Expanded measured uncertainty W_{CM}	**8.95**	**%**		**10.01**	**%**
Bornheim					
Uncertainty between Reference	**0.54**	**µg/m³**			
Uncertainty between Candidates	**0.82**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**47**			**47**	
Slope b	**1.064**			**1.022**	
Uncertainty of b	**0.037**			**0.037**	
Ordinate intercept a	**-0.425**			**-0.597**	
Uncertainty of a	**0.693**			**0.681**	
Expanded measured uncertainty W_{CM}	**13.33**	**%**		**7.44**	**%**
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.67**	**µg/m³**			
Uncertainty between Candidates	**1.10**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**35**			**35**	
Slope b	**0.979**			**0.919**	
Uncertainty of b	**0.036**			**0.037**	
Ordinate intercept a	**1.526**			**2.795**	
Uncertainty of a	**1.539**			**1.56**	
Expanded measured uncertainty W_{CM}	**10.30**	**%**		**11.37**	**%**
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.61**	**µg/m³**			
Uncertainty between Candidates	**0.55**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**194**			**194**	
Slope b	**1.046**			**1.002**	
Uncertainty of b	**0.021**			**0.020**	
Ordinate intercept a	**-0.510**			**-0.305**	
Uncertainty of a	**0.372**			**0.358**	
Expanded measured uncertainty W_{CM}	**9.79**	**%**		**6.52**	**%**
All comparisons					
Uncertainty between Reference	**0.62**	**µg/m³**			
Uncertainty between Candidates	**0.64**	**µg/m³**			
	SN 0111			**SN 0112**	
Number of data pairs	**229**			**229**	
Slope b	**1.017**	**not significant**		**0.981**	**not significant**
Uncertainty of b	**0.011**			**0.011**	
Ordinate intercept a	**-0.037**	**not significant**		**0.081**	**not significant**
Uncertainty of a	**0.252**			**0.249**	
Expanded measured uncertainty W_{CM}	**8.05**	**%**		**8.01**	**%**

6.1 5.5 Requirements on 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.

6.2 Equipment

Not applicable.

6.3 Method

The Fidas® 200 S is an automated measuring system based on the measurement technology of optical light scattering. The output of measurements of PM fractions is continuous and simultaneous.

The test was carried out in compliance with the requirements on testing the different PM fractions.

6.4 Evaluation

The evaluation of the individual performance criteria was made with regard to the respective measurement components.

6.5 Assessment

Upon assessing the minimum requirements, the measured values for both components were available at the same time.

Performance criterion met? yes

6.6 Detailed presentation of test results

No equipment is necessary to test this performance criterion.

7. Extension of the equivalence test by English comparison campaigns

Subsequent to the type approval testing in Germany, consisting of a laboratory test and a field test (4 comparison campaigns), two further comparison campaigns have been carried out with the candidates SN 0111 and SN 0112 at the National Physical Laboratory NPL in Teddington (UK). The objective is the approval (MCERTS respectively DEFRA Approval) of the measuring system Fidas® 200 S respectively Fidas® 200 for future applications in the UK.

Against the background of European harmonisation and for the increase of robustness of the equivalence testing, an extended equivalence test for the combination of the 4 comparison campaigns from Germany with the 2 comparison campaigns from the UK is depicted in this chapter. In the scope of the evaluations, the measured data have been determined with the evaluation algorithm PM_ENVIRO_0011.

The investigations on site have been carried out by the British test institutes Bureau Veritas UK and National Physical Laboratory NPL. The obtained measuring data have been evaluated in parallel and independently by TÜV Rheinland and Bureau Veritas UK.

The evaluations can be found in the following items in chapter 7 as well as in the annexes 8, and 9 to this report. Hereby it is abstained from an anew presentation of the German comparison campaigns – these can be found in chapter 6.1 5.4.9 Determination of uncertainty between candidates u_{bs} respectively 6.1 5.4.10 Calculation of expanded uncertainty between candidates.

As a summary it can be stated that both additional comparison campaings from the UK fit very well to the already existing 4 campaigns from Germany and the equivalence for both PM_{10} and $PM_{2.5}$ can also be surely demonstrated with in total 6 comparison campaigns.

7.1 5.4.9 Determination of uncertainty between systems under test u_{bs} (PM_ENVIRO_0011, GER + UK)

For the test of $PM_{2.5}$ measuring systems the uncertainty between the systems under test shall be determined according to chapter 9.5.3.1 of the Guide "Demonstration of equivalence of Ambient Air Monitoring Methods" in the field test at least at four sampling sites representative of the future application.

The tests were also carried out for the component PM_{10}.

7.2 Equipment

No equipment is necessary to test this performance criterion.

7.3 Method

The test was carried out at six different comparisons during the field test. Different seasons and varying concentrations for $PM_{2.5}$ and PM_{10} were taken into consideration.

At least 20 % of the concentration values from the complete dataset determined with the reference method shall exceed the upper assessment threshold according to 2008/50/EC [8]. The upper assessment threshold is 17 µg/m³ for $PM_{2.5}$ and 28 µg/m³ for PM_{10}.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (6 test sites, PM_{10}: 318 valid data pairs for SN 0111 and 318 valid data pairs for SN 0112; $PM_{2.5}$: 315 valid data pairs for SN 0111 and 315 valid data pairs for SN 0112), 24.3 % of the measured values exceed the upper assessment threshold of 17 µg/m for $PM_{2.5}$ and a total of 17.7 % of the measured values (corresponds to 56 > 32 data pairs) exceed the upper assessment threshold of 28 µg/m³ for PM_{10}. The measured concentrations were brought into relation with ambient conditions.

7.4 Evaluation

According to **chapter 9.5.3.1** of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" the following applies:

The uncertainty between the candidates u_{bs} shall be ≤ 2.5 µg/m³. If the uncertainty between the candidates exceeds 2.5 µg/m³, one or both systems might not be working properly. In such a case, equivalence cannot be declared.

Uncertainty is determined for:

- All test sites/comparisons together (complete dataset)
- 1 dataset with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: mean values of reference measurement)
- 1 dataset with measured values ≥ 30 µg/m³ for PM_{10} (basis: mean values of reference measurement)

In addition to that, this report provides an evaluation of the following datasets:

- Each test site/comparison separately
- 1 dataset with measured values < 18 µg/m³ for $PM_{2.5}$ (basis: mean values of reference measurement)
- 1 dataset with measured values < 30 µg/m³ for PM_{10} (basis: mean values of reference measurement)

The uncertainty between the candidates u_{bs} is calculated from the differences of all daily mean values (24 h values) of the simultaneously operated candidates by means of 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 24 h values i
	n	=	number of 24 h values

7.5 Assessment

The uncertainty between the candidates u_{bs} with a maximum of 0.85 µg/m³ for $PM_{2.5}$ and a maximum of 1.19 µg/m³ for PM_{10} does not exceed the required value of 2.5 µg/m³.

Performance criterion met? yes

7.6 Detailed presentation of test results

Table 52 and Table 53 list the calculated values for the uncertainty between candidates u_{bs}. Graphical representations of the results are provided in Figure 102 to Figure 111.

Table 52: Uncertainty between candidates u_{bs} for the devices SN 0111 and SN 0112, measured component $PM_{2.5}$, PM_ENVIRO_0011

Device	**Test site**	**No. of values**	**Uncertainty u_{bs}**
SN			µg/m³
0111 / 0112	**All test sites**	**375**	**0.48**
Single test sites			
0111 / 0112	Cologne, summer	101	0.12
0111 / 0112	Cologne, winter	66	0.55
0111 / 0112	Bonn, winter	60	0.70
0111 / 0112	Bornheim, summer	58	0.50
0111 / 0112	Teddington, winter	45	0.55
0111 / 0112	Teddington, summer	45	0.37
Classification over reference value			
0111 / 0112	**Values ≥ 18 µg/m³**	**67**	**0.85**
0111 / 0112	Values < 18 µg/m³	246	0.32

Table 53: Uncertainty between candidates u_{bs} for the devices SN 0111 and SN 0112, measured component PM_{10}, PM_ENVIRO_0011

Device	**Test site**	**No. of values**	**Uncertainty u_{bs}**
SN			µg/m³
0111 / 0112	**All test sites**	**375**	**0.67**
Single test sites			
0111 / 0112	Cologne, summer	101	0.27
0111 / 0112	Cologne, winter	66	0.67
0111 / 0112	Bonn, winter	60	0.90
0111 / 0112	Bornheim, summer	58	0.87
0111 / 0112	Teddington, winter	45	0.76
0111 / 0112	Teddington, summer	45	0.56
Classification over reference values			
0111 / 0112	**Values ≥ 30 µg/m³**	**67**	**1.19**
0111 / 0112	Values < 30 µg/m³	246	0.57

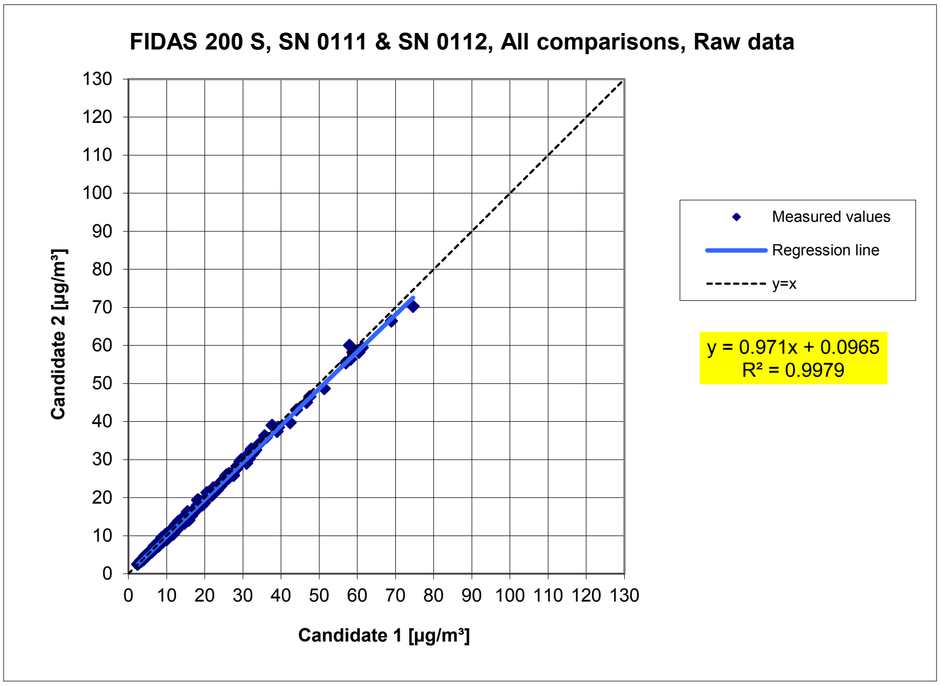


Figure 102: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites (GER+UK), PM_ENVIRO_0011

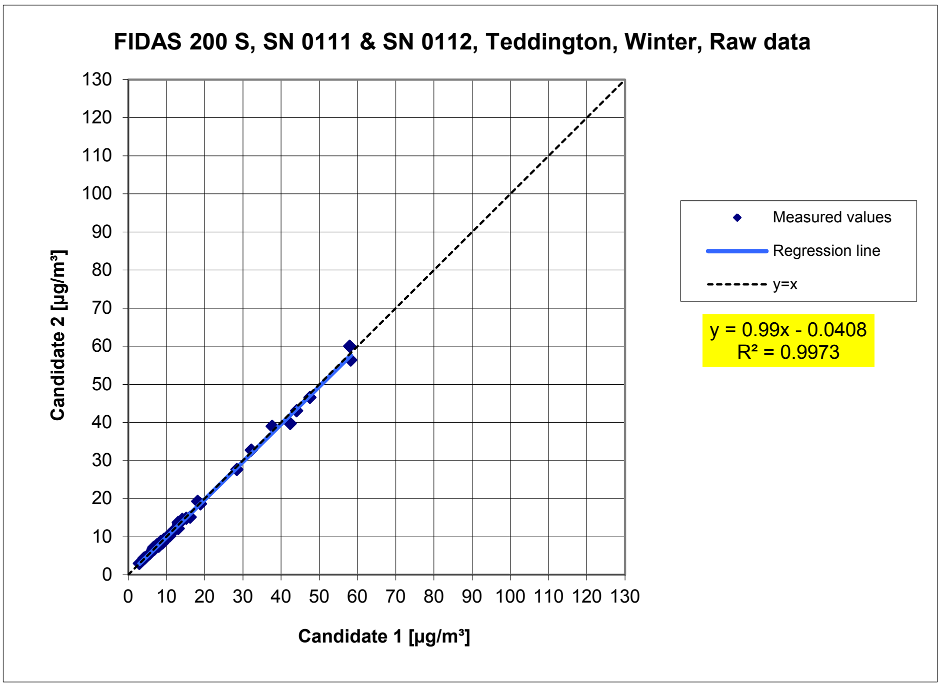


Figure 103: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Teddington, winter, PM_ENVIRO_0011

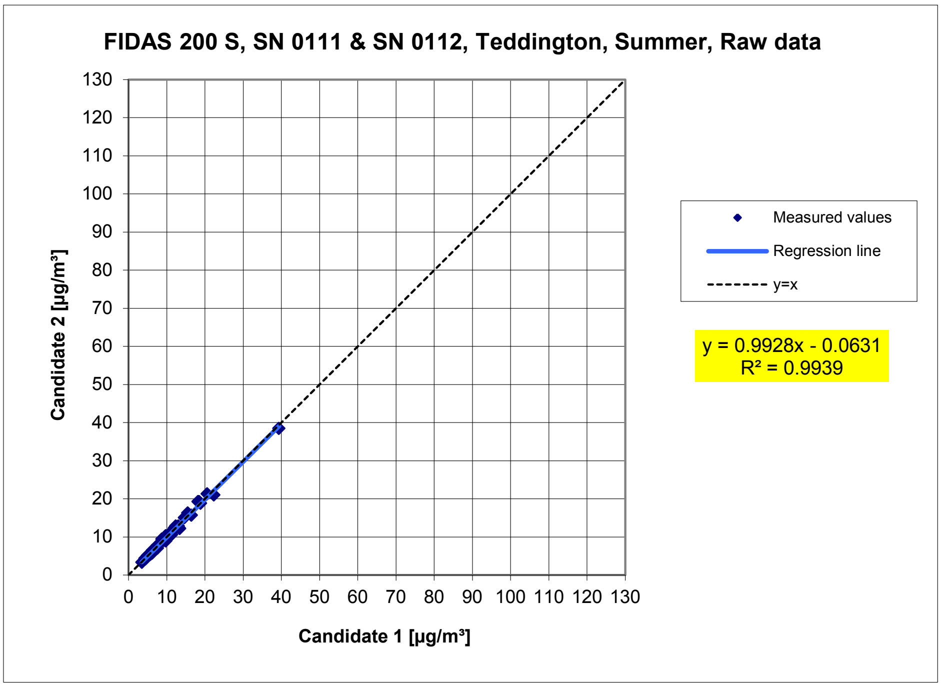


Figure 104: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Teddington, summer, PM_ENVIRO_0011

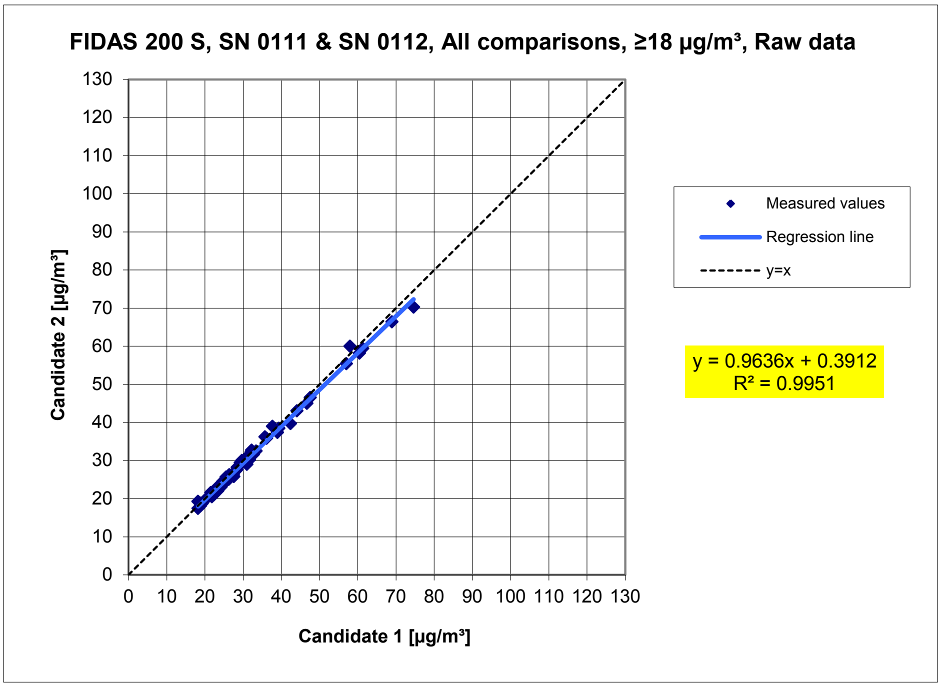


Figure 105: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites (GER+UK), values ≥ 18 µg/m³, PM_ENVIRO_0011

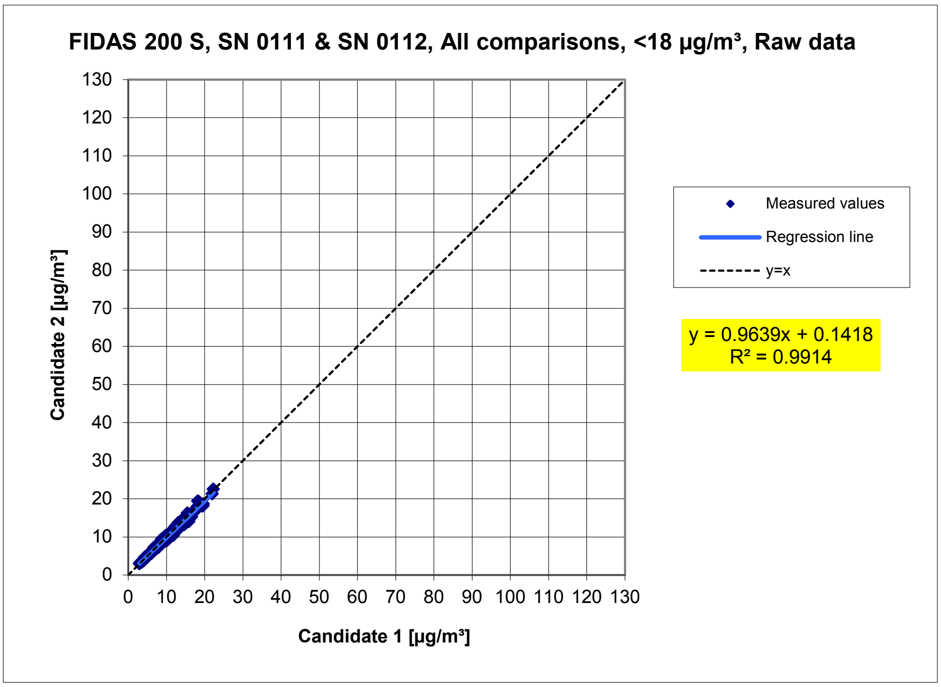


Figure 106: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites (GER+UK), values < 18 µg/m³, PM_ENVIRO_0011

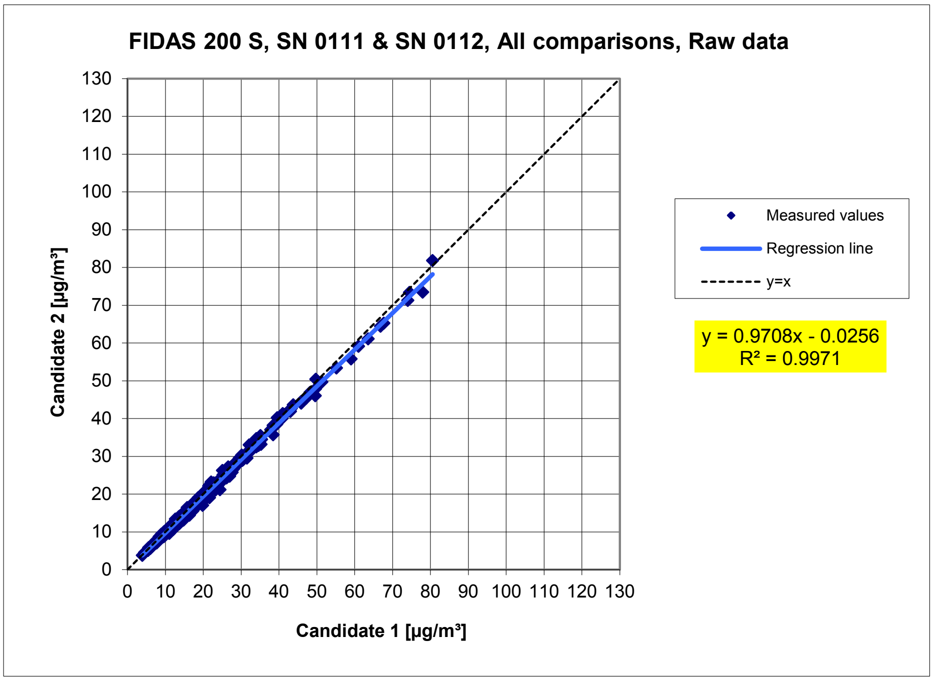


Figure 107: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, all test sites (GER+UK), PM_ENVIRO_0011

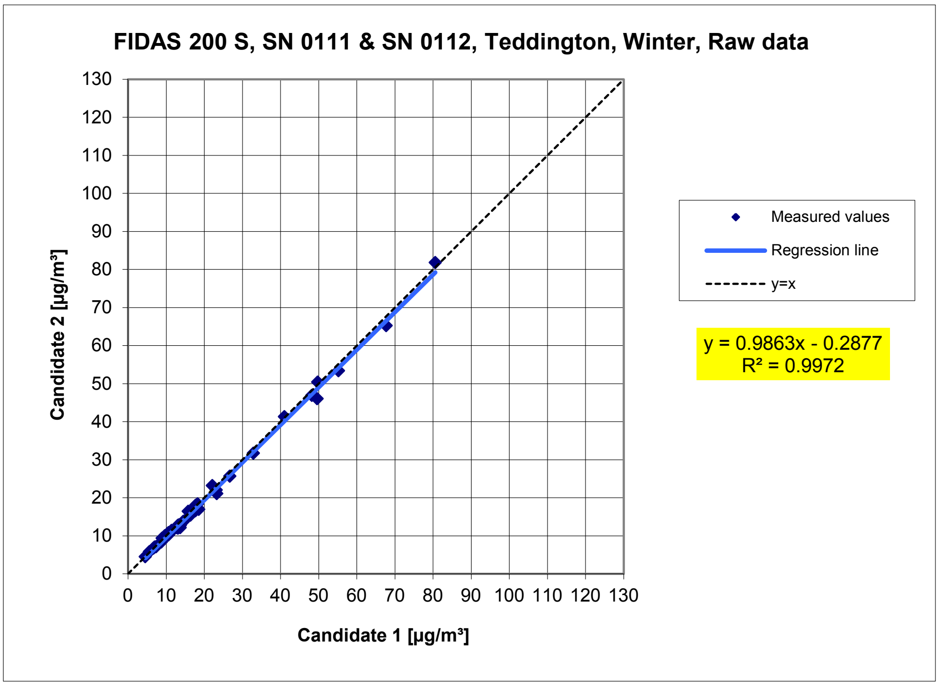


Figure 108: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, test site Teddington, winter, PM_ENVIRO_0011

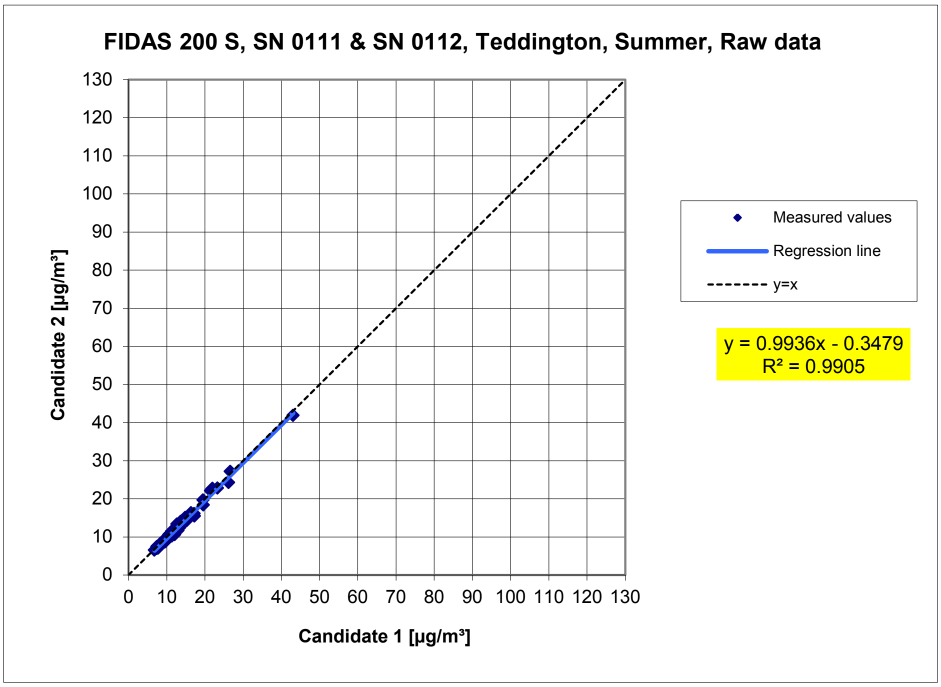


Figure 109: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, test site Teddington, summer, PM_ENVIRO_0011

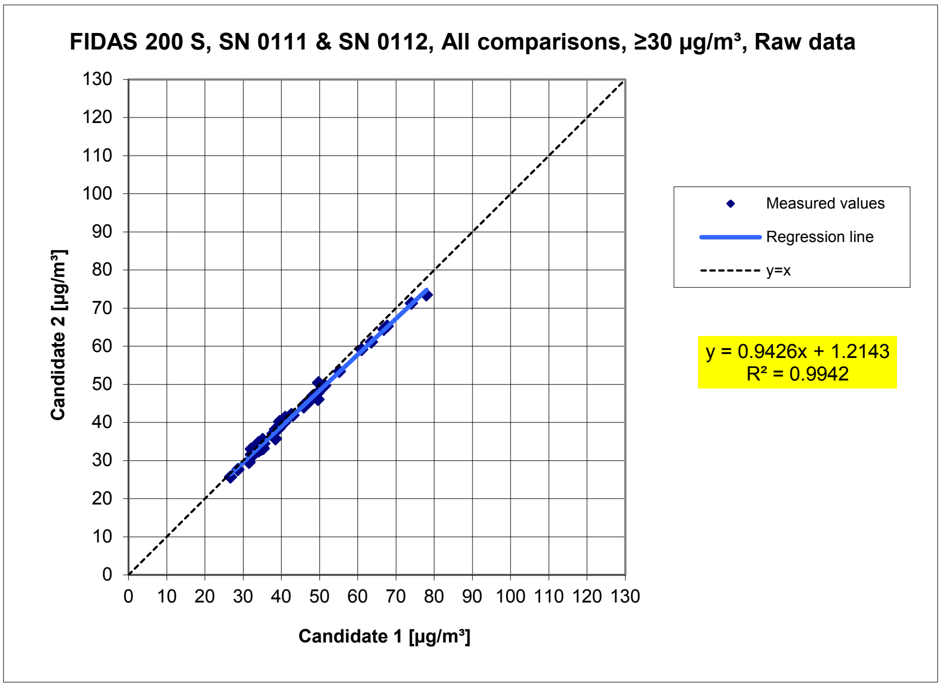


Figure 110: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, all test sites (GER+UK), values ≥ 30 µg/m³, PM_ENVIRO_0011

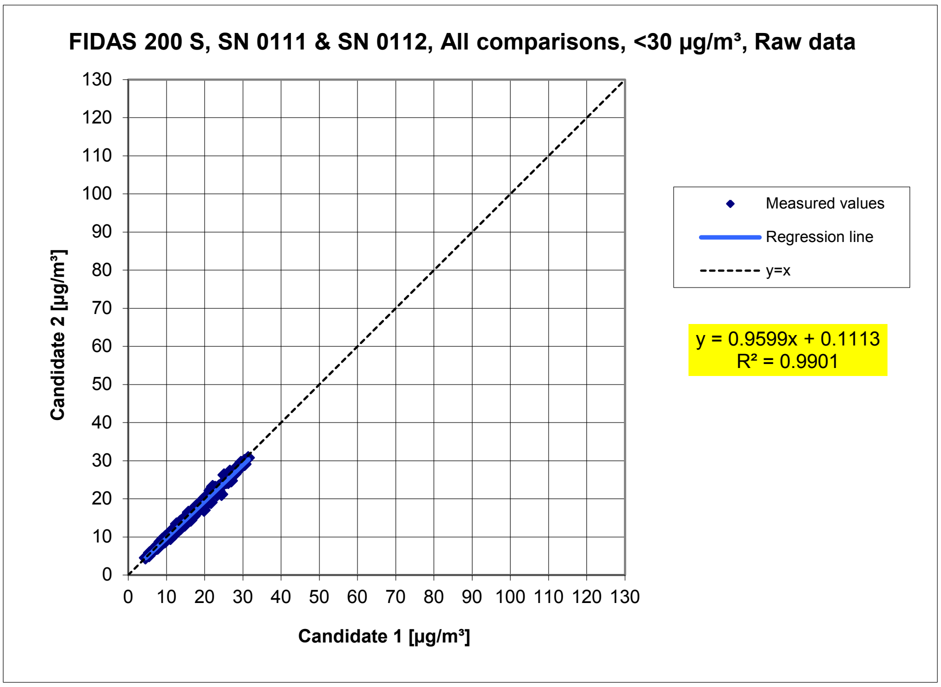


Figure 111: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{10}, all test sites (GER+UK), values < 30 µg/m³, PM_ENVIRO_0011

7.1 5.4.10 Calculation of expanded uncertainty between systems under test (PM_ENVIRO_0011, GER+UK)

For the test of $PM_{2.5}$ measuring systems the equivalency with reference method shall be demonstrated according to chapter 9.5.3.2 to 9.6 of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" in the field test at least at four sampling sites representative of the future application. The maximum expanded uncertainty of the systems under test shall be compared with data quality objectives to Annex A of VDI Standard 4202, Sheet 1 (September 2010).

The tests were also carried out for the component PM_{10}.

7.2 Equipment

Additional instruments according to item 5 of this report were used in the testing of this performance criterion.

7.3 Method

The test was carried out at six different comparisons during the field test. Different seasons and varying concentrations for $PM_{2.5}$ and PM_{10} were taken into consideration.

At least 20 % of the concentration values from the complete dataset determined with the reference method shall exceed the upper assessment threshold according to 2008/50/EC [8]. The upper assessment threshold is 17 µg/m³ for $PM_{2.5}$ and 28 µg/m³ for PM_{10}.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (6 test sites, PM_{10}: 318 valid data pairs for SN 0111 and 318 valid data pairs for SN 0112; $PM_{2.5}$: 315 valid data pairs for SN 0111 and 315 valid data pairs for SN 0112), 24.3 % of the measured values exceed the upper assessment threshold of 17 µg/m for $PM_{2.5}$ and a total of 17.7 % of the measured values (corresponds to 56 > 32 data pairs) exceed the upper assessment threshold of 28 µg/m³ for PM_{10}. The measured concentrations were brought into relation with ambient conditions.

7.4 Evaluation

[Item 9.5.3.2] The calculation of expanded uncertainty is preceded by an uncertainty check between the two simultaneously operated reference devices u_{ref}.

The uncertainty between the simultaneously operated reference devices is determined analogous to the uncertainty between the candidates and shall be ≤ 2 µg/m³.

The evaluated results are given in 8.6 of this test item.

In order to evaluate the comparability between the candidates y and the reference method x, a linear correlation $y_i = a + bx_i$ between the measured results obtained from both methods is assumed. The correlation between the mean values of the reference devices and the candidates, which shall be assessed individually, is established by means of orthogonal regression.

Regression is calculated for:

- All test sites/comparisons together
- Each test site/comparison separately
- 1 dataset with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: mean values of reference measurement)
- 1 dataset with measured values ≥ 30 µg/m³ for PM_{10} (basis: mean values of reference measurement)

For further evaluation, the results of the uncertainty u_{c_s} of the candidates compared with the reference method is described in the following equation, which describes u_{CR} as a function of the OM 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 the value u_{bs}, which is calculated for using the candidates, can be used in this test (refer to item 6.1 5.4.9 Determination of uncertainty between candidates ubs)

Algorithms for the calculation of intercept a as well as slope b and its variances by means of orthogonal regression are specified in Annex B of [5].

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

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

Uncertainty u_{CR} is calculated for:

- All test sites/comparisons together
- Each test site/comparison separately
- 1 dataset with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: mean values of reference measurement)
- 1 dataset with measured values ≥ 30 µg/m³ for PM_{10} (basis: mean values of reference measurement)

According to the Guide, preconditions for acceptance of the complete dataset are that:

- the slope b differs insignificantly from 1: $|b-1| \le 2 \cdot u(b)$

and that

- the intercept a differs insignificantly from 0: $|a| \le 2 \cdot u(a)$

with u(b) and u(a) being the standard uncertainties of slope and intercept, each calculated as the square root of their variances. If these preconditions are not met, the candidates may be calibrated according to item 9.7 of the guideline (refer to 6.1 5.4.11 Application of correction factors and terms. The calibration shall only be applied to the complete dataset.

[Item 9.5.4] The combined uncertainty of the candidates $w_{c,CM}$ is calculated for each dataset 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 = 30 µg/m³ for $PM_{2.5}$ and at the level of y_i = 50 µg/m³ for PM_{10}.

[Item 9.5.5] The expanded relative uncertainty of the results of the candidates is calculated for each dataset by multiplying $w_{c,CM}$ with a coverage factor k according to the following equation:

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

In practice k=2 for large n is used.

[Item 9.6] The highest resulting uncertainty W_{CM} is compared with the requirements on data quality of ambient air measurements according to EU Standard [8] and assessed. There are two possible results:

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

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 % [8].

7.5 Assessment

The determined uncertainties W_{CM} for PM_{10} for all datasets under consideration are below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter without the application of correction factors. The determined uncertainties W_{CM} for $PM_{2.5}$ for all datasets under consideration with exception of Bornheim, summer are below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter without the application of correction factors. Correction factors shall be applied according to chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK).

Performance criterion met? no

Because of the exceeded uncertainty W_{CM} at the test site Bornheim, summer for $PM_{2.5}$, the significance of the slope for the complete dataset $PM_{2.5}$ and the significance of the slope and the intercept for PM_{10}, correction factors are applied according to chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK).

Table 54 and Table 55 provide an overview of all results from the equivalence test of the Fidas® 200 S for $PM_{2.5}$ and PM_{10}. In the event that a criterion has not been met, the respective cell is marked in red.

Table 54: Overview of equivalence test of Fidas® 200 S for $PM_{2.5}$ (D+UK, PM_ENVIRO_0011)

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.48**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**313**				
Slope b	**1.060**	**significant**			
Uncertainty of b	**0.008**				
Ordinate intercept a	**-0.210**	**not significant**			
Uncertainty of a	**0.144**				
Expanded meas. uncertainty W_{CM}	**14.43**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.60**	**µg/m³**			
Uncertainty between Candidates	**0.85**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**67**				
Slope b	**1.041**				
Uncertainty of b	**0.021**				
Ordinate intercept a	**0.300**				
Uncertainty of a	**0.668**				
Expanded meas. uncertainty W_{CM}	**16.63**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.51**	**µg/m³**			
Uncertainty between Candidates	**0.32**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**246**				
Slope b	**1.133**				
Uncertainty of b	**0.024**				
Ordinate intercept a	**-0.866**				
Uncertainty of a	**0.237**				
Expanded meas. uncertainty W_{CM}	**22.55**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne, Summer					
Uncertainty between Reference	0.66	µg/m³			
Uncertainty between Candidates	0.12	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	81			82	
Slope b	1.119			1.116	
Uncertainty of b	0.034			0.035	
Ordinate intercept a	-0.925			-0.885	
Uncertainty of a	0.363			0.378	
Expanded meas. uncertainty W_{CM}	20.11	%		20.13	%
Cologne, Winter					
Uncertainty between Reference	0.54	µg/m³			
Uncertainty between Candidates	0.55	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	51			50	
Slope b	1.051			1.014	
Uncertainty of b	0.014			0.014	
Ordinate intercept a	0.691			0.679	
Uncertainty of a	0.313			0.326	
Expanded meas. uncertainty W_{CM}	17.05	%		11.42	%
Bonn					
Uncertainty between Reference	0.62	µg/m³			
Uncertainty between Candidates	0.70	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	50			50	
Slope b	1.114			1.070	
Uncertainty of b	0.025			0.027	
Ordinate intercept a	-0.783			-0.519	
Uncertainty of a	0.571			0.619	
Expanded meas. uncertainty W_{CM}	21.21	%		16.63	%
Bornheim					
Uncertainty between Reference	0.42	µg/m³			
Uncertainty between Candidates	0.50	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	45			45	
Slope b	1.214			1.186	
Uncertainty of b	0.054			0.054	
Ordinate intercept a	-1.487			-1.606	
Uncertainty of a	0.644			0.643	
Expanded meas. uncertainty W_{CM}	35.02	%		29.11	%
Teddington, Winter					
Uncertainty between Reference	0.42	µg/m³			
Uncertainty between Candidates	0.55	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	44			44	
Slope b	1.022			1.022	
Uncertainty of b	0.012			0.012	
Ordinate intercept a	-0.007			-0.154	
Uncertainty of a	0.237			0.220	
Expanded meas. uncertainty W_{CM}	7.71	%		6.65	%
Teddington, Summer					
Uncertainty between Reference	0.25	µg/m³			
Uncertainty between Candidates	0.37	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	44			44	
Slope b	0.991			0.982	
Uncertainty of b	0.021			0.021	
Ordinate intercept a	0.483			0.418	
Uncertainty of a	0.246			0.243	
Expanded meas. uncertainty W_{CM}	5.89	%		5.68	%
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	0.60	µg/m³			
Uncertainty between Candidates	0.85	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	67			67	
Slope b	1.060			1.024	
Uncertainty of b	0.022			0.022	
Ordinate intercept a	0.117			0.443	
Uncertainty of a	0.681			0.68	
Expanded meas. uncertainty W_{CM}	18.51	%		15.51	%
All comparisons, <18 µg/m³					
Uncertainty between Reference	0.51	µg/m³			
Uncertainty between Candidates	0.32	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	248			248	
Slope b	1.152			1.119	
Uncertainty of b	0.024			0.024	
Ordinate intercept a	-0.929			-0.827	
Uncertainty of a	0.241			0.239	
Expanded meas. uncertainty W_{CM}	25.80	%		20.34	%
All comparisons					
Uncertainty between Reference	0.53	µg/m³			
Uncertainty between Candidates	0.48	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	315			315	
Slope b	1.075	significant		1.045	significant
Uncertainty of b	0.009			0.009	
Ordinate intercept a	-0.247	not significant		-0.154	not significant
Uncertainty of a	0.146			0.146	
Expanded meas. uncertainty W_{CM}	16.71	%		12.75	%

The results of the check of the five criteria given in chapter 6.1 Methodology of the equivalence check (modules 5.4.9 – 5.4.11) are as follows:

Criterion 1: More than 20 % of the data are greater than 17 µg/m³.

Criterion 2: The uncertainty between the candidates is less than 2.5 µg/m³.

Criterion 3: The uncertainty between the reference devices is less than 2.0 µg/m³.

Criterion 4: All expanded uncertainties except for the test site Bornheim, summer, are below 25 %.

Criterion 5: For both candidates, the slope is significantly greater than the permissible value for the evaluation of the complete dataset.

Other: For both candidates, the total slope is 1.060 and the intercept is -0.210 at an expanded overall uncertainty of 14.43 % for the complete dataset.

Table 55: Overview of equivalence test of Fidas® 200 S for PM_{10} (D+UK, PM_ENVIRO_0011)

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**316**				
Slope b	**1.037**	significant			
Uncertainty of b	**0.009**				
Ordinate intercept a	**-1.390**	significant			
Uncertainty of a	**0.216**				
Expanded measured uncertainty WCM	**7.54**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.68**	**µg/m³**			
Uncertainty between Candidates	**1.19**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**44**				
Slope b	**0.991**				
Uncertainty of b	**0.035**				
Ordinate intercept a	**0.704**				
Uncertainty of a	**1.545**				
Expanded measured uncertainty WCM	**10.92**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.56**	**µg/m³**			
Uncertainty between Candidates	**0.57**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**272**				
Slope b	**1.045**				
Uncertainty of b	**0.018**				
Ordinate intercept a	**-1.543**				
Uncertainty of a	**0.311**				
Expanded measured uncertainty WCM	**7.08**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne, Summer					
Uncertainty between Reference	0.80	µg/m³			
Uncertainty between Candidates	0.27	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	81			82	
Slope b	1.045			1.028	
Uncertainty of b	0.028			0.028	
Ordinate intercept a	-1.637			-1.524	
Uncertainty of a	0.490			0.489	
Expanded measured uncertainty W_{CM}	6.98	%		6.56	%
Cologne, Winter					
Uncertainty between Reference	0.53	µg/m³			
Uncertainty between Candidates	0.67	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	51			50	
Slope b	1.064			1.027	
Uncertainty of b	0.015			0.015	
Ordinate intercept a	-1.260			-1.284	
Uncertainty of a	0.399			0.398	
Expanded measured uncertainty W_{CM}	9.66	%		5.53	%
Bonn					
Uncertainty between Reference	0.38	µg/m³			
Uncertainty between Candidates	0.90	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	50			50	
Slope b	1.043			1.004	
Uncertainty of b	0.027			0.029	
Ordinate intercept a	-0.082			0.061	
Uncertainty of a	0.821			0.865	
Expanded measured uncertainty W_{CM}	11.98	%		9.29	%
Bornheim					
Uncertainty between Reference	0.54	µg/m³			
Uncertainty between Candidates	0.87	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	47			47	
Slope b	1.128			1.083	
Uncertainty of b	0.040			0.039	
Ordinate intercept a	-1.986			-2.169	
Uncertainty of a	0.733			0.720	
Expanded measured uncertainty W_{CM}	19.05	%		10.63	%
Teddington, Winter					
Uncertainty between Reference	0.48	µg/m³			
Uncertainty between Candidates	0.76	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	44			44	
Slope b	0.999			0.969	
Uncertainty of b	0.017			0.016	
Ordinate intercept a	-1.598			-1.580	
Uncertainty of a	0.441			0.420	
Expanded measured uncertainty W_{CM}	9.16	%		13.91	%
Teddington, Summer					
Uncertainty between Reference	0.46	µg/m³			
Uncertainty between Candidates	0.56	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	45			45	
Slope b	0.946			0.944	
Uncertainty of b	0.029			0.031	
Ordinate intercept a	-0.090			-0.502	
Uncertainty of a	0.474			0.507	
Expanded measured uncertainty W_{CM}	12.26	%		14.26	%
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	0.68	µg/m³			
Uncertainty between Candidates	1.19	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	44			44	
Slope b	1.021			0.964	
Uncertainty of b	0.036			0.036	
Ordinate intercept a	0.096			1.252	
Uncertainty of a	1.574			1.56	
Expanded measured uncertainty W_{CM}	11.98	%		11.20	%
All comparisons, <30 µg/m³					
Uncertainty between Reference	0.56	µg/m³			
Uncertainty between Candidates	0.57	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	274			274	
Slope b	1.064			1.028	
Uncertainty of b	0.019			0.018	
Ordinate intercept a	-1.597			-1.522	
Uncertainty of a	0.320			0.308	
Expanded measured uncertainty W_{CM}	9.38	%		6.49	%
All comparisons					
Uncertainty between Reference	0.58	µg/m³			
Uncertainty between Candidates	0.67	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	318			318	
Slope b	1.054	significant		1.020	significant
Uncertainty of b	0.010			0.010	
Ordinate intercept a	-1.420	significant		-1.355	significant
Uncertainty of a	0.220			0.216	
Expanded measured uncertainty W_{CM}	9.13	%		7.47	%

The results of the check of the five criteria given in chapter 6.1 Methodology of the equivalence check (modules 5.4.9 – 5.4.11) are as follows:

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

Criterion 2: The uncertainty between the candidates is less than 2.5 µg/m³.

Criterion 3: The uncertainty between the reference devices is less than 2.0 µg/m³.

Criterion 4: All of the expanded uncertainties are below 25 %.

Criterion 5: For both candidates, the slope and the intercept are significantly greater than the permissible value for the evaluation of the complete dataset.

Other: For both candidates, the total slope is 1.037 and the intercept is -1.390 at an expanded overall uncertainty of 7.54 % for the complete dataset.

The January 2010 version of the Guide is ambiguous with respect to which slope and which intercept should be used to correct a candidate should it fail the test of equivalence. After consultation with the convenor (Mr Theo Hafkenscheid) of the EC working group responsible for setting up the Guide, it was decided that the requirements of the November 2005 version of the Guide are still valid, and that the slope and intercept from the orthogonal regression of all the paired data be used. These are stated additionally under “Other” in the above.

The 2006 UK Equivalence Report [10] has highlighted this was a flaw in the mathematics required for equivalence as per the November 2005 version of the Guide as it penalised instruments that were more accurate (Annex E Section 4.2 therein). This same flaw is copied in the January 2010 version. Hence, the Fidas® 200 S measuring system for $PM_{2.5}$ and PM_{10} is indeed being penalised by the mathematics for being accurate. It is proposed that the same pragmatic approach is taken here that was previously undertaken in earlier studies.

Therefore, according to Table 54, the slope has to be corrected for $PM_{2.5}$ due to its determined significance for both candidates and the exceeded measurement uncertainty at the test site Bornheim, summer. For PM_{10}, the slope and the intercept have to be corrected due to their significance according to Table 55.

Nonetheless it should be noted that, even without application of correction factors, the determined uncertainties W_{CM} for PM_{10} are below the specified expanded relative uncertainty W_{dqo} of 25 % for particulate matter for all datasets considered.

For $PM_{2.5}$:

The slope for the complete dataset is 1.060. Thus, an additional evaluation applying the respective calibration factor to the datasets is made in chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK).

For PM_{10}:

The slope for the complete dataset is 1.037. The intercept for the complete data set is -1.390. Thus, an additional evaluation applying the respective calibration factors to the datasets is made in chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK).

The revised January 2010 version of the Guide requires that, in order to monitor the processes in compliance with the guidelines, random checks shall be performed on a number of systems within a measuring network and that the number of measuring sites shall depend on the expanded uncertainty of the system. Either the network operator or the responsible authority of the member state is responsible for the appropriate realisation of the requirement mentioned above. However, TÜV Rheinland recommends that the expanded uncertainty for the complete dataset (here: uncorrected raw data) shall be referred to, i.e. 14.43 % for $PM_{2.5}$, which would require annual checks at 3 sites, and 7.54 %, for PM_{10}, which would require annual checks a 2 sites (Guide [5], Chapter 9.9.2, Table 6). Due to the necessary application of the corresponding calibration factors, this assessment should be made on the basis of the evaluation of the corrected datasets (refer to chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK)).

7.6 Detailed presentation of test results

Table 56 and Table 57 present an overview of the uncertainties between the reference devices u_{ref} obtained in the field tests.

Table 56: Uncertainty between reference devices u_{ref} for $PM_{2.5}$

Reference devices	Test site	No. of values	Uncertainty u_{bs}
No.			µg/m³
1 / 2	Cologne, summer	82	0.66
1 / 2	Cologne, winter	52	0.54
1 / 2	Bonn, winter	50	0.62
1 / 2	Bornheim, summer	47	0.42
1 / 2	Teddington, winter	44	0.42
1 / 2	Teddington, summer	44	0.25
1 / 2	All test sites	319	0.53

Table 57: Uncertainty between reference devices u_{ref} for PM_{10}

Reference devices	Test site	No. of values	Uncertainty u_{bs}
Nr.			µg/m³
1 / 2	Cologne, summer	82	0.80
1 / 2	Cologne, winter	52	0.53
1 / 2	Bonn, winter	50	0.38
1 / 2	Bornheim, summer	49	0.54
1 / 2	Teddington, winter	44	0.48
1 / 2	Teddington, summer	45	0.46
1 / 2	All test sites	322	0.58

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

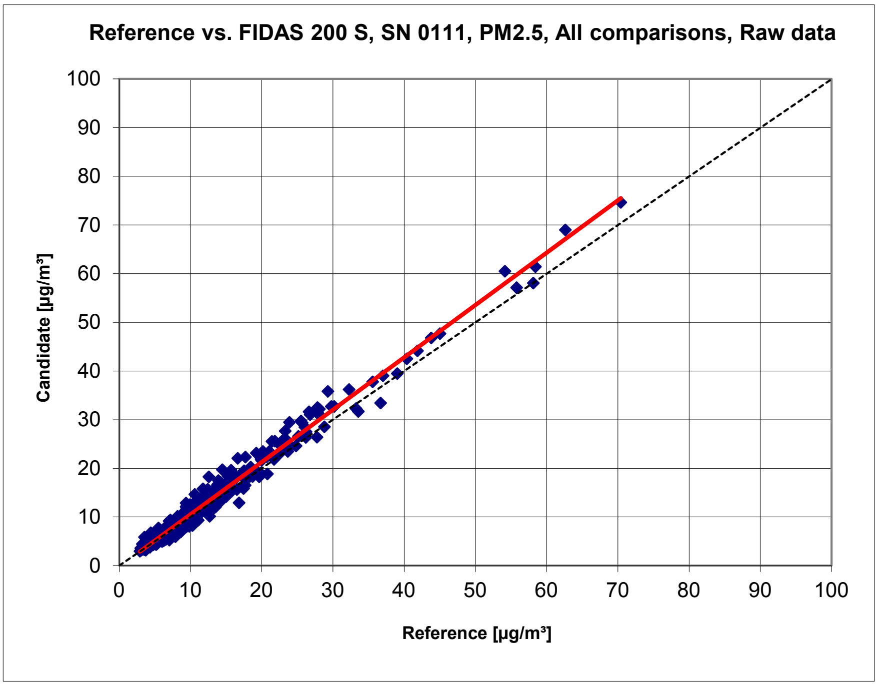


Figure 112: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, all test sites (GER+UK), PM_ENVIRO_0011

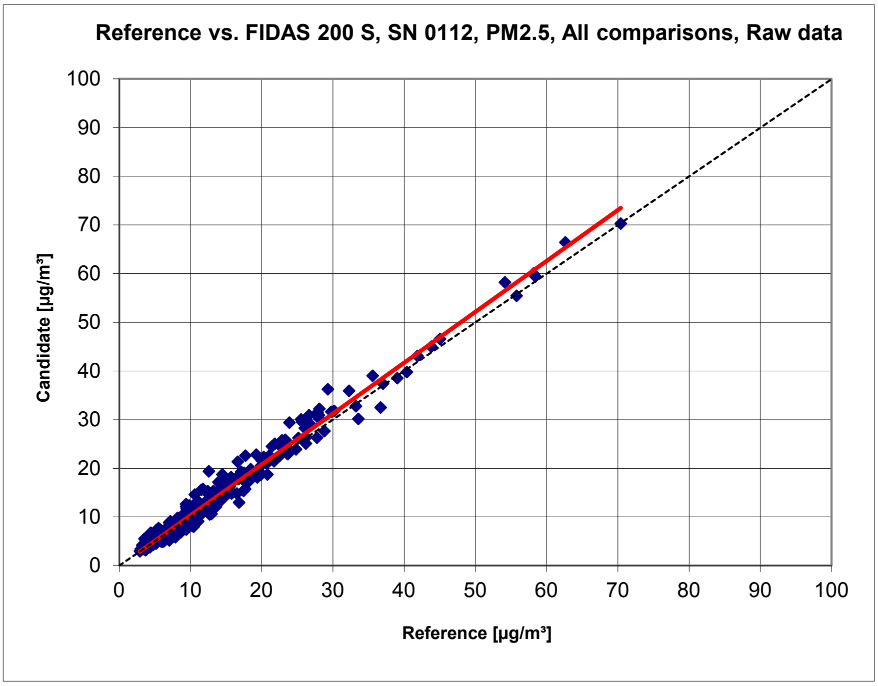


Figure 113: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, all test sites (GER+UK), PM_ENVIRO_0011

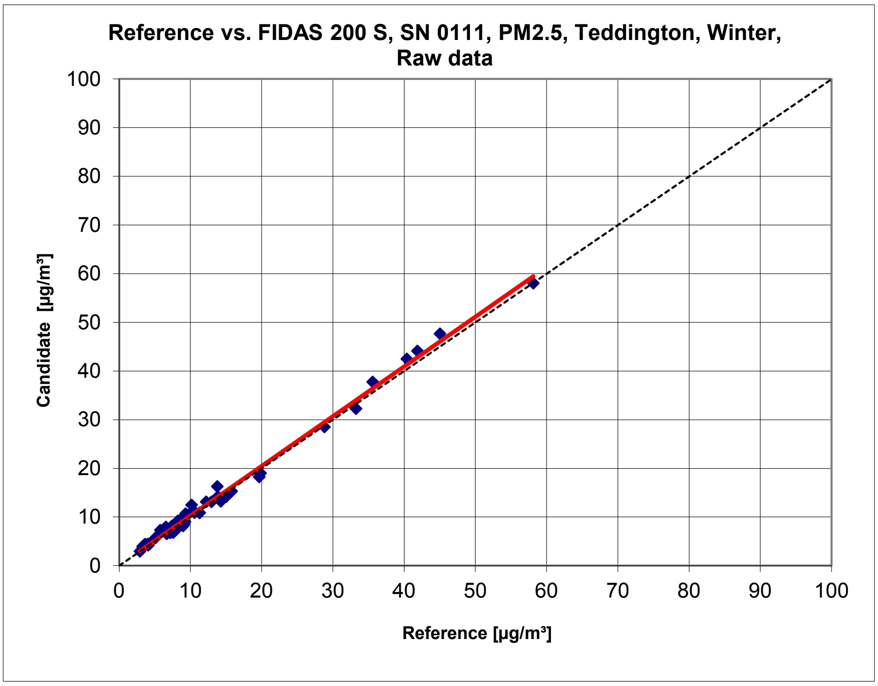


Figure 114: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Teddington, winter, PM_ENVIRO_0011

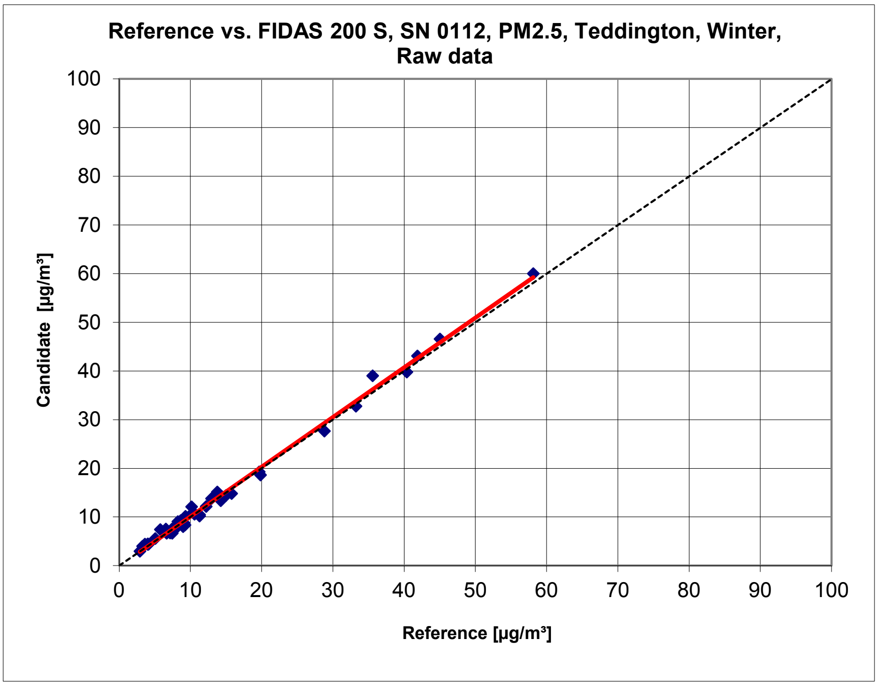


Figure 115: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Teddington, winter, PM_ENVIRO_0011

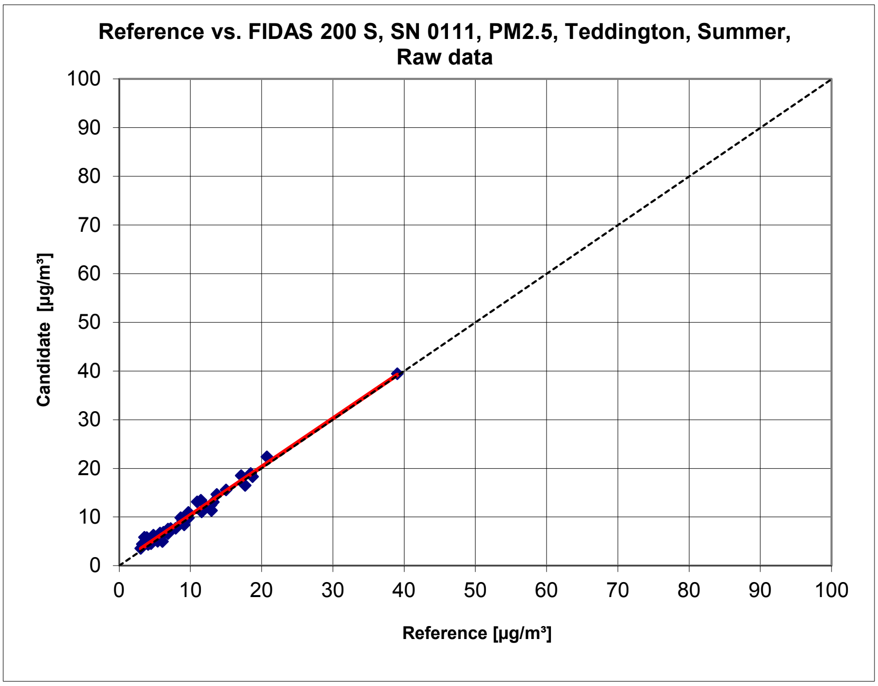


Figure 116: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Teddington, summer, PM_ENVIRO_0011

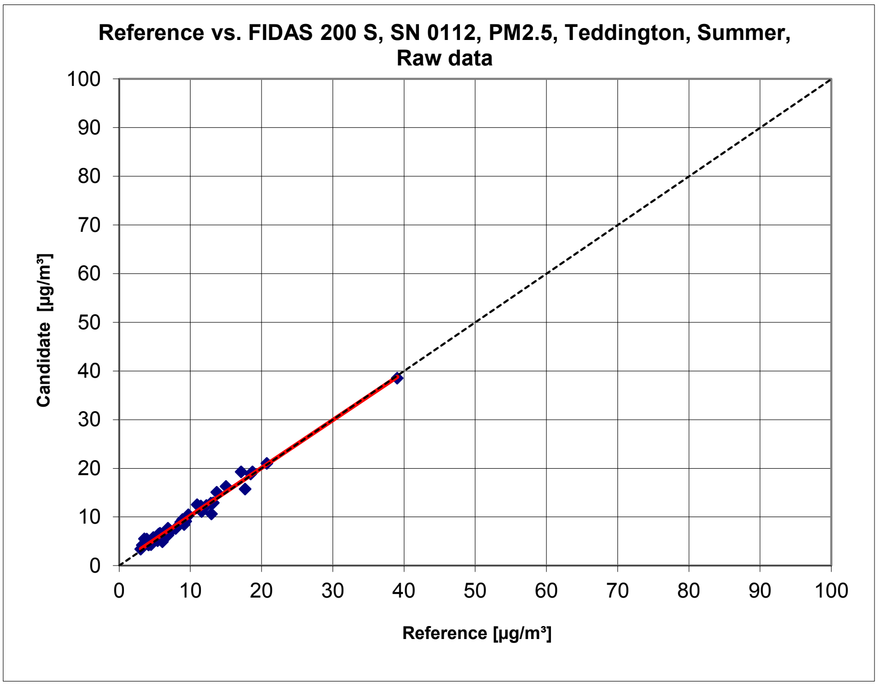


Figure 117: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Teddington, summer, PM_ENVIRO_0011

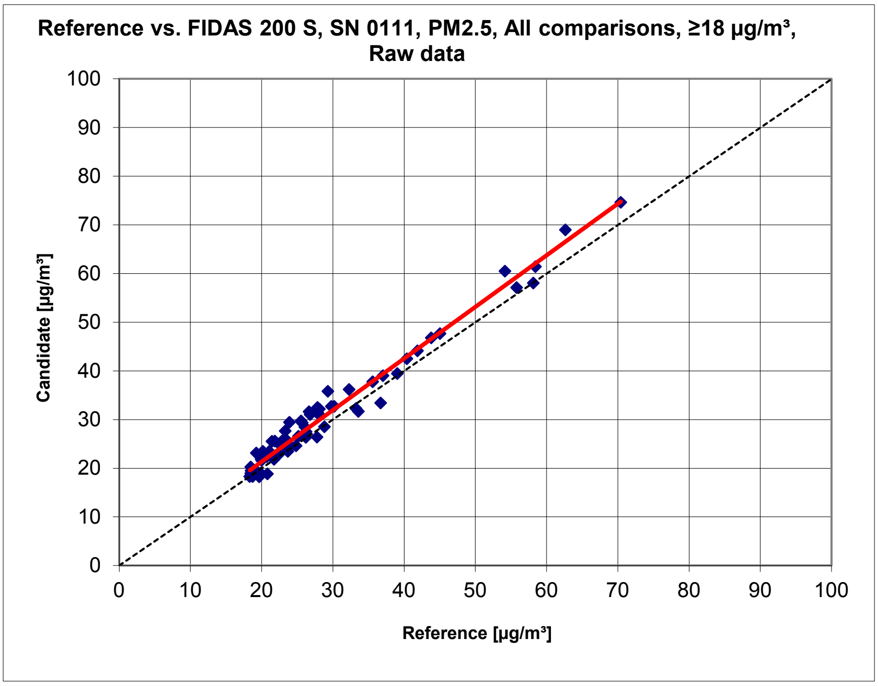


Figure 118: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, values ≥ 18 µg/m³ (GER+UK), PM_ENVIRO_0011

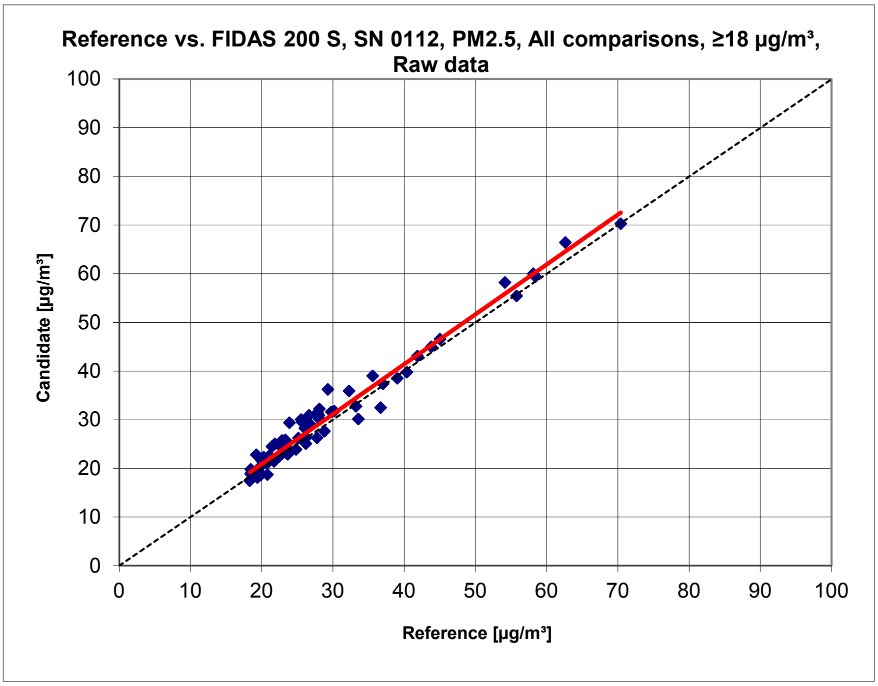


Figure 119: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, values ≥ 18 µg/m³ (GER+UK), PM_ENVIRO_0011

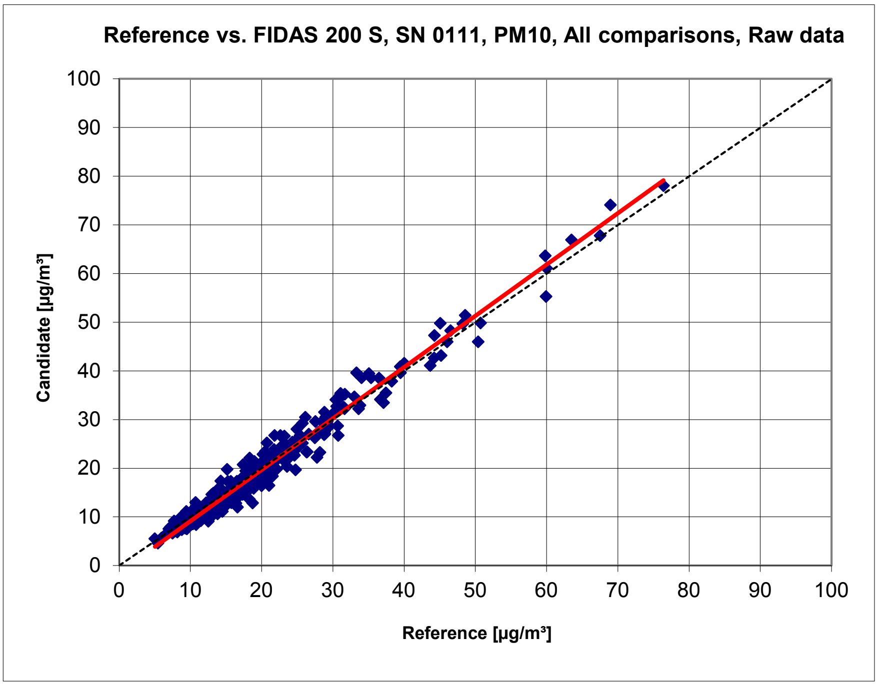


Figure 120: Reference device vs. candidate, SN 0111, measured component PM_{10}, all test sites (GER+UK), PM_ENVIRO_0011

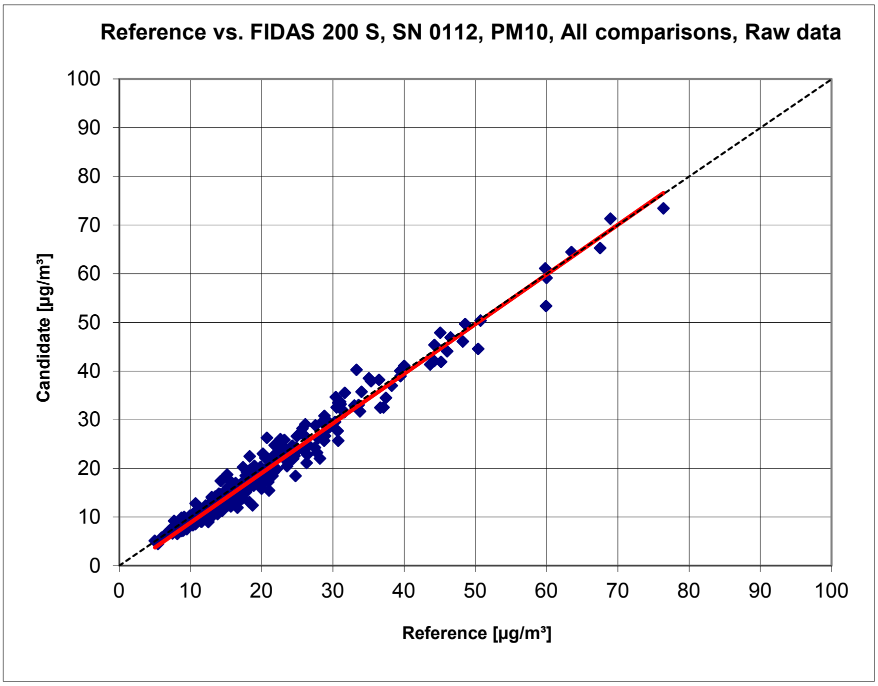


Figure 121: Reference device vs. candidate, SN 0112, measured component PM_{10}, all test sites (GER+UK), PM_ENVIRO_0011

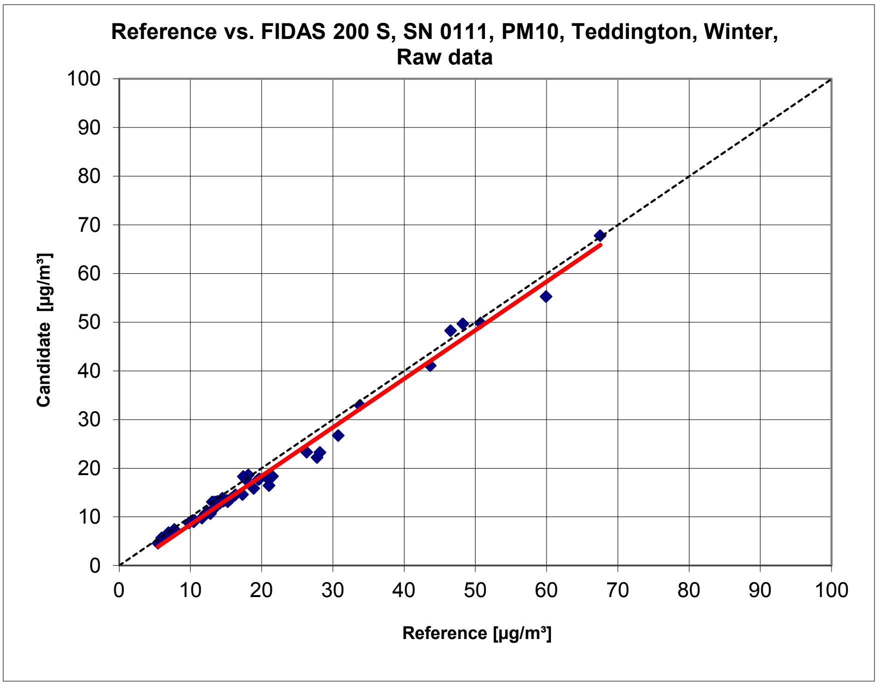


Figure 122: Reference device vs. candidate, SN 0111, measured component PM_{10}, Teddington, winter, PM_ENVIRO_0011

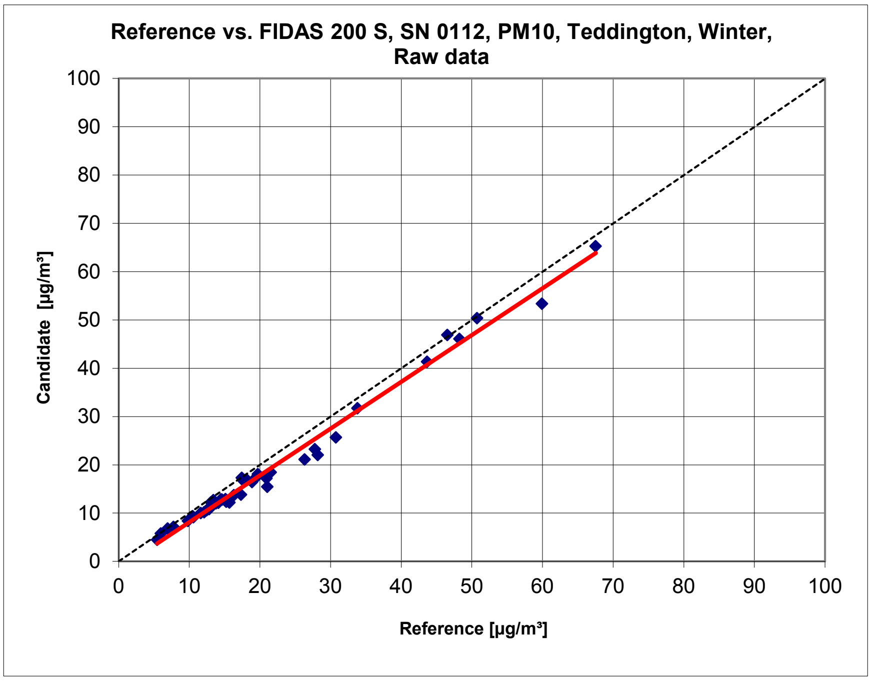


Figure 123: Reference device vs. candidate, SN 0112, measured component PM_{10}, Teddington, winter, PM_ENVIRO_0011

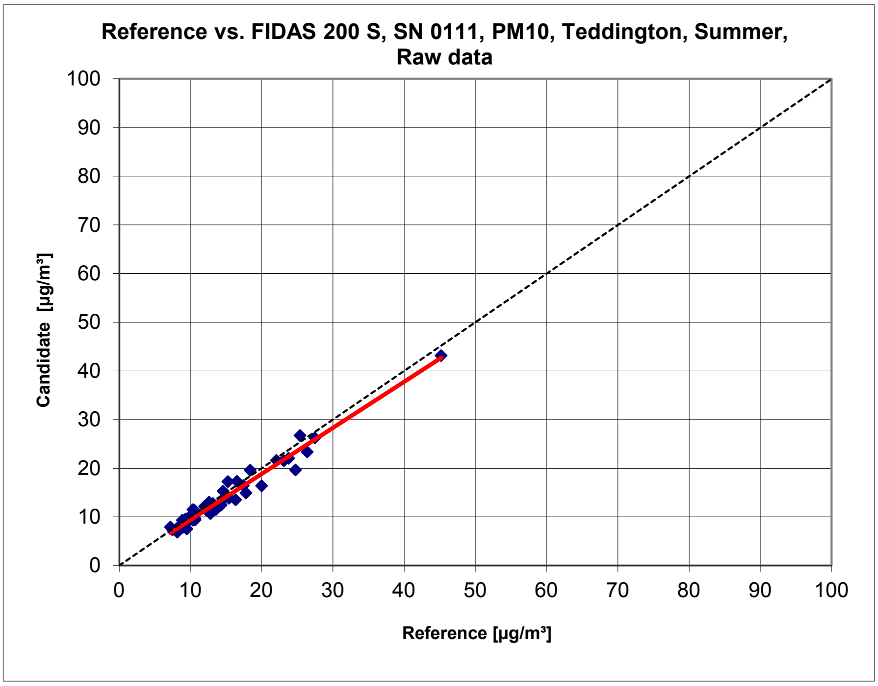


Figure 124: Reference device vs. candidate, SN 0111, measured component PM_{10}, Teddington, summer, PM_ENVIRO_0011

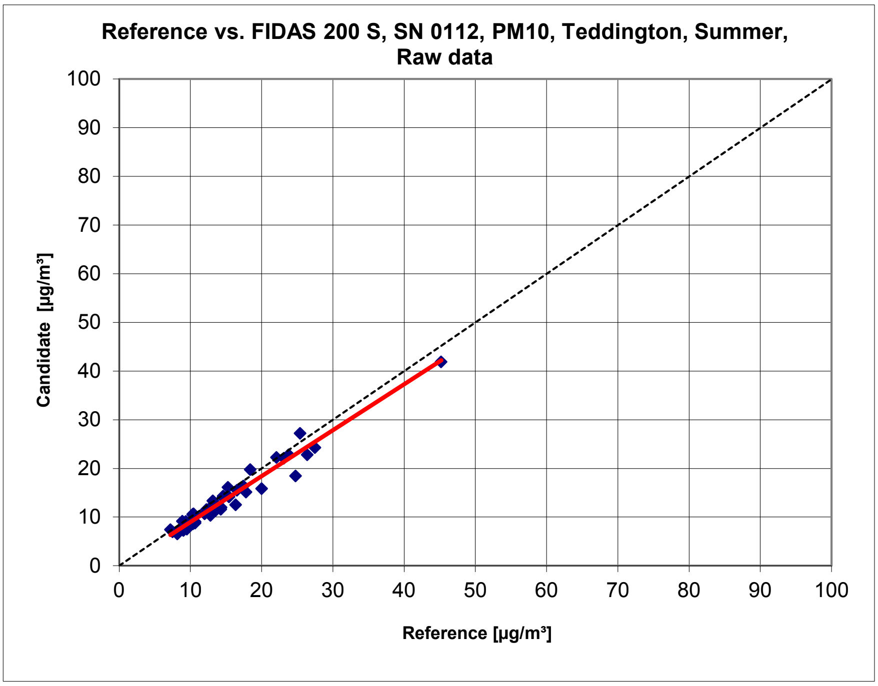


Figure 125: Reference device vs. candidate, SN 0112, measured component PM_{10}, Teddington, summer, PM_ENVIRO_0011

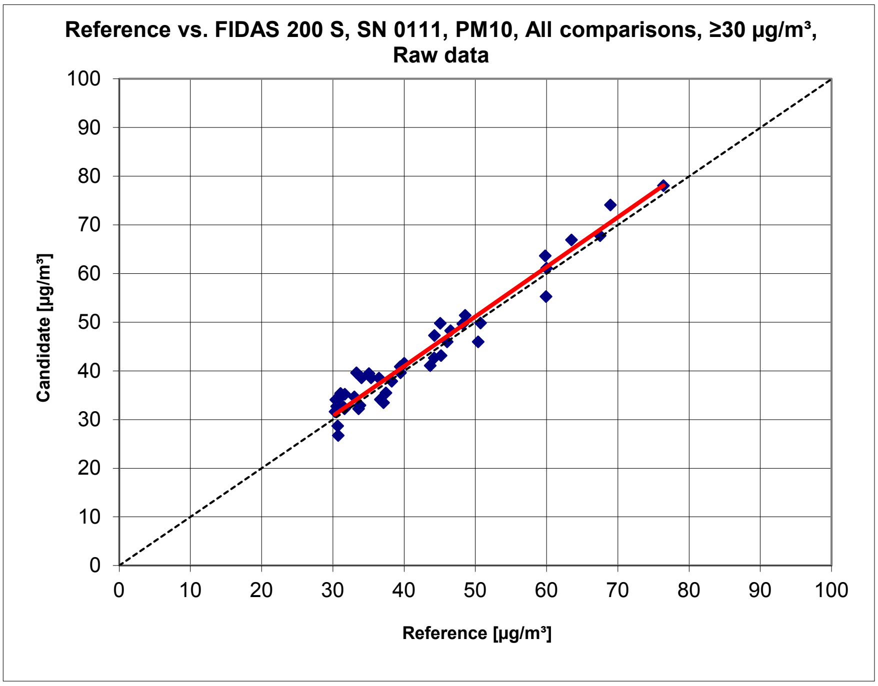


Figure 126: Reference device vs. candidate, SN 0111, measured component PM_{10}, values ≥ 30 µg/m³ (GER+UK), PM_ENVIRO_0011

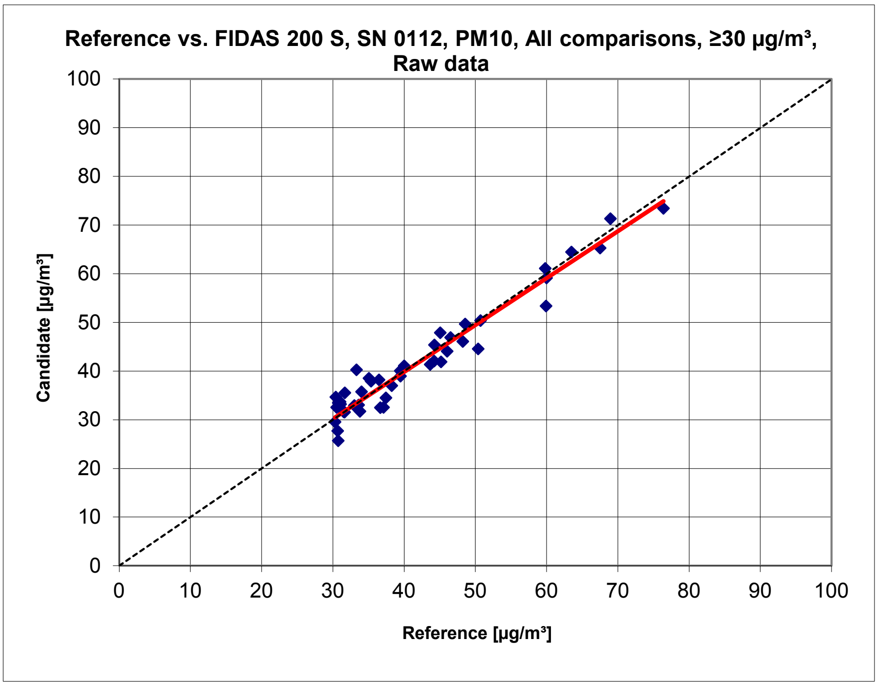


Figure 127: Reference device vs. candidate, SN 0112, measured component PM_{10}, values ≥ 30 µg/m³ (GER+UK), PM_ENVIRO_0011

7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK)

If the maximum expanded uncertainty of the systems under test exceeds the data quality objectives according to Annex B of Standard VDI 4202, Sheet 1 (September 2010) for the test of $PM_{2.5}$ measuring systems, the application of factors and terms is allowed. Values corrected shall meet the requirements of chapter 9.5.3.2ff of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods".

The tests were also carried out for the component PM_{10}.

7.2 Equipment

No equipment is necessary to test this performance criterion.

7.3 Method

Refer to module 5.4.10.

7.4 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 complete dataset. The corrected values shall satisfy the requirements for all datasets 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 [4]. 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 term 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 [4]. 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 [5]. 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 dataset, uncertainty $w_{c,CM,corr}$ is calculated at the daily limit value by taking y_i as 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 $W_{CM,corr}$ is compared and assessed with the requirements on data quality of ambient air measurements according to EU Standard [8]. 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 % [8].

7.5 Assessment

Due to application of the correction factors, the candidates meet the requirements on data quality of ambient air quality measurements for all datasets for $PM_{2.5}$ and PM_{10}. For PM_{10}, the requirements are met even without application of correction factors. The corrections of slope and intercept nevertheless lead to a (slight) improvement of the expanded measurement uncertainties of the complete data set.

Performance criterion met? yes

The evaluation of the complete dataset for $PM_{2.5}$ shows a significant slope and for PM_{10} a significant slope and intercept.

For $PM_{2.5}$:

The slope for the complete dataset is 1.060. The intercept for the complete dataset is -0.210 (refer to Table 54).

For PM_{10}:

The slope for the complete dataset is 1.037. The intercept for the complete dataset -1.390 (refer to Table 55).

For $PM_{2.5}$, a slope correction for the complete data set has been performed and all datasets were then re-evaluated using the corrected values.

For PM_{10}, a slope and a intercept correction for the complete data set has been performed and all datasets were then re-evaluated using the corrected values.

After correction, all datasets fulfil the requirements on data quality and the measurement uncertainties improve significantly for some of the sites.

The January 2010 version of the Guide requires that the systems are tested annually at a number of sites corresponding to the highest expanded uncertainty found during equivalence testing, if the AMS is operated within a network. The corresponding criterion for determining the number of test sites is divided into 5 % steps (Guide [4], chapter 9.9.2, Table 6). It should be noted that the highest expanded uncertainty determined for $PM_{2.5}$ lies in the range of <10 % after correction whereas it has been in the range of 10 % to 15 % before the correction. For PM_{10}, the highest expanded uncertainty determined lies in the range of <10 % before as well as after the correction.

The network operator or the responsible authority of the member state is responsible for the appropriate realisation of the required regular checks in networks mentioned above. However, TÜV Rheinland recommends to use the expanded uncertainty for the complete dataset, i.e. 14.43 % for $PM_{2.5}$: (uncorrected dataset) respectively 9.35 % (dataset after slope correction), which would require an annual test at 3 measurement sites (uncorrected) or 2 measurement sites (corrected); for PM_{10}: 7.54 % (uncorrected dataset) respectively 7.33 % (dataset after slope and intercept correction), which would require an annual test at 2 measurement sites (uncorrected and corrected).

7.6 Detailed presentation of test results

Table 58 and Table 59 present the results of the evaluations of the equivalence test after application of the correction factors on the complete dataset.

Table 58: Summary of the results of the equivalence test, SN 0111 & SN 0112, measured component $PM_{2.5}$ after correction of slope, GER+UK, PM_ENVIRO_0011

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	30	µg/m³
Status of measured values	Slope corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.45**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**313**				
Slope b	**0.999**	**not significant**			
Uncertainty of b	**0.008**				
Ordinate intercept a	**-0.190**	**not significant**			
Uncertainty of a	**0.136**				
Expanded meas. uncertainty W_{CM}	**9.35**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.60**	**µg/m³**			
Uncertainty between Candidates	**0.80**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**67**				
Slope b	**0.981**				
Uncertainty of b	**0.020**				
Ordinate intercept a	**0.306**				
Uncertainty of a	**0.630**				
Expanded meas. uncertainty W_{CM}	**12.51**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.51**	**µg/m³**			
Uncertainty between Candidates	**0.31**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**246**				
Slope b	**1.065**				
Uncertainty of b	**0.023**				
Ordinate intercept a	**-0.782**				
Uncertainty of a	**0.224**				
Expanded meas. uncertainty W_{CM}	**11.34**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	30	µg/m³
Status of measured values	Slope corrected		Allowed uncertainty	25	%
Cologne, Summer					
Uncertainty between Reference	0.66	µg/m³			
Uncertainty between Candidates	0.11	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	81			82	
Slope b	1.053			1.050	
Uncertainty of b	0.032			0.033	
Ordinate intercept a	-0.850			-0.810	
Uncertainty of a	0.342			0.357	
Expanded meas. uncertainty W_{CM}	10.46	%		10.77	%
Cologne, Winter					
Uncertainty between Reference	0.54	µg/m³			
Uncertainty between Candidates	0.52	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	51			50	
Slope b	0.991			0.956	
Uncertainty of b	0.013			0.013	
Ordinate intercept a	0.656			0.645	
Uncertainty of a	0.296			0.307	
Expanded meas. uncertainty W_{CM}	8.50	%		9.43	%
Bonn					
Uncertainty between Reference	0.62	µg/m³			
Uncertainty between Candidates	0.66	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	50			50	
Slope b	1.050			1.008	
Uncertainty of b	0.024			0.026	
Ordinate intercept a	-0.723			-0.471	
Uncertainty of a	0.539			0.584	
Expanded meas. uncertainty W_{CM}	12.32	%		12.33	%
Bornheim					
Uncertainty between Reference	0.42	µg/m³			
Uncertainty between Candidates	0.47	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	45			45	
Slope b	1.142			1.115	
Uncertainty of b	0.051			0.050	
Ordinate intercept a	-1.370			-1.482	
Uncertainty of a	0.607			0.607	
Expanded meas. uncertainty W_{CM}	22.40	%		17.49	%
Teddington, Winter					
Uncertainty between Reference	0.42	µg/m³			
Uncertainty between Candidates	0.52	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	44			44	
Slope b	0.964			0.963	
Uncertainty of b	0.012			0.011	
Ordinate intercept a	-0.004			-0.143	
Uncertainty of a	0.223			0.208	
Expanded meas. uncertainty W_{CM}	9.46	%		10.01	%
Teddington, Summer					
Uncertainty between Reference	0.25	µg/m³			
Uncertainty between Candidates	0.35	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	44			44	
Slope b	0.934			0.926	
Uncertainty of b	0.020			0.020	
Ordinate intercept a	0.461			0.399	
Uncertainty of a	0.232			0.229	
Expanded meas. uncertainty W_{CM}	11.50	%		13.40	%
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	0.60	µg/m³			
Uncertainty between Candidates	0.80	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	67			67	
Slope b	0.999			0.965	
Uncertainty of b	0.020			0.021	
Ordinate intercept a	0.134			0.443	
Uncertainty of a	0.642			0.65	
Expanded meas. uncertainty W_{CM}	12.67	%		13.39	%
All comparisons, <18 µg/m³					
Uncertainty between Reference	0.51	µg/m³			
Uncertainty between Candidates	0.31	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	248			248	
Slope b	1.083			1.052	
Uncertainty of b	0.023			0.023	
Ordinate intercept a	-0.841			-0.744	
Uncertainty of a	0.227			0.226	
Expanded meas. uncertainty W_{CM}	13.84	%		9.97	%
All comparisons					
Uncertainty between Reference	0.53	µg/m³			
Uncertainty between Candidates	0.45	µg/m³			
	SN 0111			**SN 0112**	
Number of data pairs	315			315	
Slope b	1.014	not significant		0.985	not significant
Uncertainty of b	0.008			0.008	
Ordinate intercept a	-0.225	not significant		-0.137	not significant
Uncertainty of a	0.137			0.137	
Expanded meas. uncertainty W_{CM}	9.50	%		10.17	%

Table 59: Summary of the results of the equivalence test, SN 0111 & SN 0112, measured component PM_{10} after correction of slope & intercept, GER+UK, PM_ENVIRO_0011

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Limit value	50	µg/m³
Status of measured values	Slope & offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.65**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**316**				
Slope b	**1.000**	**not significant**			
Uncertainty of b	**0.009**				
Ordinate intercept a	**0.010**	**not significant**			
Uncertainty of a	**0.208**				
Expanded measured uncertainty WCM	**7.33**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.68**	**µg/m³**			
Uncertainty between Candidates	**1.15**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**44**				
Slope b	**0.955**				
Uncertainty of b	**0.034**				
Ordinate intercept a	**2.060**				
Uncertainty of a	**1.490**				
Expanded measured uncertainty WCM	**10.68**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.56**	**µg/m³**			
Uncertainty between Candidates	**0.55**	**µg/m³**			
	SN 0111 & SN 0112				
Number of data pairs	**272**				
Slope b	**1.006**				
Uncertainty of b	**0.018**				
Ordinate intercept a	**-0.122**				
Uncertainty of a	**0.300**				
Expanded measured uncertainty WCM	**6.63**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010

Candidate	FIDAS 200 S	SN	SN 0111 & SN 0112	
		Limit value	50	µg/m³
Status of measured values	Slope & offset corrected	Allowed uncertainty	25	%

	SN 0111		SN 0112	
Cologne, Summer				
Uncertainty between Reference	0.80	µg/m³		
Uncertainty between Candidates	0.26	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	81		82	
Slope b	1.007		0.990	
Uncertainty of b	0.027		0.027	
Ordinate intercept a	-0.221		-0.112	
Uncertainty of a	0.473		0.471	
Expanded measured uncertainty W_{CM}	6.59	%	7.00	%
Cologne, Winter				
Uncertainty between Reference	0.53	µg/m³		
Uncertainty between Candidates	0.64	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	51		50	
Slope b	1.026		0.990	
Uncertainty of b	0.014		0.014	
Ordinate intercept a	0.130		0.107	
Uncertainty of a	0.385		0.384	
Expanded measured uncertainty W_{CM}	8.19	%	5.89	%
Bonn				
Uncertainty between Reference	0.38	µg/m³		
Uncertainty between Candidates	0.87	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	50		50	
Slope b	1.005		0.968	
Uncertainty of b	0.026		0.028	
Ordinate intercept a	1.279		1.419	
Uncertainty of a	0.792		0.834	
Expanded measured uncertainty W_{CM}	10.60	%	9.15	%
Bornheim				
Uncertainty between Reference	0.54	µg/m³		
Uncertainty between Candidates	0.84	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	47		47	
Slope b	1.086		1.043	
Uncertainty of b	0.038		0.038	
Ordinate intercept a	-0.555		-0.731	
Uncertainty of a	0.707		0.694	
Expanded measured uncertainty W_{CM}	16.74	%	9.15	%
Teddington, Winter				
Uncertainty between Reference	0.48	µg/m³		
Uncertainty between Candidates	0.73	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	44		44	
Slope b	0.963		0.934	
Uncertainty of b	0.017		0.016	
Ordinate intercept a	-0.195		-0.179	
Uncertainty of a	0.426		0.405	
Expanded measured uncertainty W_{CM}	10.41	%	15.18	%
Teddington, Summer				
Uncertainty between Reference	0.46	µg/m³		
Uncertainty between Candidates	0.54	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	45		45	
Slope b	0.912		0.910	
Uncertainty of b	0.028		0.029	
Ordinate intercept a	1.264		0.868	
Uncertainty of a	0.457		0.489	
Expanded measured uncertainty W_{CM}	13.68	%	15.62	%
All comparisons, ≥30 µg/m³				
Uncertainty between Reference	0.68	µg/m³		
Uncertainty between Candidates	1.15	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	44		44	
Slope b	0.983		0.928	
Uncertainty of b	0.035		0.034	
Ordinate intercept a	1.474		2.590	
Uncertainty of a	1.518		1.50	
Expanded measured uncertainty W_{CM}	11.17	%	11.47	%
All comparisons, <30 µg/m³				
Uncertainty between Reference	0.56	µg/m³		
Uncertainty between Candidates	0.55	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	274		274	
Slope b	1.025		0.990	
Uncertainty of b	0.018		0.017	
Ordinate intercept a	-0.172		-0.102	
Uncertainty of a	0.308		0.297	
Expanded measured uncertainty W_{CM}	8.05	%	6.99	%
All comparisons				
Uncertainty between Reference	0.58	µg/m³		
Uncertainty between Candidates	0.65	µg/m³		
	SN 0111		**SN 0112**	
Number of data pairs	318		318	
Slope b	1.016	not significant	0.983	not significant
Uncertainty of b	0.009		0.009	
Ordinate intercept a	-0.019	not significant	0.043	not significant
Uncertainty of a	0.212		0.209	
Expanded measured uncertainty W_{CM}	8.16	%	8.01	%

8. Description of instrument modifications based on the statement of 27 September 2014

8.1 Qualification of the indoor version Fidas® 200

The measuring system Fidas® 200 S is designed for outdoor installation. This means, that the Fidas® control unit (incl. the aerosol sensor) is installed in a weatherproof cabinet (IP65, with heating and ventilation).

In order to increase the application range of the measuring system, an indoor version with the designation Fidas® 200 shall be approved, which can be installed directly in measuring stations / cabinets. For this instrument version, the weatherproof cabinet is obsolete - apart from that the measuring system is identical in construction with the version Fidas® 200 S.

In order to quantify possible influences of ambient temperature on the indoor version Fidas® 200, a new climate chamber test has been carried out with two complete measuring systems in the range of +5 °C to +40 °C. All test results fulfill the respective minimum requirements without problems. Based on the available documentation (Statement of TÜV Rheinland of 27 September 2014), the publication of the issue (Approval of indoor version Fidas® 200 as an additional instrument version) has been recommended during the 35th expert meeting “Test reports”. The official announcement in the Federal Gazette “Bundesanzeiger” has happened with announcement of Federal Environment Agency UBA of 25 February 2015 (BAnz AT 02.04.2015 B15, chapter IV, 14th notification).

Technical documentation on the Qualification of the indoor version Fidas® 200

The measuring system Fidas® 200 S is designed for outdoor installation. This means, that the Fidas® control unit (incl. the aerosol sensor) is installed in a weatherproof cabinet (IP65, with heating and ventilation).

In order to increase the application range of the measuring system, an indoor version with the designation Fidas® 200 shall be approved, which can be installed directly in measuring stations / cabinets. For this instrument version, the weatherproof cabinet is obsolete - apart from that the measuring system is identical in construction with the version Fidas® 200 S.

In order to quantify possible influences of ambient temperature on the indoor version Fidas® 200, a new climate chamber test has been carried out with two complete measuring systems in the range of +5 °C to +40 °C.

In order to test the dependence of zero point and measured values on the surrounding temperature, the complete measuring systems were operated within a climatic chamber (refer to Figure 128).

Figure 128: Candidates Fidas® 200 in climate chamber

For the zero point test particle free sampling air was applied to both measuring systems SN 5048 and SN 5049 by means of zero filters installed at the instrument inlets.

The reference point test comprised a check and evaluation of the peak position upon application of CalDust 1100 in order to test the stability of the sensitivity of both candidates SN 5048 and SN 5049.

The sensitivity test was carried out with monodisperse dust (CalDust 1100). When applying this calibration dust, the size distribution is expected to peak in channel 130 (this corresponds with a particle size of 0.93 µm). In order to make the quantification of deviations in the classification possible, the datasets obtained in the field test were used to calculate the effects of a peak shift of max. ±3 channels on a measured PM value. For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for PM_{10} were defined. The concentration value to be expected depending on the peak shift was then calculated according to the matrix in chapter 4.2 Laboratory test.

The ambient temperature within the climatic chamber was altered in the sequence

20 °C – 5 °C – 20 °C – 40 °C – 20 °C.

The measured values at zero point (3 x 24 h per temperature level) and the measured values at reference point (3 x 24 h per temperature level) were recorded after an equilibration period of 24 h per temperature level.

The evaluation of the tests has been carried out as follows:

Zero point:

The measured concentration values obtained in the individual 24-hour measurements were collected and evaluated. The absolute deviation in µg/m³ per temperature level in relation to the default temperature of 20 °C is considered.

Reference value: B_0 = 2 µg/m³

Looking at the values that were output by the AMS, the maximum dependence of ambient temperature in the range of +5 °C to +40 °C at zero was 5.5 x 10^{-5} µg/m³ for $PM_{2.5}$ and 5.7 x 10^{-5} µg/m³ for PM_{10}

Performance criterion met? yes

Reference point:

The measured value's change in percentage for each temperature level in relation to the initial temperature of 20 °C is checked.

At the reference point, no deviations > -2.2 % for $PM_{2,5}$ rspectively > -2.2 % for PM_{10} related to the base value at 20 °C could be determined for an ambient temperature in the range of +5 °C to +40 °C.

Performance criterion met? yes

Thus the indoor version Fidas® 200 fulfills the minimum requirements in the relevant ambient temperature in the range of +5 °C to +40 °C.

Detailed presentation of test results:

Table 60: Dependence of zero point on ambient temperature, deviations in µg/m³, mean value of three measurements, PM_{10}, SN 5048 & SN 5049

Ambient temperature		Deviation	
Start temperature	End temperature	SN 5048	SN 5049
°C	°C	µg/m³	µg/m³
20	5	5.7E-05	7.9E-07
5	20	4.2E-05	0.0E+00
20	40	-9.8E-06	0.0E+00
40	20	-7.5E-06	0.0E+00

Table 61: Dependence of zero point on ambient temperature, deviations in µg/m³, mean value of three measurements, $PM_{2,5}$, SN 5048 & SN 5049

Ambient temperature		Deviation	
Start temperature	End temperature	SN 5048	SN 5049
°C	°C	µg/m³	µg/m³
20	5	5.5E-05	7.9E-07
5	20	4.2E-05	0.0E+00
20	40	-9.8E-06	0.0E+00
40	20	-7.5E-06	0.0E+00

Table 62: Dependence of sensitivity (CalDust 1100) on ambient temperature, deviation in %, mean value of three measurements, PM_{10}, SN 5048 & SN 5049

Ambient temperature		Deviation	
Start temperature	End temperature	SN 5048	SN 5049
°C	°C	[%]	[%]
20	5	-2.2	-1.9
5	20	-0.9	-0.5
20	40	1.0	0.6
40	20	-0.1	-0.5

Table 63: Dependence of sensitivity (CalDust 1100) on ambient temperature, deviation in %, mean value of three measurements, $PM_{2,5}$, SN 5048 & SN 5049

Ambient temperature		Deviation	
Start temperature	End temperature	SN 5048	SN 5049
°C	°C	[%]	[%]
20	5	-2.2	-1.9
5	20	-0.9	-0.5
20	40	1.1	0.7
40	20	-0.1	-0.5

8.2 Qualification of hardware modifications „new LED“ and „additional digital output“

Since the initial certification, the following noteworthy modifications have been applied to the measuring system Fidas® 200 respectively Fidas® 200 S:

Modification #1 (Type 0):

An additional port for a digital signal (digital out, e.g. for threshold monitoring) is added to the rear side of the instrument.

The modification has been correctly classified as a Type 0 – modification and thus has got no impact on the measuring instrument. The modification is depicted in the following technical documentation.

Modification #2 (Type 1):

Due to discontinuation of the currently implemented LED in the Fidas-sensor, a respective new follow-up LED must be applied in the measuring instrument. The new LED of the company Osram of the type Ostar Stage Art.-Nr. LE ATB S2W is hereby the official follow-up LED for the currently implemented LED of the company Osram of the type Ostar Projektion Art.-Nr. LE B H3W. Regarding the light spectrum (dominant wave length), both LEDs are almost identical.

As the modification could potentially have an impact on the performance of the measuring instrument, the modification has been classified as a Type 1- modification. The company Palas has carried out extensive tests for the qualification of the new LED and it could be confirmed, that the application of the new LED has no impact on the performance of the measuring system. The performed investigations and evaluations of the data have been examined in detail during the 2014 surveillance audit and are described extensively in the following technical documentation.

Based on the available documentation and test results, no significant influence on the measuring system is to expect.

Based on the available documentation (Statement of TÜV Rheinland of 27 September 2014), the publication of the issue (Approval of new LED and additional digital output) has been recommended during the 35th expert meeting “Test reports”. The official announcement in the Federal Gazette “Bundesanzeiger” has happened with announcement of Federal Environment Agency UBA of 25 February 2015 (BAnz AT 02.04.2015 B15, chapter IV, 14th notification).

Technical documentation for depiction of the additional digital output on the rear side of the instrument

The measuring system receives an additional port for a digital output signal on the rear side of the instrument (refer to Figure 129). This modification has no impact on the measuring system.

Figure 129: Rear side of instrument with additional port (marked in yellow)

Technical documentation for the qualification of the LED in the Fidas® – Sensor

Due to discontinuation of the currently implemented LED in the Fidas-sensor, a respective new follow-up LED must be applied in the measuring instrument. The new LED of the company Osram of the type Ostar Stage Art.-Nr. LE ATB S2W is hereby the official follow-up LED for the currently implemented LED of the company Osram of the type Ostar Projektion Art.-Nr. LE B H3W.

When choosing for the LED, special emphasis was put on as identical as possible optical data.

The currently implemented LED of the company Osram of the type Ostar Projektion Art.-Nr. LE B H3W operates in the relevant range with a dominant wavelength in a range between 456 nm and 469 nm (typical wavelength 464 nm).

The new LED of the company Osram of the type Ostar Stage Art.-Nr. LE ATB S2W operates in the relevant range with a dominant wavelength in a range between 462 nm and 466 nm

In order to ascertain, that the switch of the LED has got no significant influence on the measuring instrument, the company Palas has performed extensive tests for the following points:

a) Dependency on temperature – Comparison LED, old vs. LED, new
b) Comparison of PM measured values of instruments with new LED compared to the reference device SN 0108 (with old LED) at the aerosol test rig

Re a): Dependency on temperature – Comparison LED, old vs. LED, new

One instrument with the old LED and one instrument with the new LED have been operated in the climate chamber at ambient temperatures of -10 °C und +50 °C as well as between +5 °C und +60 °C and the LED temperatures were recorded. By offering CalDust1100, the peak position was determined at different LED-temperatures.

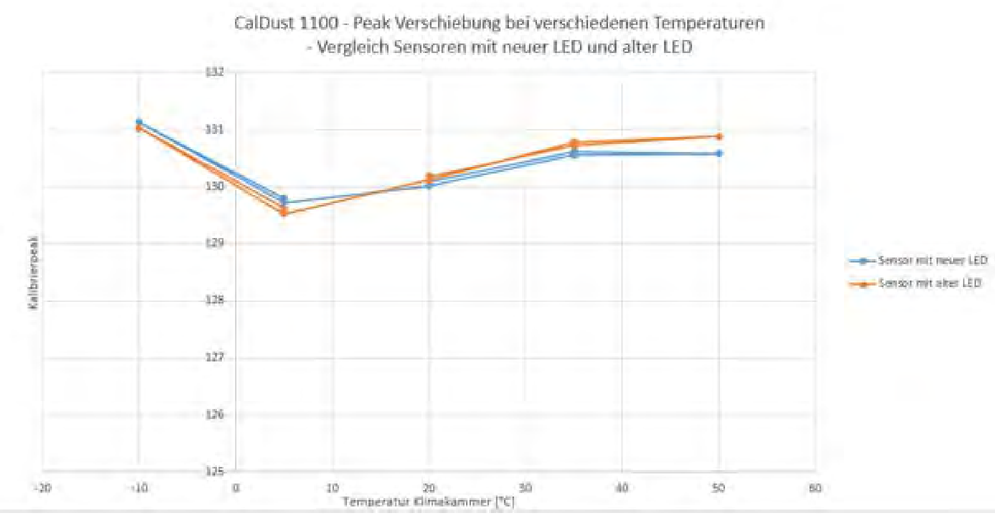


Figure 130: Comparison of temperature behaviour between -10 °C and +50 °C, LED, old vs. LED, new

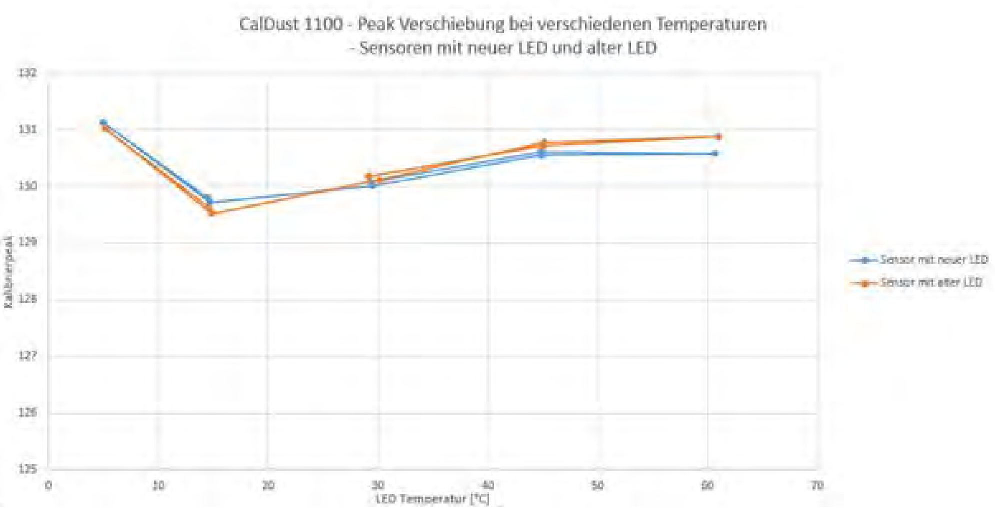


Figure 131: Comparison of temperature behaviour between -+5 °C and +60 °C, LED, old vs. LED, new

It is demonstrated, that there is no significant difference in the temperature behavior between the old LED and the new LED.

Re b): Comparison of PM measured values of instruments with new LED compared to the reference device SN 0108 (with old LED) at the aerosol test rig

In total 10 sensors with the new LED (always installed in one and the same instrument – thus other influences on the result, e.g. by the flow, are excluded and only the dependency on the sensor itself is measured) have been tested against the reference device SN 0108 (with old LED) at the aerosol test rig. For this, PM values in the range of 0 to approx. 180 µg/m³ $PM_{2,5}$ respectively 0 to 260 µg/m³ PM_{10} have been offered to the instruments. Based on the comparison measurements, the slope (mean value of $PM_{2.5}$ and PM_{10}) between the instrument with the old LED and the instrument with the new LED has been determined.

Sensor ID	Steigung
Fidas A 20.Aug.2014	1,01
Fidas B 20.Aug.2014	1,02
Fidas C 20.Aug.2014	0,98
Fidas D 20.Aug.2014	1,01
Fidas E 20.Aug.2014	1,03
Fidas F 20.Aug.2014	1,03
Fidas G 20.Aug.2014	1,01
Fidas H 20.Aug.2014	1,00
Fidas I 20.Aug.2014	1,00
Fidas J 20.Aug.2014	0,97

Steigung = Slope

The results of the comparison measurements show, that the determined deviations between the candidates and the reference device show no significant deviation between candidates with new LED and the reference device with old LED. The determined slopes are all in the range of 0.97 – 1.03.

Based on the available documentation and test results, no significant influence on the measuring system is thus to expect.

8.3 New software

The measuring system has been tested and approved with the following software versions:

Measuring system:	100327
Implemented evaluation algorithm:	PM_ENVIRO_0011
Evaluation software PDAnalyze:	1.010 (for evaluation on an external PC)

The stated software version for the measuring system (in this case: 100327) is used for the operation of the Panel-PC. As there are - beyond the mentioned software version - 3 further software versions independently from each other implemented in the instrument (precisely on the boards SLA (Scattered light evaluation), MIO (multifunctional board, internal control of eg pump control) and Pt100 (control of IADS heater)), it was discussed during the 2014 surveillance audit to depict the software versions more precisely in a single and unique string.

The following general structure for the software string has been defined for the future:

FirmwarePanel.FirmwareSLA.FirmwareMIO.FirmwarePt100.EvaluationAlgorithm

The software implemented during the type approval test is then defined as follows:

100327.0007.0001.0001.0011

Since the initial certification of the measuring system, the firmware (Panel) and the firmware (SLA) have been modified. The firmware (MIO) and the firmware (Pt100) as well as the implemented evaluation algorithm remain unchanged.

For the firmware (Panel) the following modifications have been implemented:

a) Serial IO protocol extended (not covered by type approval test)
b) Digital alarm added
c) Automatic monitoring of calibration according to upcoming patent added (Add-On, not yet tested, thus not covered yet by type approval)
d) Cosmetic changes to the user interface
e) Calibration screen extended for flow calibration (-> increased usability)
f) Bug in Bayern/Hessen-Protocol fixed

g) Various modifications, which are only relevant for the measuring systems UF-CPC and Fidas mobile, but not for Fidas 200.
h) Additonal integration DiSC mini in Fidas Software Plug In
i) Modification of distribution presentation
j) E-Mail Alarm for Fidas – Bugfix for SMTP sending
k) Extension Fidas plugin to Horiba APDA (OEM-Version)
l) Start-Up-Manager extended to Horiba APDA (OEM-Version)
m) As an option calibration can be secured, so that calibration is only possible if 35 °C are really reached in a stable way.
n) Reworking of the depiction of the firmwareversion in one string

The modifications in the firmware (Panel) serve mainly for extension of functionality and increasement of safe operation.

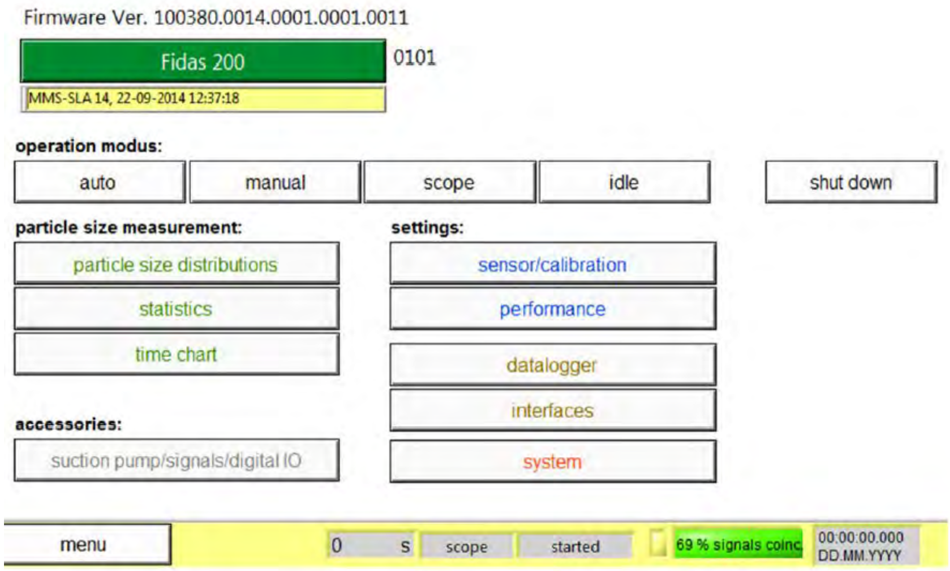
The current firmware version (Panel) is now 100380.

The modifications of the firmware (SLA) comprise additional modes for signal aquisition as well as new commands and are all not relevant for the measuring system Fidas 200 S respectively Fidas 200. It is to note, that the SLA board (and thus also the firmware) is used for all aerosol spectrometers and condensation nucleus counters of the company Palas GmbH.

The current firmware version (SLA) is now 0014.

The current software version is then defined as follows:

100380.0014.0001.0001.0011



The modification has been correctly classified as a Type 0 – modification and thus has got no impact on the measuring instrument. The respective documentation is available at the test institute.

Based on the available documentation (Statement of TÜV Rheinland of 27 September 2014), the publication of the issue (Approval of new software and new structure) has been recommended during the 35th expert meeting “Test reports”. The official announcement in the Federal Gazette “Bundesanzeiger” has happened with announcement of Federal Environment Agency UBA of 25 February 2015 (BAnz AT 02.04.2015 B15, chapter IV, 14th notification).

9. Recommendations for practical use

9.1 Works in the maintenance interval (4 weeks)

The following procedures are required to be carried out at regular intervals:

- Regular visual inspection / telemetrical monitoring
- Check of instrument status
  The instrument status may be controlled directly at the instrument or monitored on-line.
- The sensitivity of the particle sensor shall be checked with CalDust 1100 or MonoDust1500 once a month. Should the sensitivity of the particle sensor deviate from the nominal value 130 by more than ±1.5 channels (CalDust1100) respectively more than ±1.5 channels from the given nominal value (MonoDust1500) , it shall be readjusted with CalDust 1100; otherwise it shall be readjusted at least every 3 months.

As for the rest, the instructions and recommendations provided by the manufacturer shall be followed.

9.2 Further maintenance work

In addition to the regular maintenance work in the maintenance interval, the following procedures are necessary:

- As a matter of principle, the sampling head shall be cleaned according to the instructions provided by the manufacturer. Local concentrations of suspended particulate matter shall be taken into account (during type approval testing approx. every 3 months).
- The system’s leak tightness shall be inspected every 3 months according to the manufacturer’s information.
- A flow rate check shall be carried out every 3 months according to the manufacturer’s information.
- The sensors of the weather station WS600-UMB shall be checked once a year (or when necessary) according to the specifications provided by the manufacturer.
- Cleaning the optical sensor is only required if the photomultiplier-voltage exceeds the calibration value obtained after the last cleaning or on delivery by more than 15 %.
- The filter shall be cleaned or changed if the suction pump capacity exceeds 50 %.

Further details are provided in the user manual.

Department of Environmental Protection/Air Pollution Control

Dipl.-Ing. Karsten Pletscher	Dipl.-Ing. Guido Baum	Dipl.-Ing. Ruth Steinhagen

Cologne, 12 October 2016
936/21227195/C

10. Literature

[1] VDI Standard 4202, Part 1, "Performance criteria for type approval tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants", June 2002 & September 2010

[2] VDI Standard 4203, Part 3, "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", August 2004 & September 2010

[3] 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 EN 12341: 1998

[4] Standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005

[5] Guidance document "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version of January 2010

[6] Operator's manual Fidas® 200 S respectively Fidas® 200, comprising the manuals Fidas®, Fidas® Firmware, PDAnalyze Software, and Compact Weather Station WS600-UMB, Status 2014

[7] Operator's manual LVS3, Status 2000

[8] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

[9] Technical Specification CEN/TS 16450, "Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2.5)"; English version, May 2013

[10] Report "UK Equivalence Programme for Monitoring of Particulate Matter", Report No.: BV/AQ/AD202209/DH/2396 of 5 June 2006

[11] TÜV Rheinland Report No.: 936/21218896/A of 20 September 2013, Report on type approval testing of the Fidas® 200 S measuring system manufactured by PALAS GmbH for the components suspended particulate matter PM_{10} and $PM_{2.5}$

5.1 Fidas® 200 S für Schwebstaub PM_{10} und $PM_{2,5}$

Hersteller:
PALAS GmbH, Karlsruhe

Eignung:
Zur kontinuierlichen parallelen Immissionsmessung der PM_{10}- und der $PM_{2,5}$-Fraktion im Schwebstaub im stationären Einsatz

Messbereiche in der Eignungsprüfung:

Komponente	Zertifizierungsbereich	Einheit
PM_{10}	0 – 10 000	µg/m³
$PM_{2,5}$	0 – 10 000	µg/m³

Softwareversionen: Messsystem: 100327
Implementierter Auswertealgorithmus: PM_ENVIRO_0011
Auswertesoftware PDAnalyze: 1.010

Einschränkungen:
Keine

Hinweise:

1. Die Anforderungen gemäß des Leitfadens „Demonstration of Equivalence of Ambient Air Monitoring Methods" werden für die Messkomponenten PM_{10} und $PM_{2,5}$ eingehalten.
2. Die Anforderungen an den Variationskoeffizienten R^2 gemäß Richtlinie EN 12341 wurden für den Standort Köln, Sommer für einen der beiden Prüflinge nicht eingehalten.
3. Die Empfindlichkeit des Partikelsensors muss monatlich mit CalDust 1100 überprüft werden.
4. Die Messeinrichtung ist mit dem gravimetrischen PM_{10}-Referenzverfahren nach DIN EN 12341 regelmäßig am Standort zu kalibrieren.
5. Die Messeinrichtung ist mit dem gravimetrischen $PM_{2,5}$-Referenzverfahren nach DIN EN 14907 regelmäßig am Standort zu kalibrieren.
6. Der Prüfbericht über die Eignungsprüfung ist im Internet unter www.qal1.de einsehbar.

Prüfinstitut: TÜV Rheinland Energie und Umwelt GmbH, Köln
Bericht-Nr.: 936/21218896/A vom 20. September 2013

Figure 132: Text for publication of type approval in Federal Gazette BAnz. AT 01.04.2014 B12, Chapter IV Number 5.1

14 Mitteilung zu der Bekanntmachung des Umweltbundesamtes vom 27. Februar 2014 (BAnz AT 01.04.2014 B12, Kapitel IV Nummer 5.1)

Die Messeinrichtung Fidas® 200 S für Schwebstaub PM_{10} und $PM_{2,5}$ der Fa. PALAS GmbH ist auch als Indoor-Variante zur Installation an temperaturkontrollierten Orten unter der Bezeichnung Messeinrichtung Fidas® 200 für Schwebstaub PM_{10} und $PM_{2,5}$ verfügbar.

Die Messeinrichtung erhält auf der Geräterückseite eine zusätzliche Buchse für ein digitales Ausgangssignal.

Die LED im Fidas® Sensor vom Typ Osram Ostar Projektion Art.-Nr. LE B H3W wurde abgekündigt und durch die LED vom Typ Osram Ostar Stage Art.-Nr. LE ATB S2W ersetzt.

Die Darstellung der Softwareversion der Messeinrichtung wurde überabeitet.

Die bislang bekanntgegebene Softwareversion der Messeinrichtung stellt sich nun wie folgt dar:

100327.0007.0001.0001.0011

Die aktuelle Softwareversion der Messeinrichtung lautet:

100380.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 27. September 2014

Figure 133: Text for publication of notification in Federal Gazette BAnz. AT 02.04.2015 B5, Chapter IV Notification 14

11. Annex

Appendix 1 **Measured and calculated values**

Annex 1: Detection limit

Annex 2: Temperature dependence of zero point

Annex 3: Temperature dependence of the sensitivity

Annex 4: Dependence on supply voltage

Annex 5: Measured values at the field test sites, PM_ENVIRO_0011, GER

Annex 6: Ambient conditions at the field test sites, GER

Annex 7: Measured values at the field test sites, PM_ENVIRO_0011, UK

Annex 8: Ambient conditions at the field test sites, UK

Appendix 2 **Filter weighing procedure**

Appendix 3 **Manuals**

Annex 1 **Detection limit** **Page 1 of 2**

Manufacturer	Palas
Type	FIDAS 200
Serial-No.	SN 0111 / SN 0112

Standards ZP Zero filter

No.	Date	Measured values [µg/m³] SN 0111	Date	Measured values [µg/m³] SN 0112
1	4/5/2012	0.0000000	4/5/2012	0.0000000
2	4/6/2012	0.0000000	4/6/2012	0.0000005
3	4/7/2012	0.0000000	4/7/2012	0.0000000
4	4/8/2012	0.0000000	4/8/2012	0.0000000
5	4/9/2012	0.0000000	4/9/2012	0.0000000
6	4/10/2012	0.0000008	4/10/2012	0.0000000
7	4/11/2012	0.0000000	4/11/2012	0.0000008
8	4/12/2012	0.0000008	4/12/2012	0.0000003
9	4/13/2012	0.0000000	4/13/2012	0.0000006
10	4/14/2012	0.0000000	4/14/2012	0.0000000
11	4/15/2012	0.0000177	4/15/2012	0.0000008
12	4/16/2012	0.0012831	4/16/2012	0.0000000
13	4/17/2012	0.0010071	4/17/2012	0.0000000
14	4/18/2012	0.0001465	4/18/2012	0.0000000
15	4/19/2012	0.0004303	4/19/2012	0.0000000
	No. of values	15	No. of values	15
	Mean	0.0001924	Mean	0.0000002
	Standard deviation s_{x0}	0.0004064	Standard deviation s_{x0}	0.0000003
	Detection limit x	8.7E-04	Detection limit x	6.6E-07

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

Annex 1 **Detection limit** **Page 2 of 2**

Manufacturer Palas

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

Standards ZP Zero filter

No.	Date	Measured values [µg/m³] SN 0111	Date	Measured values [µg/m³] SN 0112
1	4/5/2012	0.0000003	4/5/2012	0.0000000
2	4/6/2012	0.0000000	4/6/2012	0.0000005
3	4/7/2012	0.0000000	4/7/2012	0.0000000
4	4/8/2012	0.0000000	4/8/2012	0.0000000
5	4/9/2012	0.0000000	4/9/2012	0.0000000
6	4/10/2012	0.0000000	4/10/2012	0.0000000
7	4/11/2012	0.0000008	4/11/2012	0.0000008
8	4/12/2012	0.0000000	4/12/2012	0.0000003
9	4/13/2012	0.0000008	4/13/2012	0.0000006
10	4/14/2012	0.0000000	4/14/2012	0.0000000
11	4/15/2012	0.0000000	4/15/2012	0.0000008
12	4/16/2012	0.0000177	4/16/2012	0.0000000
13	4/17/2012	0.0012831	4/17/2012	0.0000000
14	4/18/2012	0.0010071	4/18/2012	0.0000000
15	4/19/2012	0.0001465	4/19/2012	0.0000000
	No. of values	15	No. of values	15
	Mean	0.0001638	Mean	0.0000002
	Standard deviation s_{x0}	0.0004036	Standard deviation s_{x0}	0.0000003
	Detection limit x	8.7E-04	Detection limit x	6.6E-07

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

Annex 2 Dependence of zero point on ambient temperature (PM10) Page 1 of 2

Manufacturer PALAS

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

Standards ZP Zero filter

			Cycle 1		Cycle 2		Cycle 3	
SN 0111	No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]
ZP	1	20	0.0000000	-	0.0000000	-	0.0000000	-
	2	-20	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	3	20	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	4	50	0.0000005	0.0000005	0.0000014	0.0000014	0.0000014	0.0000014
	5	20	0.0000000	0.0000000	0.0000008	0.0000008	0.0000000	0.0000000
SN 0112	No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]
ZP	1	20	0.0000003	-	0.0000000	-	0.0000332	-
	2	-20	0.0000000	-0.0000003	0.0000017	0.0000017	0.0000000	-0.0000332
	3	20	0.0000000	-0.0000003	0.0000001	0.0000001	0.0000040	-0.0000292
	4	50	0.0000000	-0.0000003	0.0000000	0.0000000	0.0000000	-0.0000332
	5	20	0.0000006	0.0000003	0.0000000	0.0000000	0.0000000	-0.0000332

Annex 2 **Dependence of zero point on ambient temperature (PM2.5)** **Page 2 of 2**

Manufacturer	PALAS
Type	FIDAS 200
Serial-No.	SN 0111 / SN 0112
Standards	ZP: Zero filter

			Cycle 1		Cycle 2		Cycle 3	
SN 0111	No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]
ZP	1	20	0.0000000	-	0.0000000	-	0.0000000	-
	2	-20	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	3	20	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
	4	50	0.0000005	0.0000005	0.0000014	0.0000014	0.0000014	0.0000014
	5	20	0.0000000	0.0000000	0.0000008	0.0000008	0.0000000	0.0000000
SN 0112	No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]
ZP	1	20	0.0000003	-	0.0000000	-	0.0000332	-
	2	-20	0.0000000	-0.0000003	0.0000017	0.0000017	0.0000000	-0.0000332
	3	20	0.0000000	-0.0000003	0.0000001	0.0000001	0.0000040	-0.0000292
	4	50	0.0000000	-0.0000003	0.0000000	0.0000000	0.0000000	-0.0000332
	5	20	0.0000006	0.0000003	0.0000000	0.0000000	0.0000000	-0.0000332

Annex 3 **Dependence of measured value on ambient temperature (PM10)** **Page 1 of 2**

Manufacturer	Palas								
					Standards		CalDust 1100		
Type	FIDAS 200								
Serial-No.	SN 0111 / SN 0112								
			Cycle 1		Cycle 2		Cycle 3		
SN 0111	No.	Temperature [°C]	Measured value	Dev. [%]	Measured value	Dev. [%]	Measured value	Dev. [%]	
	1	20	40.0	-	40.0	-	40.0	-	
	2	-20	38.2	-4.4	38.2	-4.4	38.2	-4.4	
RP	3	20	39.9	-0.3	39.9	-0.3	40.0	0.0	
	4	50	39.4	-1.4	39.7	-0.9	39.7	-0.9	
	5	20	40.0	0.0	40.1	0.2	40.0	0.0	
SN 0112	No.	Temperature [°C]	Measured value	Dev. [%]	Measured value	Dev. [%]	Measured value	Dev. [%]	
	1	20	40.0	-	40.0	-	40.0	-	
	2	-20	41.8	4.6	41.8	4.6	41.8	4.6	
RP	3	20	40.0	0.0	40.0	0.0	40.1	0.2	
	4	50	39.9	-0.3	40.1	0.2	40.1	0.2	
	5	20	40.0	0.0	40.1	0.2	40.1	0.2	

Annex 3 **Dependence of measured value on ambient temperature (PM2.5)** **Page 2 of 2**

Manufacturer Palas

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

Standards CalDust 1100

			Cycle 1		Cycle 2		Cycle 3			
SN 0111	No.	Temperature [°C]	Measured value	Dev. [%]	Measured value	Dev. [%]	Measured value	Dev. [%]		
RP	1	20	25.0	-	25.0	-	25.0	-		
	2	-20	23.9	-4.4	23.9	-4.4	23.9	-4.4		
	3	20	24.9	-0.3	24.9	-0.3	25.0	0.0		
	4	50	24.6	-1.5	24.8	-0.9	24.8	-0.9		
	5	20	25.0	0.0	25.1	0.3	25.0	0.0		
SN 0112	No.	Temperature [°C]	Measured value	Dev. [%]	Measured value	Dev. [%]	Measured value	Dev. [%]		
RP	1	20	25.0	-	25.0	-	25.0	-		
	2	-20	26.2	5.0	26.2	5.0	26.2	5.0		
	3	20	25.0	0.0	25.0	0.0	25.1	0.3		
	4	50	24.9	-0.3	25.1	0.3	25.1	0.3		
	5	20	25.0	0.0	25.1	0.3	25.1	0.3		

Annex 4 **Dependence of measured value on mains voltage (PM10)** **Page 1 of 2**

Manufacturer PALAS

Standards CalDust 1100

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

SN 0111	No.	Mains voltage [V]	Cycle 1 Measured value	Dev. [%]	Cycle 2 Measured value	Dev. [%]	Cycle 3 Measured value	Dev. [%]		
RP	1	230	40.1	-	39.9	-	40.0	-		
	2	210	40.0	-0.2	40.0	0.3	40.0	0.0		
	3	230	40.1	0.0	40.0	0.3	40.0	0.0		
	4	245	40.1	0.0	40.1	0.5	40.1	0.2		
	5	230	40.0	-0.2	40.0	0.3	40.2	0.5		
SN 0112	**No.**	**Mains voltage [V]**	**Measured value**	**Dev. [%]**	**Measured value**	**Dev. [%]**	**Measured value**	**Dev. [%]**		
RP	1	230	40.1	-	40.0	-	40.0	-		
	2	210	40.2	0.2	40.3	0.7	40.2	0.5		
	3	230	40.4	0.7	40.3	0.7	40.3	0.7		
	4	245	40.2	0.2	40.4	1.0	40.2	0.5		
	5	230	40.1	0.0	39.7	-0.9	40.3	0.7		

Annex 4 **Dependence of measured value on mains voltage (PM2.5)** **Page 2 of 2**

Manufacturer	PALAS	
Type	FIDAS 200	Standards: CalDust 1100
Serial-No.	SN 0111 / SN 0112	

SN 0111	No.	Mains voltage [V]	Cycle 1 Measured value	Dev. [%]	Cycle 2 Measured value	Dev. [%]	Cycle 3 Measured value	Dev. [%]		
RP	1	230	25.1	-	24.9	-	25.0	-		
	2	210	25.0	-0.3	25.0	0.3	25.0	0.0		
	3	230	25.1	0.0	25.0	0.3	25.0	0.0		
	4	245	25.1	0.0	25.1	0.6	25.1	0.3		
	5	230	25.0	-0.3	25.0	0.3	25.1	0.5		
SN 0112	**No.**	**Mains voltage [V]**	**Measured value**	**Dev. [%]**	**Measured value**	**Dev. [%]**	**Measured value**	**Dev. [%]**		
RP	1	230	25.1	-	25.0	-	25.0	-		
	2	210	25.1	0.3	25.2	0.8	25.1	0.5		
	3	230	25.3	0.8	25.2	0.8	25.2	0.8		
	4	245	25.1	0.3	25.3	1.1	25.1	0.5		
	5	230	25.1	0.0	24.8	-0.9	25.2	0.8		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 1 of 22**

Manufacturer	PALAS	
Type of instrument	FIDAS 200 S	PM10 and PM2.5 Measured values in µg/m³ (ACT)
Serial-No.	SN 0111 / SN 0112	

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM2,5 [µg/m³]	SN 0112 PM2,5 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
1	5/14/2012						12.9	13.0	20.1	20.3		Cologne, summer
2	5/15/2012	6.8	7.2	11.7	10.0	64.1	7.0	7.0	10.5	10.5		
3	5/16/2012	6.4	8.2	13.8	13.1	54.4	7.0	7.0	12.0	11.9		
4	5/17/2012	6.5	7.6	12.4	11.6	58.9	6.8	6.9	11.1	11.1		
5	5/18/2012			14.4	11.7		8.8	9.0	13.8	13.9	Outlier Ref. PM2,5	
6	5/19/2012						9.2	9.4	13.5	13.5		
7	5/20/2012	12.0	12.8	19.1	16.8	69.0	13.3	13.4	19.1	19.2		
8	5/21/2012	27.7	28.6				32.1	32.2	43.8	43.6	Outlier Ref. PM10	
9	5/22/2012						58.8	58.2	74.5	73.3		
10	5/23/2012			45.2	43.3		32.2	32.0	42.6	42.0	Outlier Ref. PM2,5	
11	5/24/2012	10.7	9.1	19.7	17.0	54.1	11.1	11.2	22.1	22.4		
12	5/25/2012	6.8	6.6	16.6	14.8	42.6	6.1	6.2	17.3	17.2		
13	5/26/2012						8.8	9.0	18.7	19.0		
14	5/27/2012						9.2	9.4	14.6	14.9		
15	5/28/2012	12.2	12.3	20.6	19.8	60.5	15.1	15.2	22.8	23.0		
16	5/29/2012	11.3	11.9	26.8	25.2	44.5		15.5		26.8	SN 0111 accidentally switched off via remote control	
17	5/30/2012	17.6	17.8	34.8	32.4	52.8	22.3	22.6	32.2	33.0		
18	5/31/2012	11.6	12.0	22.6	21.2	53.8	15.8	15.7	23.1	22.8		
19	6/1/2012	9.5	9.3	16.6	15.2	59.1	12.1	12.1	15.9	16.0		
20	6/2/2012						10.6	10.6	13.9	14.1		
21	6/3/2012	10.7	10.6	16.7	16.0	65.0	14.6	14.5	16.9	16.9		
22	6/4/2012	4.1	4.8	11.5	11.2	39.4	6.7	6.7	11.2	11.4		
23	6/5/2012	5.7	4.8	14.2	13.2	38.2	7.1	7.2	11.4	11.6		
24	6/6/2012						6.7	6.8	10.1	10.1		
25	6/7/2012	4.9	4.0	8.5	7.0	57.7	5.3	5.4	9.1	9.2		
26	6/8/2012						3.9	3.9	8.3	8.3		
27	6/9/2012						4.6	4.7	8.8	8.8		
28	6/10/2012										Power failure	
29	6/11/2012	4.2	8.1	9.4	8.2	70.2	5.7	5.7	10.0	9.8		
30	6/12/2012	13.2	12.3	19.5	19.7	65.1	14.1	14.0	18.0	17.7		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 2 of 22**

Manufacturer: PALAS

Type of instrument: FIDAS 200 S

Serial-No.: SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
31	6/13/2012	9.7	10.0	21.2	20.7	47.0	12.4	12.3	17.7	17.8		Cologne, summer
32	6/14/2012	11.7	13.0	22.9	21.4	55.9	14.8	14.9	19.8	19.8		
33	6/15/2012										Inlet -> Zero filter	
34	6/16/2012										Zero filter	
35	6/17/2012										Zero filter	
36	6/18/2012	11.2	10.9	17.1	15.8	67.3	10.8	10.8	15.4	15.5		
37	6/19/2012	19.5	19.1	29.2	28.7	66.7	23.1	22.8	27.0	26.6		
38	6/20/2012	13.5	13.0	18.8	18.3	71.5	15.5	15.3	18.9	18.5		
39	6/21/2012	3.6	3.8	9.6	8.7	40.4	5.0	5.1	10.2	10.0		
40	6/22/2012	5.3	7.1	13.4	13.4	46.2	6.5	6.5	11.6	11.6		
41	6/23/2012						6.9	7.0	10.5	10.6		
42	6/24/2012	6.0	5.0	8.9	10.8	55.7	5.4	5.4	9.0	8.9		
43	6/25/2012	10.0	11.3	15.2	16.5	67.1	9.6	9.5	14.7	14.4		
44	6/26/2012	13.4	13.7		19.8		12.0	12.2	16.4	16.5		
45	6/27/2012	11.8	11.8	17.6	18.7	64.9	12.4	12.1	18.2	17.7		
46	6/28/2012	8.0	10.3	17.7	17.1	52.7	9.3	9.3	20.7	20.2		
47	6/29/2012	10.4	10.8	22.9	23.5	45.8	12.6	12.7	26.6	25.8		
48	6/30/2012						8.3	8.3	17.8	17.3		
49	7/1/2012	6.3	7.3	12.4	12.1	55.8	5.8	5.8	10.9	10.7		
50	7/2/2012	6.7	8.5	11.5	12.3	64.2	6.9	6.9	10.8	10.6		
51	7/3/2012	8.7	9.5	17.1	15.1	56.6	7.8	7.9	13.3	13.7		
52	7/4/2012	9.9	10.6	15.8	16.8	62.9	10.4	10.4	16.0	15.7		
53	7/5/2012	8.8	8.6	13.2	13.8	64.3	9.5	9.4	14.6	14.2		
54	7/6/2012	7.0	5.8	10.8	10.4	60.0	5.3	5.3	9.8	9.8		
55	7/7/2012						4.6	4.6	8.0	7.9		
56	7/8/2012	3.4	4.1	6.4	6.7	57.6	3.1	3.2	6.3	6.3		
57	7/9/2012	7.2	7.7	12.4	12.1	60.4	8.0	8.0	12.2	12.1		
58	7/10/2012	7.1	7.1	12.8	11.5	58.4	8.0	8.0	12.4	12.4		
59	7/11/2012	3.7	2.9	7.0	8.1	43.9	3.3	3.4	6.7	6.6		
60	7/12/2012	3.6	3.6	8.2	7.0	46.7	3.3	3.3	7.2	7.2		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 3 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
61	7/13/2012	3.2	3.1	6.6	6.5	47.9	3.2	3.2	6.4	6.4		Cologne, summer
62	7/14/2012						3.8	3.9	6.6	6.5		
63	7/15/2012	6.0	7.1	12.0	11.3	56.6	6.3	6.5	10.2	10.2		
64	7/16/2012	3.7	4.3	9.1	7.3	48.6	3.7	3.8	7.2	7.1		
65	7/17/2012	5.4	5.7	12.6	13.1	43.0	7.7	7.7	12.2	12.0		
66	7/18/2012	5.1	5.6	10.6	9.3	53.6	5.2	5.2	10.2	10.3		
67	7/19/2012	5.4	5.6	14.5	13.8	39.2	6.5	6.5	12.6	12.3		
68	7/20/2012										Zero filter	
69	7/21/2012										Zero filter	
70	7/22/2012										Zero filter	
71	7/23/2012	8.1	6.3	13.0	12.6	56.5	6.4	6.5	11.0	11.3		
72	7/24/2012	17.1	16.6	24.5	22.7	71.5	12.9	12.9	20.3	20.5		
73	7/25/2012	27.6	28.0	39.0	37.6	72.6	26.4	26.3	37.8	37.0		
74	7/26/2012	26.0	26.1	35.7	35.1	73.7	28.5	28.2	38.6	37.9		
75	7/27/2012	22.3	22.7	31.6	31.4	71.4	23.0	22.5	32.5	31.6		
76	7/28/2012						18.6	18.2	24.3	23.8		
77	7/29/2012	4.9	4.7	9.9	8.7	51.7	4.2	4.2	7.7	7.8		
78	7/30/2012	5.8	6.1	12.3	12.8	47.4	5.0	5.0	9.1	9.0		
79	7/31/2012	8.0	7.9	14.4	14.6	55.0	6.4	6.5	11.1	11.3		
80	8/1/2012	10.2	10.4	16.5	17.1	61.3	8.2	8.1	15.4	15.0		
81	8/2/2012	6.4	6.7	13.2	13.4	49.2	5.3	5.3	11.3	11.4		
82	8/3/2012	6.7	7.0	14.4	15.5	45.9	6.6	6.6	12.2	12.3		
83	8/4/2012						7.6	7.6	10.9	10.8		
84	8/5/2012	4.2	5.4	8.4	8.9	54.9	4.9	4.9	8.0	7.8		
85	8/6/2012	4.0	4.0	8.1	9.6	44.9	3.6	3.6	7.4	7.1		
86	8/7/2012	6.8	5.5	13.5	12.8	46.8	5.3	5.3	10.3	10.2		
87	8/8/2012	10.4	9.0	16.2	16.6	59.2	8.7	8.6	12.8	12.7		
88	8/9/2012	7.7	7.6	12.3	12.7	61.1	8.1	8.0	11.7	11.6		
89	8/10/2012	8.6	8.7	13.3	14.3	62.7	6.9	6.9	10.6	10.6		
90	8/11/2012						6.0	5.9	8.9	8.7		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 4 of 22**

Manufacturer: PALAS
Type of instrument: FIDAS 200 S
Serial-No.: SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
91	8/12/2012	6.2	5.6	10.0	10.0	59.1	5.4	5.4	9.7	9.7		Cologne, summer
92	8/13/2012	9.7	9.2	15.4	16.8	58.6	8.2	8.2	15.0	14.8		
93	8/14/2012	10.3	10.1	17.2	16.6	60.4	8.9	8.8	14.6	14.3		
94	8/15/2012	10.1	10.4	19.5	20.0	51.7	9.8	9.7	20.2	19.4		
95	8/16/2012	7.6	7.9	18.0	19.5	41.5	6.7	6.6	12.8	12.4		
96	8/17/2012										Zero filter	
97	8/18/2012										Zero filter	
98	8/19/2012										Zero filter	
99	8/20/2012	17.1	17.9	28.6	29.0	60.8	15.8	15.3	26.9	25.6		
100	8/21/2012	18.3	19.8	29.3	29.3	65.1	19.3	18.7	29.6	28.3		
101	8/22/2012	8.7	9.9	20.7	19.9	45.7	8.9	8.9	17.5	17.1		
102	8/23/2012	7.6	8.3	14.5	13.8	56.1	5.9	5.8	11.7	11.3		
103	8/24/2012	9.0	10.3	15.2	15.0	64.0	8.8	8.6	13.8	13.1		
104	8/25/2012						3.2	3.1	6.3	6.0		
105	8/26/2012	6.6	7.3	12.0	11.1	60.0	7.6	7.4	10.3	10.1		
106	8/27/2012	5.4	6.5	10.7	10.7	55.2	5.0	4.9	8.7	8.5		
107	8/28/2012	8.2	7.9	14.7	16.9	50.9	6.5	6.4	12.9	12.3		
108	8/29/2012	8.4	8.9	16.5	16.5	52.5	6.9	6.8	13.7	13.6		
109	8/30/2012	5.6	6.1	14.2	14.4	40.8	6.6	6.5	12.3	12.0		
110	8/31/2012	4.4	5.0	10.7	10.9	43.4	5.7	5.6	9.9	9.8		
111	9/1/2012						8.7	8.4	12.6	12.0		
112	9/2/2012	10.3	11.9	18.7	17.9	60.7	9.3	9.1	13.6	13.0		
113	11/19/2012										Zero filter	Cologne, winter
114	11/20/2012										Zero filter	
115	11/21/2012											
116	11/22/2012						11.4	11.3	14.2	13.8		
117	11/23/2012	15.3	15.1	19.6	19.6	77.8	16.8	16.3	20.4	19.7		
118	11/24/2012						15.0	14.8	19.2	19.0		
119	11/25/2012	5.1	5.8	10.8	10.4	51.1	6.0	6.0	10.1	9.9		
120	11/26/2012	6.1	6.9	11.0	11.6	57.4	7.2	7.2	11.0	10.8		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 5 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
121	11/27/2012	10.9	11.5	18.5	17.6	62.0	11.2	11.2	15.8	15.8		Cologne, winter
122	11/28/2012	23.3	23.5	29.0	29.1	80.5	26.0	25.7	30.5	30.0		
123	11/29/2012	9.0	9.3	14.2	14.4	64.0	10.3	10.2	14.7	14.6		
124	11/30/2012	17.8	19.3	24.5	24.3	76.0	19.5	19.0	23.4	22.7		
125	12/1/2012						14.4	14.0	15.9	15.5		
126	12/2/2012	10.0	11.0	14.8	14.6	71.2	11.8	11.6	14.6	14.3		
127	12/3/2012	8.8	9.0	14.1	14.4	62.2	10.6	10.3	13.5	13.0		
128	12/4/2012	8.3	7.6	11.6	11.6	68.3	9.1		11.8		SN 0112 Fuse for heater burned	
129	12/5/2012	8.7	8.5	12.1	12.5	69.8		9.6		12.1	SN 0111 Fuse for heater burned	
130	12/6/2012	9.5	10.3	16.5	16.1	60.7	12.5	12.2	16.7	16.0		
131	12/7/2012	13.0	12.8	15.4	15.4	83.8	13.2	12.7	15.5	14.7		
132	12/8/2012						29.0		31.5		SN 0112 Fuse for heater burned	
133	12/9/2012	5.5	5.8	10.1	8.9	59.5	7.2		9.8		SN 0112 Fuse for heater burned	
134	12/10/2012	10.6	11.2	14.5	13.5	77.5	13.3	12.6	15.9	14.8		
135	12/11/2012	17.3	17.7	23.6	22.8	75.4	19.2	18.3	23.7	22.6		
136	12/12/2012	18.2	18.5	24.7	24.2	75.1	18.2	17.4	22.9	22.0		
137	12/13/2012	23.4	23.7	29.3	28.2	82.0	24.3	23.0	27.8	26.4		
138	12/14/2012	7.3	6.7	8.9	8.8	79.5	7.7	7.3	9.2	8.9		
139	12/15/2012						4.5	4.3	6.5	6.1		
140	12/16/2012	5.4	5.9	9.7	9.5	58.9	6.9	6.6	9.2	8.7		
141	12/17/2012	6.8	7.2	13.7	13.4	51.9	9.1	8.8	13.4	12.7		
142	12/18/2012	12.9	13.3	20.1	20.5	64.5	15.0	14.3	19.0	18.1		
143	12/19/2012	13.4	13.3	18.3	18.0	73.7	15.4	14.6	18.1	17.3		
144	12/20/2012	11.6	11.6	14.1	13.6	83.8	12.3	11.7	13.8	13.2		
145	12/21/2012	11.7	10.8	18.1	17.8	62.7	13.7	12.9	17.2	16.2		
146	12/22/2012						4.4	4.2	6.4	6.0		
147	12/23/2012						4.0	3.9	6.3	6.0		
148	12/24/2012						7.8	7.8	14.6	14.2		
149	12/25/2012						2.5	2.4	3.9	3.8		
150	12/26/2012						5.5	5.4	9.3	8.9		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 6 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
151	12/27/2012						12.3	12.1	16.3	16.1		Cologne, winter
152	12/28/2012						5.1	5.0	7.0	6.7		
153	12/29/2012						4.1	4.0	5.9	5.7		
154	12/30/2012						5.7	5.5	8.7	8.4		
155	12/31/2012										Power failure	
156	1/1/2013										Power failure	
157	1/2/2013	9.7	9.3	16.1	15.0	60.9	12.2	11.7	15.7	14.9		
158	1/3/2013	11.9	13.1	19.4	18.6	65.6	15.7	15.3	21.4	20.5		
159	1/4/2013	9.5	9.9	13.8	13.0	72.5	11.6	11.3	14.3	13.9		
160	1/5/2013						18.7	18.5	21.2	20.8		
161	1/6/2013	26.7	26.6	37.5	37.4	71.3	31.6	30.9	35.4	34.5		
162	1/7/2013	17.6	19.4	24.6	25.0	74.5	20.2	19.8	23.8	23.3		
163	1/8/2013	13.6	14.7	19.6	20.1	71.4	17.1	16.8	20.7	20.3		
164	1/9/2013	11.6	13.3	18.9	19.7	64.5	15.3	15.0	19.6	18.9		
165	1/10/2013	13.6	14.7	21.9	21.5	65.1	15.8	15.5	19.5	19.2		
166	1/11/2013										Zero filter	
167	1/12/2013										Zero filter	
168	1/13/2013										Zero filter	
169	1/14/2013	24.9	24.8	28.4	29.4	86.0	24.6	23.9	27.5	26.6		
170	1/15/2013	33.4	33.8	36.3	37.1	91.5	31.6	30.1	34.1	32.5		
171	1/16/2013	58.5	58.4	63.7	63.3	92.0	61.4	59.4	66.9	64.4		
172	1/17/2013	55.4	56.2	60.2	59.8	93.0	57.1	55.4	61.0	59.1		
173	1/18/2013	17.4	17.5	19.0	18.6	92.7	18.2	17.6	20.1	19.6		
174	1/19/2013	21.1	21.1	22.6	23.0	92.4	23.2	22.6	24.5	23.8		
175	1/20/2013	29.7	30.0	30.9	31.2	96.2	32.7	31.6	35.0	33.6		
176	1/21/2013	44.9	42.8	45.4	44.8	97.2	46.7	45.0	49.7	47.8		
177	1/22/2013	53.5	54.9	61.5	58.2	90.5	60.5	58.2	63.6	61.1	Outlier Ref. PM10 - not discarded	
178	1/23/2013	62.1	63.2	69.2	68.8	90.8	69.0	66.4	74.0	71.3		
179	1/24/2013	23.6	24.5	27.8	28.1	86.1	24.5	23.5	27.3	26.1		
180	1/25/2013	19.6	19.3	21.2	20.4	93.3	18.9	18.1	20.5	19.5		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 7 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
181	1/26/2013	26.6	25.9	28.3	28.4	92.5	26.3	25.1	27.8	26.5		Cologne, winter
182	1/27/2013	9.1	9.2	15.0	15.0	61.1	10.6	10.2	14.8	14.2		
183	1/28/2013	5.7	5.9	8.9	7.9	68.6	6.2	5.9	8.4	8.0		
184	1/29/2013	3.4	3.9	5.5	4.5	72.0	4.1	3.7	5.5	5.1		
185	1/30/2013	6.4	6.8	15.2	14.8	43.8	7.4	7.2	13.5	12.7		
186	1/31/2013	8.0	8.5	20.3	19.2	41.6	10.1	9.8	17.2	16.4		
187	2/1/2013	9.2	9.4	11.9	10.9	81.4	9.3	8.8	10.9	10.4		
188	2/2/2013						6.9	6.7	11.9	11.3		
189	2/3/2013						8.7	8.2	10.6	10.0		
190	2/4/2013						9.4	9.0	14.5	13.7		
191	2/5/2013										Zero filter	
192	2/6/2013										Zero filter	
193	2/27/2013										Zero filter	Bonn, winter
194	2/28/2013										Zero filter	
195	3/1/2013	24.9	23.0	36.3	36.7	65.6	29.4	29.4	38.5	38.1		
196	3/2/2013						34.3	34.1	43.3	42.7		
197	3/3/2013	22.1	23.2	29.3	29.8	76.6	24.7	24.5	28.6	28.4		
198	3/4/2013	19.6	20.5	28.2	28.7	70.2	21.6	21.6	29.6	29.5		
199	3/5/2013	28.4	27.7	40.2	39.9	70.1	31.0	30.9	41.6	41.1		
200	3/6/2013	25.8	24.5	39.3	39.7	63.8	26.5	26.2	39.6	38.9		
201	3/7/2013	28.0	28.3	39.5	39.5	71.2	30.9	30.1	40.9	40.0		
202	3/8/2013	28.8	27.0	35.4	34.8	79.5	32.4	31.4	39.4	38.5		
203	3/9/2013						12.1	11.8	15.6	15.1		
204	3/10/2013	21.8	22.0	23.1	22.3	96.5	25.6	25.0	26.7	26.0		
205	3/11/2013	27.6	28.1	31.2	30.3	90.6	31.5	30.7	34.1	33.4		
206	3/12/2013	15.6	15.6	17.8	17.7	87.9	16.1	15.3	19.4	18.5		
207	3/13/2013	36.7	36.7	50.8	50.0	72.9	33.4	32.5	45.9	44.5		
208	3/14/2013	19.6	19.2	27.5	27.6	70.3	19.2	18.7	29.6	28.8		
209	3/15/2013	22.0	21.5	31.7	31.7	68.7	21.8	21.4	32.2	31.5		
210	3/16/2013						14.4	14.2	25.2	25.1		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 8 of 22**

Manufacturer PALAS
Type of instrument FIDAS 200 S
Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
211	3/17/2013	7.0	7.4	11.0	10.5	67.2	9.4	9.1	12.9	12.8		Bonn, winter
212	3/18/2013	7.7	8.2	17.4	17.2	45.9	9.0	8.7	17.4	16.7		
213	3/19/2013	9.5	9.9	17.1	16.8	57.5	11.0	10.5	17.2	16.1		
214	3/20/2013	21.3	20.9	25.2	24.5	84.7	23.4	22.1	25.7	24.3		
215	3/21/2013	37.5	36.6	46.3	45.9	80.5	39.0	37.4	45.9	44.0		
216	3/22/2013	21.4	21.6	26.0	26.3	82.2	25.5	24.5	30.4	29.0		
217	3/23/2013						25.3	24.4	28.3	27.5		
218	3/24/2013	15.1	15.9	19.7	18.8	80.6	17.5	16.8	20.8	20.0		
219	3/25/2013	20.1	20.6	26.0	25.6	78.9	23.2	22.3	29.2	28.1		
220	3/26/2013	15.7	15.3	21.1	20.4	74.7	16.9	16.2	22.9	22.1		
221	3/27/2013	26.6	25.9	33.3	32.8	79.5	27.5	26.3	34.6	32.9		
222	3/28/2013						51.4	48.7	59.1	55.8		
223	3/29/2013	71.1	69.8	76.5	76.3	92.2	74.6	70.3	78.0	73.4		
224	3/30/2013										Zero filter	
225	3/31/2013										Zero filter	
226	4/1/2013										Zero filter	
227	4/2/2013	20.2	20.2	24.7	25.2	81.0	23.4	22.0	28.0	26.6		
228	4/3/2013	27.2	26.5	31.4	30.8	86.3	31.0	29.0	35.3	33.2		
229	4/4/2013	29.5	29.1	33.5	33.2	88.0	35.8	36.2	39.6	40.2		
230	4/5/2013	25.8	25.4	30.8	30.0	84.1	29.7	30.0	34.1	34.6		
231	4/6/2013						25.8	26.0	30.2	30.3		
232	4/7/2013	23.0	22.8	30.9	30.2	74.9	25.5	25.7	32.7	32.5		
233	4/8/2013	26.3	25.1	31.7	31.7	81.0	29.3	29.4	35.2	35.5		
234	4/9/2013	16.5	16.5	21.6	21.0	77.4	18.1	18.0	21.3	21.2		
235	4/10/2013	12.2	12.2	17.9	17.8	68.4	12.3	12.1	16.7	16.2		
236	4/11/2013	9.4	8.8	15.9	15.7	57.4	7.5	7.4	13.6	13.2		
237	4/12/2013	6.2	6.3	10.4	10.4	60.4	5.1	4.9	9.5	8.8		
238	4/13/2013						6.5	6.4	10.9	10.4		
239	4/14/2013	7.2	6.9	11.9	11.1	61.4	5.2	5.2	9.2	9.1		
240	4/15/2013	18.5	16.8	31.2	30.2	57.3	18.1	17.6	28.7	27.6		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 9 of 22**

Manufacturer	PALAS	
Type of instrument	FIDAS 200 S	PM10 and PM2.5 Measured values in µg/m³ (ACT)
Serial-No.	SN 0111 / SN 0112	

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
241	4/16/2013	12.7	11.2	21.1	20.7	57.2	12.3	12.0	20.8	20.3		Bonn, winter
242	4/17/2013	9.9	9.8	19.5	19.7	50.2	8.0	8.0	19.1	18.6		
243	4/18/2013	9.4	8.7	21.4	21.5	42.2	8.3	8.3	20.7	20.3		
244	4/19/2013	10.3	10.3	21.0	20.8	49.4	11.7	11.5	20.6	19.8		
245	4/20/2013						13.5	13.3	20.8	20.1		
246	4/21/2013	24.4	23.0	36.7	37.6	63.8	23.4	22.9	33.4	32.5		
247	4/22/2013	31.0	29.4	44.7	43.9	68.3	32.7	31.7	47.2	45.3		
248	4/23/2013	11.0	10.4	18.2	18.8	57.6	9.8	9.4	19.5	18.6		
249	4/24/2013	14.3	12.7	24.2	24.4	55.6	13.3	12.8	25.3	24.6		
250	4/25/2013	13.8	12.1	23.3	23.6	55.3	11.9	11.5	24.7	23.8		
251	4/26/2013										Zero filter	
252	4/27/2013										Zero filter	
253	4/28/2013										Zero filter	
254	4/29/2013	14.3	12.9	20.6	21.4	64.9	12.7	12.1	20.5	19.3		
255	4/30/2013						16.0	15.2	24.5	23.1		
256	5/1/2013	16.9	18.2	21.4	22.2	80.7	19.5	18.1	23.8	21.9		
257	5/2/2013						20.0	18.6	27.7	25.7		
258	5/3/2013	23.2	23.4	33.7	34.4	68.5	27.6	25.8	38.5	35.7		
259	5/4/2013	20.2	19.7	30.1	30.6	65.7	21.9	20.5	31.6	29.5		
260	5/5/2013	9.6	9.3	14.0	14.8	65.4	7.9	7.4	13.2	12.3		
261	5/14/2013										Zero filter	Bornheim, summer
262	5/15/2013										Zero filter	
263	5/16/2013	21.0	20.7	24.5	24.7	84.6	18.8	18.7	22.6	22.5		
264	5/17/2013	16.1	15.5	18.3	19.4	83.8	15.3	15.1	17.3	17.1		
265	5/18/2013						9.5	9.7	12.3	12.3		
266	5/19/2013						18.9	18.8	22.6	22.2		
267	5/20/2013	11.3	10.3	13.9	14.7	75.2	11.2	11.0	14.3	13.9		
268	5/21/2013		5.4	8.3	8.8		4.9	4.9	8.2	8.2	Power failure Ref. PM2,5 Device#1	
269	5/22/2013						6.9	6.9	11.1	10.8		
270	5/23/2013						5.5	5.5	7.4	7.2		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 10 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
271	5/24/2013			10.1	10.7		5.9	5.8	8.6	8.3	Power failure Ref. PM2,5 Device#1	Bornheim, summer
272	5/25/2013						10.5	10.5	14.1	14.0		
273	5/26/2013		6.6	12.9	13.4		7.9	7.6	11.1	10.7	Power failure Ref. PM2,5 Device#1	
274	5/27/2013	11.7	11.0	16.9	17.6	65.7	10.6	10.5	16.4	16.0		
275	5/28/2013	8.7	7.7	12.8	12.2	65.8	6.8	6.7	11.7	11.4		
276	5/29/2013						4.1	3.9	6.1	5.6		
277	5/30/2013						9.1	8.7	11.1	10.5		
278	5/31/2013						16.7	15.6	22.9	21.5		
279	6/1/2013						15.7	14.9	19.3	18.3		
280	6/2/2013	5.3	5.0	10.8	10.7	47.7	4.9	4.8	8.9	8.7		
281	6/3/2013	8.0	7.0	14.5	14.5	51.5	8.0	7.8	13.5	12.9		
282	6/4/2013	9.5	9.5	18.2	18.4	51.9	11.6	11.0	17.9	16.8		
283	6/5/2013	9.1	9.3	17.2	18.8	51.2	9.8	9.3	19.0	17.6		
284	6/6/2013	10.8	10.2	17.0	17.5	60.8	8.5	8.0	16.9	15.8		
285	6/7/2013	17.0	16.1	28.6	29.9	56.6	15.6	14.8	30.6	29.1		
286	6/8/2013						17.6	16.5	25.3	23.7		
287	6/9/2013	14.0	13.6	20.1	21.3	66.9	16.6	15.2	20.7	19.1		
288	6/10/2013	16.1	15.4	26.1	27.1	59.1	19.6	18.2	27.0	24.7		
289	6/11/2013	13.0	12.2	20.8	20.7	60.7	18.2	19.4	25.2	26.3		
290	6/12/2013	7.1	6.4	14.6	14.0	47.4	7.4	7.8	17.3	17.4		
291	6/13/2013	5.6	5.4	13.4	12.7	42.1	5.1	5.3	14.5	14.1		
292	6/14/2013	5.0	5.7	10.8	10.8	49.3	4.4	4.7	8.4	8.7		
293	6/15/2013	5.1	5.3	10.6	10.2	50.0	4.3	4.5	8.7	8.7		
294	6/16/2013	7.3	7.6	16.7	16.6	44.8	7.0	7.4	11.9	11.9		
295	6/17/2013	12.2	13.3	21.3	20.9	60.3	10.1	10.5	19.0	18.8		
296	6/18/2013	17.8	17.3	28.6	29.1	60.9	18.7	19.0	31.5	30.8		
297	6/19/2013	31.9	32.7	48.7	48.5	66.5	36.2	35.9	51.4	49.7		
298	6/20/2013	8.7	10.1	15.5	14.9	62.1	12.8	12.6	19.7	18.7		
299	6/21/2013	4.2	4.5	7.2	6.8	62.2	3.7	3.8	7.5	7.1		
300	6/22/2013	3.3	4.1	5.7	5.9	63.8					Zero filter	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 11 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
301	6/23/2013	3.1	3.0	4.6	5.5	59.8					Zero filter	Bornheim, summer
302	6/24/2013	8.7	8.0	13.9	13.2	61.6	9.8	9.6	13.5	13.0		
303	6/25/2013	6.3	6.6	12.9	12.7	50.4	7.2	7.0	11.2	10.9		
304	6/26/2013	9.1	9.4	14.6	14.5	63.4	9.0	8.8	13.1	12.4		
305	6/27/2013	9.8	9.6	14.2	13.8	69.5	9.9	9.5	14.0	13.1		
306	6/28/2013	8.8	8.7	14.2	14.7	60.4	9.4	8.9	15.5	14.7		
307	6/29/2013	6.0	5.8	11.7	11.5	50.8	5.4	5.0	9.9	9.0		
308	6/30/2013	7.4	6.9	14.6	14.4	49.3	6.9	6.5	13.1	11.9		
309	7/1/2013	7.7	7.6	13.4	13.2	57.5	8.0	7.4	14.8	13.1		
310	7/2/2013	7.9	7.9	12.5	12.0	64.9	7.8	7.3	12.9	11.8		
311	7/3/2013	3.6	3.8	9.0	9.9	39.1	4.6	4.2	11.1	9.6		
312	7/4/2013	7.5	7.9	13.5	13.6	56.8	8.0	7.2	13.3	11.9		
313	7/5/2013	12.9	13.1	20.9	19.9	63.8	14.8	13.2	21.7	19.0		
314	7/6/2013	13.3	13.1	18.7	18.5	71.0	15.2	13.8	20.3	18.3		
315	7/7/2013	11.3	10.7	14.9	14.4	75.0	10.9	9.8	15.0	13.2		
316	7/8/2013	11.3	10.6	16.3	16.1	67.7	10.1	9.0	16.4	14.4		
317	7/9/2013	14.2	14.5	24.9	22.6	60.5	15.9	14.1	24.5	21.1		
318	7/10/2013	9.7	10.2	19.1	17.5	54.6	11.8	10.4	19.9	17.0		
319	7/11/2013	13.6	14.3	26.6	24.9	54.1	17.5	17.1	25.1	24.0		
320	7/12/2013	16.5	16.8				22.0	21.3	30.3	28.8	Outlier Ref. PM10	
321	7/13/2013	15.3	15.3	20.4	20.7	74.5	18.3	17.5	23.4	22.1		
322	7/14/2013	14.5	14.5	22.2	21.5	66.5	19.7	18.7	26.7	24.7		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 12 of 22**

Manufacturer	PALAS		PM10
Type of instrument	FIDAS 200 S		Measured values in µg/m³ (STD)
Serial-No.	SN 0111 / SN 0112		

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
1	5/14/2012	-	-			-	21.3	21.5		Cologne, summer
2	5/15/2012	-	-	12.1	10.5	-	10.9	10.9		
3	5/16/2012	-	-	14.1	13.5	-	12.4	12.2		
4	5/17/2012	-	-	13.1	12.3	-	11.7	11.7		
5	5/18/2012	-	-	15.3	12.5	-	14.7	14.8	Outlier Ref. PM2,5	
6	5/19/2012	-	-			-	14.6	14.6		
7	5/20/2012	-	-	20.7	18.4	-	20.7	20.8		
8	5/21/2012	-	-			-	48.0	47.9	Outlier Ref. PM10	
9	5/22/2012	-	-			-	80.9	79.6		
10	5/23/2012	-	-	48.2	46.4	-	45.6	45.0	Outlier Ref. PM2,5	
11	5/24/2012	-	-	21.2	18.3	-	23.8	24.2		
12	5/25/2012	-	-	17.8	15.9	-	18.6	18.5		
13	5/26/2012	-	-			-	20.2	20.5		
14	5/27/2012	-	-			-	15.8	16.1		
15	5/28/2012	-	-	22.2	21.5	-	24.7	24.9		
16	5/29/2012	-	-	28.8	27.2	-		28.8	SN 0111 accidentally switched off via remote control	
17	5/30/2012	-	-	37.2	34.9	-	34.5	35.4		
18	5/31/2012	-	-	23.9	22.7	-	24.6	24.3		
19	6/1/2012	-	-	17.5	16.1	-	16.8	16.9		
20	6/2/2012	-	-			-	14.7	15.0		
21	6/3/2012	-	-	17.6	17.0	-	17.9	17.9		
22	6/4/2012	-	-	12.1	11.8	-	11.9	12.0		
23	6/5/2012	-	-	15.0	14.0	-	12.2	12.3		
24	6/6/2012	-	-			-	10.9	10.9		
25	6/7/2012	-	-	9.2	7.6	-	9.9	10.0		
26	6/8/2012	-	-			-	8.9	8.9		
27	6/9/2012	-	-			-	9.4	9.4		
28	6/10/2012	-	-			-			Power failure	
29	6/11/2012	-	-	10.1	8.8	-	10.7	10.6		
30	6/12/2012	-	-	20.8	21.3	-	19.2	19.0		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 13 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
31	6/13/2012	-	-	22.3	21.9	-	18.8	18.7		Cologne, summer
32	6/14/2012	-	-	24.3	22.8	-	21.1	21.1		
33	6/15/2012	-	-			-			Inlet -> Zero filter	
34	6/16/2012	-	-			-			Zero filter	
35	6/17/2012	-	-			-			Zero filter	
36	6/18/2012	-	-	18.3	16.9	-	16.6	16.6		
37	6/19/2012	-	-	31.1	30.8	-	29.1	28.5		
38	6/20/2012	-	-	20.2	19.7	-	20.3	19.8		
39	6/21/2012	-	-	10.3	9.4	-	10.9	10.8		
40	6/22/2012	-	-	14.2	14.3	-	12.3	12.3		
41	6/23/2012	-	-			-	11.2	11.3		
42	6/24/2012	-	-	9.4	11.5	-	9.6	9.5		
43	6/25/2012	-	-	16.0	17.5	-	15.7	15.2		
44	6/26/2012	-	-	0.0	21.2	-	17.7	17.6		
45	6/27/2012	-	-	19.0	20.2	-	19.9	19.0		
46	6/28/2012	-	-	19.4	18.9	-	22.6	22.3		
47	6/29/2012	-	-	24.7	25.4	-	28.7	27.9		
48	6/30/2012	-	-			-	19.1	18.7		
49	7/1/2012	-	-	13.1	12.9	-	11.7	11.4		
50	7/2/2012	-	-	12.2	13.1	-	11.6	11.3		
51	7/3/2012	-	-	18.5	16.4	-	14.6	14.8		
52	7/4/2012	-	-	17.3	18.4	-	17.5	17.2		
53	7/5/2012	-	-	14.5	15.2	-	15.9	15.5		
54	7/6/2012	-	-	11.7	11.3	-	10.6	10.6		
55	7/7/2012	-	-			-	8.7	8.6		
56	7/8/2012	-	-	6.9	7.2	-	6.8	6.8		
57	7/9/2012	-	-	13.4	13.1	-	13.1	13.0		
58	7/10/2012	-	-	13.7	12.4	-	13.3	13.3		
59	7/11/2012	-	-	7.4	8.6	-	7.1	7.1		
60	7/12/2012	-	-	8.8	7.5	-	7.7	7.7		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 14 of 22**

Manufacturer	PALAS	PM10
Type of instrument	FIDAS 200 S	Measured values in µg/m³ (STD)
Serial-No.	SN 0111 / SN 0112	

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
61	7/13/2012	-	-	7.1	7.0	-	6.8	6.9		Cologne, summer
62	7/14/2012	-	-			-	7.0	7.0		
63	7/15/2012	-	-	12.6	11.9	-	10.8	10.8		
64	7/16/2012	-	-	9.6	7.8	-	7.7	7.5		
65	7/17/2012	-	-	13.4	13.9	-	13.1	12.8		
66	7/18/2012	-	-	11.5	10.2	-	11.0	11.1		
67	7/19/2012	-	-	15.4	14.7	-	13.4	13.1		
68	7/20/2012	-	-			-			Zero filter	
69	7/21/2012	-	-			-			Zero filter	
70	7/22/2012	-	-			-			Zero filter	
71	7/23/2012	-	-	13.9	13.5	-	12.0	12.0		
72	7/24/2012	-	-	26.6	24.8	-	22.3	22.3		
73	7/25/2012	-	-	42.6	41.2	-	41.6	40.5		
74	7/26/2012	-	-	39.1	38.6	-	42.2	41.6		
75	7/27/2012	-	-			-	35.3	34.6		
76	7/28/2012	-	-			-	26.0	25.7		
77	7/29/2012	-	-	10.6	9.3	-	8.2	8.3		
78	7/30/2012	-	-	13.0	13.6	-	9.7	9.5		
79	7/31/2012	-	-	15.3	15.7	-	12.0	12.1		
80	8/1/2012	-	-	18.1	18.9	-	16.8	16.5		
81	8/2/2012	-	-	14.2	14.5	-	12.2	12.2		
82	8/3/2012	-	-			-	13.2	13.3		
83	8/4/2012	-	-			-	11.7	11.7		
84	8/5/2012	-	-	9.0	9.7	-	8.6	8.4		
85	8/6/2012	-	-	8.7	10.3	-	7.9	7.6		
86	8/7/2012	-	-	14.3	13.6	-	11.0	10.8		
87	8/8/2012	-	-	17.3	17.7	-	13.6	13.5		
88	8/9/2012	-	-	13.0	13.6	-	12.5	12.3		
89	8/10/2012	-	-			-	11.3	11.2		
90	8/11/2012	-	-			-	9.6	9.3		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 15 of 22**

Manufacturer PALAS
Type of instrument FIDAS 200 S
Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
91	8/12/2012	-	-	10.8	10.9	-	10.5	10.4		Cologne, summer
92	8/13/2012	-	-	16.8	18.3	-	16.4	16.1		
93	8/14/2012	-	-	18.7	18.1	-	16.0	15.7		
94	8/15/2012	-	-	21.4	22.0	-	22.0	21.0		
95	8/16/2012	-	-	19.3	21.1	-	14.0	13.5		
96	8/17/2012	-	-			-			Zero filter	
97	8/18/2012	-	-			-			Zero filter	
98	8/19/2012	-	-			-			Zero filter	
99	8/20/2012	-	-	31.0	31.6	-	29.3	28.0		
100	8/21/2012	-	-	31.9	32.0	-	32.1	30.4		
101	8/22/2012	-	-	22.1	21.4	-	19.0	18.5		
102	8/23/2012	-	-	15.6	14.9	-	12.7	12.2		
103	8/24/2012	-	-	16.5	16.4	-	15.0	14.2		
104	8/25/2012	-	-			-	6.7	6.3		
105	8/26/2012	-	-	12.7	11.8	-	11.0	10.8		
106	8/27/2012	-	-	11.5	11.5	-	9.4	9.2		
107	8/28/2012	-	-	15.8	18.2	-	13.9	13.3		
108	8/29/2012	-	-	17.8	17.9	-	14.7	14.5		
109	8/30/2012	-	-	15.2	15.4	-	13.0	12.6		
110	8/31/2012	-	-	11.2	11.5	-	10.4	10.2		
111	9/1/2012	-	-			-	13.3	12.7		
112	9/2/2012	-	-	19.8	19.0	-	14.4	13.9		
113	11/19/2012	-	-			-			Zero filter	Cologne, winter
114	11/20/2012	-	-			-			Zero filter	
115	11/21/2012	-	-			-				
116	11/22/2012	-	-			-	14.6	14.3		
117	11/23/2012	-	-	20.2	20.3	-	21.1	20.3		
118	11/24/2012	-	-			-	20.2	20.0		
119	11/25/2012	-	-	11.2	10.9	-	10.5	10.4		
120	11/26/2012	-	-	11.5	12.2	-	11.6	11.3		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 16 of 22**

Manufacturer	PALAS	
Type of instrument	FIDAS 200 S	PM10 Measured values in µg/m³ (STD)
Serial-No.	SN 0111 / SN 0112	

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
121	11/27/2012	-	-	19.2	18.4	-	16.5	16.4		Cologne, winter
122	11/28/2012	-	-	30.0	30.2	-	31.7	31.2		
123	11/29/2012	-	-	14.6	14.8	-	15.1	15.1		
124	11/30/2012	-	-	24.7	24.7	-	23.7	23.0		
125	12/1/2012	-	-			-	16.3	15.8		
126	12/2/2012	-	-	15.1	15.0	-	14.9	14.6		
127	12/3/2012	-	-	14.5	14.8	-	13.9	13.4		
128	12/4/2012	-	-	12.0	12.1	-	12.2		SN 0112 Fuse for heater burned	
129	12/5/2012	-	-	12.3	12.8	-		12.4	SN 0111 Fuse for heater burned	
130	12/6/2012	-	-	16.7	16.3	-	16.9	16.2		
131	12/7/2012	-	-	15.4	15.5	-	15.5	14.7		
132	12/8/2012	-	-			-	31.1		SN 0112 Fuse for heater burned	
133	12/9/2012	-	-	10.4	9.1	-	10.0		SN 0112 Fuse for heater burned	
134	12/10/2012	-	-	14.6	13.7	-	16.0	14.8		
135	12/11/2012	-	-	23.4	22.7	-	23.6	22.6		
136	12/12/2012	-	-	24.6	24.3	-	23.0	22.3		
137	12/13/2012	-	-	29.7	28.7	-	28.2	27.4		
138	12/14/2012	-	-	9.3	9.2	-	9.7	9.3		
139	12/15/2012	-	-			-	6.8	6.4		
140	12/16/2012	-	-	10.1	9.9	-	9.6	9.1		
141	12/17/2012	-	-	14.2	13.9	-	13.9	13.1		
142	12/18/2012	-	-	20.5	21.0	-	19.5	18.4		
143	12/19/2012	-	-	18.5	18.3	-	18.4	17.6		
144	12/20/2012	-	-	14.3	13.9	-	14.1	13.5		
145	12/21/2012	-	-	18.5	18.4	-	17.7	16.9		
146	12/22/2012	-	-			-	6.7	6.3		
147	12/23/2012	-	-			-	6.6	6.4		
148	12/24/2012	-	-			-	15.5	14.9		
149	12/25/2012	-	-			-	4.1	3.9		
150	12/26/2012	-	-			-	9.7	9.2		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 17 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
151	12/27/2012	-	-			-	16.9	16.6		Cologne, winter
152	12/28/2012	-	-			-	7.2	7.0		
153	12/29/2012	-	-			-	6.1	5.9		
154	12/30/2012	-	-			-	9.0	8.7		
155	12/31/2012	-	-			-			Power failure	
156	1/1/2013	-	-			-			Power failure	
157	1/2/2013	-	-	16.4	15.3	-	16.0	15.2		
158	1/3/2013	-	-	19.8	19.1	-	21.9	20.9		
159	1/4/2013	-	-	14.0	13.3	-	14.6	14.2		
160	1/5/2013	-	-			-	21.7	21.2		
161	1/6/2013	-	-	38.2	38.4	-	36.4	35.3		
162	1/7/2013	-	-	25.0	25.7	-	24.5	23.9		
163	1/8/2013	-	-	20.0	20.6	-	21.4	20.8		
164	1/9/2013	-	-	19.2	20.2	-	20.1	19.4		
165	1/10/2013	-	-	22.3	22.0	-	20.1	19.6		
166	1/11/2013	-	-			-			Zero filter	
167	1/12/2013	-	-			-			Zero filter	
168	1/13/2013	-	-			-			Zero filter	
169	1/14/2013	-	-	28.4	29.5	-	27.6	26.7		
170	1/15/2013	-	-	36.5	37.6	-	34.5	32.7		
171	1/16/2013	-	-	63.6	63.6	-	66.9	64.4		
172	1/17/2013	-	-	59.9	59.9	-	60.9	59.4		
173	1/18/2013	-	-	19.2	18.9	-	20.4	20.0		
174	1/19/2013	-	-	22.9	23.4	-	24.9	24.2		
175	1/20/2013	-	-	31.5	32.0	-	35.7	34.2		
176	1/21/2013	-	-	45.8	45.8	-	50.8	48.7		
177	1/22/2013	-	-	62.3	59.3	-	64.7	61.9	Outlier Ref. PM10 - not discarded	
178	1/23/2013	-	-	69.6	69.6	-	75.1	71.8		
179	1/24/2013	-	-	27.7	28.1	-	27.3	26.1		
180	1/25/2013	-	-	21.1	20.5	-	20.5	19.6		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 18 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
181	1/26/2013	-	-	28.5	28.7	-	28.0	26.7		Cologne, winter
182	1/27/2013	-	-	15.3	15.4	-	15.2	14.5		
183	1/28/2013	-	-	9.2	8.2	-	8.6	8.2		
184	1/29/2013	-	-	5.8	4.8	-	5.8	5.4		
185	1/30/2013	-	-	15.8	15.6	-	14.2	13.4		
186	1/31/2013	-	-	21.0	20.0	-	17.9	17.1		
187	2/1/2013	-	-	12.3	11.4	-	11.4	10.7		
188	2/2/2013	-	-			-	12.2	11.6		
189	2/3/2013	-	-			-	10.9	10.3		
190	2/4/2013	-	-			-	15.2	14.4		
191	2/5/2013	-	-			-			Zero filter	
192	2/6/2013	-	-			-			Zero filter	
193	2/27/2013	-	-			-			Zero filter	Bonn, winter
194	2/28/2013	-	-			-			Zero filter	
195	3/1/2013	-	-	36.6	37.1	-	38.9	38.5		
196	3/2/2013	-	-			-	43.7	43.1		
197	3/3/2013	-	-	29.5	30.2	-	28.9	28.7		
198	3/4/2013	-	-	28.9	29.7	-	30.5	30.4		
199	3/5/2013	-	-	41.8	41.8	-	43.4	42.9		
200	3/6/2013	-	-	41.5	42.3	-	42.1	41.4		
201	3/7/2013	-	-	41.9	42.3	-	43.7	42.8		
202	3/8/2013	-	-	37.8	37.4	-	42.3	41.3		
203	3/9/2013	-	-	0.0	0.0	-	16.6	16.1		
204	3/10/2013	-	-	23.6	22.9	-	27.4	26.7		
205	3/11/2013	-	-	31.5	30.8	-	34.5	33.8		
206	3/12/2013	-	-	17.9	17.9	-	19.5	18.6		
207	3/13/2013	-	-	51.3	50.9	-	46.4	44.9		
208	3/14/2013	-	-	27.5	27.9	-	29.7	28.9		
209	3/15/2013	-	-	32.0	32.3	-	32.7	32.0		
210	3/16/2013	-	-			-	26.1	25.9		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 19 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
211	3/17/2013	-	-	11.4	11.0	-	13.5	13.3		Bonn, winter
212	3/18/2013	-	-	18.2	18.1	-	18.3	17.6		
213	3/19/2013	-	-	17.7	17.5	-	18.0	16.8		
214	3/20/2013	-	-	25.8	25.2	-	26.4	24.8		
215	3/21/2013	-	-	46.4	46.3	-	46.2	44.3		
216	3/22/2013	-	-	26.4	26.8	-	31.0	29.5		
217	3/23/2013	-	-			-	28.7	27.8		
218	3/24/2013	-	-	19.9	19.1	-	21.1	20.3		
219	3/25/2013	-	-	26.2	25.9	-	29.6	28.5		
220	3/26/2013	-	-	21.4	20.8	-	23.3	22.5		
221	3/27/2013	-	-	33.9	33.6	-	35.4	33.6		
222	3/28/2013	-	-			-	60.6	57.2		
223	3/29/2013	-	-	78.1	77.4	-	79.3	74.6		
224	3/30/2013	-	-			-			Zero filter	
225	3/31/2013	-	-			-			Zero filter	
226	4/1/2013	-	-			-			Zero filter	
227	4/2/2013	-	-	25.2	25.8	-	28.7	27.2		
228	4/3/2013	-	-	31.9	31.5	-	36.0	33.8		
229	4/4/2013	-	-	34.3	34.2	-	40.7	41.4		
230	4/5/2013	-	-	31.5	30.8	-	34.9	35.5		
231	4/6/2013	-	-			-	30.7	30.8		
232	4/7/2013	-	-	31.7	31.2	-	33.6	33.4		
233	4/8/2013	-	-	32.9	33.1	-	36.7	37.0		
234	4/9/2013	-	-	22.6	22.2	-	22.4	22.3		
235	4/10/2013	-	-	18.7	18.8	-	17.6	17.1		
236	4/11/2013	-	-	16.9	16.9	-	14.5	14.1		
237	4/12/2013	-	-	11.0	11.1	-	10.1	9.3		
238	4/13/2013	-	-			-	11.4	10.9		
239	4/14/2013	-	-	12.6	11.9	-	9.8	9.7		
240	4/15/2013	-	-	33.0	32.3	-	30.6	29.5		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 20 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
241	4/16/2013	-	-	22.4	22.2	-	22.2	21.7		Bonn, winter
242	4/17/2013	-	-	20.9	21.2	-	20.5	20.0		
243	4/18/2013	-	-	22.6	22.9	-	22.0	21.5		
244	4/19/2013	-	-	21.7	21.7	-	21.4	20.5		
245	4/20/2013	-	-			-	21.5	20.8		
246	4/21/2013	-	-	38.2	39.4	-	34.9	34.0		
247	4/22/2013	-	-	46.8	46.4	-	49.7	47.7		
248	4/23/2013	-	-	19.0	19.8	-	20.5	19.5		
249	4/24/2013	-	-	25.7	26.0	-	26.9	26.1		
250	4/25/2013	-	-	24.9	25.4	-	26.6	25.6		
251	4/26/2013	-	-			-			Zero filter	
252	4/27/2013	-	-			-			Zero filter	
253	4/28/2013	-	-			-			Zero filter	
254	4/29/2013	-	-	21.5	22.6	-	21.4	20.2		
255	4/30/2013	-	-			-	25.6	24.1		
256	5/1/2013	-	-	22.4	23.4	-	25.1	23.1		
257	5/2/2013	-	-			-	29.4	27.4		
258	5/3/2013	-	-	35.6	36.7	-	41.0	38.0		
259	5/4/2013	-	-	31.7	32.5	-	33.5	31.3		
260	5/5/2013	-	-	14.8	15.7	-	14.0	13.0		
261	5/14/2013	-	-			-			Zero filter	Bornheim, summer
262	5/15/2013	-	-			-			Zero filter	
263	5/16/2013	-	-	26.2	26.6	-	24.2	24.1		
264	5/17/2013	-	-	19.3	20.5	-	18.2	18.0		
265	5/18/2013	-	-			-	13.0	13.0		
266	5/19/2013	-	-			-	24.4	23.9		
267	5/20/2013	-	-	14.6	15.6	-	15.1	14.6		
268	5/21/2013	-	-	8.7	9.4	-	8.6	8.7	Power failure Ref. PM2,5 Device#1	
269	5/22/2013	-	-			-	11.5	11.3		
270	5/23/2013	-	-			-	7.6	7.5		

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 21 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
271	5/24/2013	-	-	10.5	11.1	-	8.9	8.6	Power failure Ref. PM2,5 Device#1	Bornheim, summer
272	5/25/2013	-	-			-	14.8	14.7		
273	5/26/2013	-	-	13.4	14.0	-	11.6	11.2	Power failure Ref. PM2,5 Device#1	
274	5/27/2013	-	-	18.0	18.7	-	17.5	17.0		
275	5/28/2013	-	-	13.8	13.3	-	12.7	12.4		
276	5/29/2013	-	-			-	6.4	5.9		
277	5/30/2013	-	-			-	11.8	11.2		
278	5/31/2013	-	-			-	24.6	23.0		
279	6/1/2013	-	-			-	20.3	19.1		
280	6/2/2013	-	-	11.3	11.3	-	9.3	9.1		
281	6/3/2013	-	-	15.0	15.1	-	14.0	13.4		
282	6/4/2013	-	-	19.2	19.5	-	18.9	17.7		
283	6/5/2013	-	-	18.4	20.2	-	20.4	18.9		
284	6/6/2013	-	-	18.2	18.9	-	18.3	17.0		
285	6/7/2013	-	-	30.8	32.3	-	33.1	31.5		
286	6/8/2013	-	-			-	27.5	25.7		
287	6/9/2013	-	-	21.4	22.8	-	22.1	20.4		
288	6/10/2013	-	-	27.6	28.9	-	28.6	26.2		
289	6/11/2013	-	-	22.2	22.3	-	27.0	28.2		
290	6/12/2013	-	-	15.7	15.1	-	18.7	18.8		
291	6/13/2013	-	-	14.2	13.6	-	15.5	15.0		
292	6/14/2013	-	-	11.5	11.5	-	8.9	9.2		
293	6/15/2013	-	-	11.3	10.9	-	9.3	9.3		
294	6/16/2013	-	-	17.9	17.7	-	12.8	12.8		
295	6/17/2013	-	-	23.3	22.8	-	20.8	20.6		
296	6/18/2013	-	-	31.5	32.1	-	34.8	34.0		
297	6/19/2013	-	-	53.8	53.8	-	56.9	55.0		
298	6/20/2013	-	-	16.8	16.1	-	21.4	20.3		
299	6/21/2013	-	-	7.7	7.3	-	8.1	7.6		
300	6/22/2013	-	-	6.1	6.4	-			Zero filter	

Annex 5 **PM_{10}-measured values from field test sites, related to standard conditions [EN 12431]** **Page 22 of 22**

Manufacturer	PALAS
Type of instrument	FIDAS 200 S
Serial-No.	SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref 2. PM10 [µg/Nm³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm³]	SN 0112 PM10 [µg/Nm³]	Remark	Test site
301	6/23/2013	-	-	4.9	5.8	-			Zero filter	Bornheim, summer
302	6/24/2013	-	-	14.6	13.9	-	14.3	13.7		
303	6/25/2013	-	-	13.5	13.2	-	11.7	11.3		
304	6/26/2013	-	-	15.3	15.2	-	13.6	12.9		
305	6/27/2013	-	-	14.9	14.5	-	14.7	13.8		
306	6/28/2013	-	-	15.0	15.6	-	16.3	15.5		
307	6/29/2013	-	-	12.3	12.2	-	10.5	9.5		
308	6/30/2013	-	-	15.5	15.4	-	13.9	12.7		
309	7/1/2013	-	-	14.3	14.2	-	15.9	14.0		
310	7/2/2013	-	-	13.6	13.0	-	14.0	12.9		
311	7/3/2013	-	-	9.7	10.6	-	11.9	10.3		
312	7/4/2013	-	-	14.4	14.6	-	14.2	12.7		
313	7/5/2013	-	-	22.2	21.2	-	23.1	20.2		
314	7/6/2013	-	-	20.0	19.9	-	21.7	19.6		
315	7/7/2013	-	-	16.0	15.5	-	16.1	14.2		
316	7/8/2013	-	-	17.6	17.3	-	17.7	15.5		
317	7/9/2013	-	-	26.9	24.5	-	26.5	22.9		
318	7/10/2013	-	-	20.4	18.8	-	21.3	18.2		
319	7/11/2013	-	-	28.1	26.3	-	26.5	25.3		
320	7/12/2013	-	-			-	32.1	30.5	Outlier Ref. PM10	
321	7/13/2013	-	-	21.7	22.0	-	24.9	23.5		
322	7/14/2013	-	-	23.7	23.0	-	28.5	26.4		

Annex 6 **Ambient conditions from field test sites** **Page 1 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	5/14/2012	Cologne, summer	15.4	22.1	1006	52.7	0.9	144	0.9
2	5/15/2012		9.2	15.7	1006	76.3	1.2	119	6.0
3	5/16/2012		8.9	14.6	1016	65.0	1.1	138	1.2
4	5/17/2012		14.4	18.8	1008	46.4	0.9	177	0.0
5	5/18/2012		15.4	20.0	1003	72.3	0.6	187	0.0
6	5/19/2012		19.3	24.9	1002	65.9	0.2	231	0.0
7	5/20/2012		19.5	27.8	997	70.6	0.2	148	0.3
8	5/21/2012		21.2	26.4	993	68.1	0.4	135	0.0
9	5/22/2012		21.5	27.6	1005	72.2	0.5	110	0.0
10	5/23/2012		20.3	26.0	1015	76.0	0.2	176	0.0
11	5/24/2012		23.2	31.5	1017	50.4	0.7	159	0.0
12	5/25/2012		21.2	28.6	1016	39.9	1.0	177	0.0
13	5/26/2012		21.3	28.1	1013	46.2	0.6	187	0.0
14	5/27/2012		21.4	28.1	1010	51.8	0.3	200	0.0
15	5/28/2012		21.7	27.8	1007	53.4	0.8	108	0.0
16	5/29/2012		20.4	25.4	1008	57.7	0.9	104	0.0
17	5/30/2012		19.8	24.7	1011	61.7	0.7	140	0.0
18	5/31/2012		17.1	24.4	1009	76.1	0.9	130	13.3
19	6/1/2012		15.0	18.4	1011	68.6	0.8	107	0.0
20	6/2/2012		15.2	20.2	1006	58.2	0.7	151	3.0
21	6/3/2012		11.9	15.2	1002	87.2	0.3	154	6.8
22	6/4/2012		12.2	20.2	1006	80.4	0.9	125	7.2
23	6/5/2012		14.2	19.0	1007	60.8	0.5	167	6.5
24	6/6/2012		16.0	20.0	1000	78.5	0.4	165	5.0
25	6/7/2012		19.7	24.5	996	69.4	1.1	178	0.3
26	6/8/2012		17.5	23.1	1003	58.9	2.7	189	0.3
27	6/9/2012		15.5	19.9	1006	57.5	1.6	166	0.0
28	6/10/2012		17.8	26.6	1000	56.8	0.3	184	0.0
29	6/11/2012		15.5	19.9	995	81.8	0.4	151	26.6
30	6/12/2012		16.4	21.1	1000	72.0	0.8	116	0.0

Annex 6 **Ambient conditions from field test sites** **Page 2 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	6/13/2012	Cologne, summer	13.9	15.4	1010	71.0	0.2	114	0.0
32	6/14/2012		16.4	20.9	1010	65.0	0.2	174	0.3
34	6/15/2012		17.8	21.8	1007	79.2	0.4	152	11.6
34	6/16/2012		15.7	18.1	1010	82.0	0.6	155	1.8
35	6/17/2012		18.4	24.1	1011	61.8	0.6	133	0.0
36	6/18/2012		18.9	24.9	1011	69.1	0.7	137	0.0
37	6/19/2012		18.6	21.4	1010	73.9	0.1	149	7.5
38	6/20/2012		18.6	23.0	1006	82.1	0.3	135	2.1
39	6/21/2012		19.0	24.6	1005	76.2	0.4	151	12.7
40	6/22/2012		17.0	21.9	1013	64.6	1.2	161	0.6
41	6/23/2012		18.6	23.4	1014	59.4	0.7	138	0.0
42	6/24/2012		15.7	20.0	1006	76.5	1.6	162	6.9
43	6/25/2012		15.5	19.9	1012	71.5	0.8	124	0.6
44	6/26/2012		19.1	24.2	1014	61.4	0.5	138	0.0
45	6/27/2012		20.3	23.2	1009	82.7	0.3	136	0.3
46	6/28/2012		24.9	32.0	1001	68.1	0.7	172	10.0
47	6/29/2012		19.7	27.4	1004	84.5	0.2	146	29.5
48	6/30/2012		21.2	26.0	1006	67.3	0.6	152	0.0
49	7/1/2012		17.3	23.2	1012	64.9	0.4	150	0.0
50	7/2/2012		17.5	21.9	1012	71.0	0.2	183	0.0
51	7/3/2012		22.2	27.7	1009	59.9	0.2	163	0.0
52	7/4/2012		24.0	28.8	1004	60.6	0.5	171	0.0
53	7/5/2012		23.6	30.6	1002	68.8	0.4	189	0.0
54	7/6/2012		21.0	27.2	1005	63.9	0.7	167	0.0
55	7/7/2012		20.6	25.9	1003	65.6	0.2	157	5.9
56	7/8/2012		18.8	22.6	1002	72.1	1.6	170	9.8
57	7/9/2012		19.8	25.2	1006	65.8	0.5	144	0.0
58	7/10/2012		18.4	24.8	1005	77.5	0.5	145	8.0
59	7/11/2012		16.1	21.6	1006	70.2	1.2	163	1.5
60	7/12/2012		17.2	22.2	1005	66.6	0.9	150	11.3

Annex 6 **Ambient conditions from field test sites** **Page 3 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	7/13/2012	Cologne, summer	16.0	22.7	996	83.8	0.8	133	implausible
62	7/14/2012		16.3	19.5	1001	74.9	1.4	110	3.0
63	7/15/2012		14.6	17.5	1011	81.4	0.9	106	9.8
64	7/16/2012		16.0	18.9	1014	77.8	1.8	130	implausible
65	7/17/2012		17.8	22.2	1014	79.3	1.3	108	implausible
66	7/18/2012		21.0	28.2	1003	60.9	1.9	128	implausible
67	7/19/2012		17.0	21.6	1005	73.5	1.6	114	implausible
68	7/20/2012		16.1	20.1	1010	80.0	0.2	117	8.6
69	7/21/2012		15.0	19.5	1017	69.3	0.4	175	0.0
70	7/22/2012		17.6	24.8	1021	62.3	0.1	202	0.0
71	7/23/2012		20.6	27.2	1016	56.2	0.6	161	0.0
72	7/24/2012		23.7	31.4	1009	60.7	0.2	166	0.0
73	7/25/2012		25.3	32.0	1008	59.5	0.1	124	0.0
74	7/26/2012		26.1	32.7	1008	59.4	0.4	138	0.0
75	7/27/2012		23.3	34.6	1002	76.6	0.4	151	12.4
76	7/28/2012		19.3	23.1	1002	83.5	0.1	137	15.4
77	7/29/2012		17.8	23.3	1008	64.0	0.9	143	6.5
78	7/30/2012		16.6	21.8	1011	69.1	0.5	144	1.2
79	7/31/2012		18.4	22.2	1010	67.4	0.2	171	0.0
80	8/1/2012		25.4	31.1	1003	57.8	0.9	182	0.0
81	8/2/2012		20.5	25.0	1008	69.7	0.4	143	0.0
82	8/3/2012		20.5	25.9	1008	67.8	0.3	161	1.8
83	8/4/2012		20.1	26.8	1005	74.3	0.3	162	3.6
84	8/5/2012		19.3	25.8	1002	81.7	0.5	159	8.9
85	8/6/2012		19.2	23.6	1008	64.4	1.8	149	0.0
86	8/7/2012		17.3	20.9	1015	66.3	0.6	137	0.0
87	8/8/2012		19.2	22.6	1017	72.0	0.3	118	0.0
88	8/9/2012		18.7	24.6	1018	65.8	0.6	136	0.0
89	8/10/2012		17.3	23.9	1018	64.3	0.5	150	0.0
90	8/11/2012		18.7	24.4	1012	61.4	0.4	174	0.0

Annex 6 **Ambient conditions from field test sites** **Page 4 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	8/12/2012	Cologne, summer	20.8	26.6	1007	53.4	0.8	170	0.0
92	8/13/2012		23.0	28.9	1006	57.3	0.4	188	0.0
93	8/14/2012		22.6	29.6	1006	69.6	0.3	156	1.5
94	8/15/2012		24.4	33.2	1005	62.6	0.8	148	8.0
95	8/16/2012		22.0	28.2	1012	58.4	0.5	149	0.0
96	8/17/2012		24.3	30.8	1012	55.0	0.5	169	implausible
97	8/18/2012		27.8	35.8	1010	53.2	0.7	170	0.0
98	8/19/2012		30.7	39.5	1008	53.8	0.7	149	0.0
99	8/20/2012		24.4	31.1	1012	70.9	0.2	154	1.2
100	8/21/2012		24.3	31.1	1008	64.2	0.3	123	0.6
101	8/22/2012		19.4	25.9	1010	60.8	0.5	139	0.0
102	8/23/2012		20.7	27.4	1004	53.8	0.4	158	3.0
103	8/24/2012		20.1	26.0	999	70.6	0.3	136	7.1
104	8/25/2012		20.5	25.7	1000	61.1	2.3	194	4.4
105	8/26/2012		15.7	18.5	1010	83.5	0.8	148	2.7
106	8/27/2012		20.3	26.0	1010	59.3	0.5	177	0.0
107	8/28/2012		21.0	26.8	1010	65.6	0.5	160	0.0
108	8/29/2012		22.3	29.9	1008	62.7	0.8	148	0.0
109	8/30/2012		18.7	23.4	1009	63.3	0.8	153	1.2
110	8/31/2012		No weather data available						
111	9/1/2012								
112	9/2/2012								
113	11/19/2012	Cologne, winter	No weather data available						
114	11/20/2012								
115	11/21/2012								
116	11/22/2012		8.2	13.4	1013	79.5	0.6	150	0.0
117	11/23/2012		8.5	9.6	1010	88.3	0.1	147	9.3
118	11/24/2012		11.6	14.7	1005	78.5	0.9	156	0.3
119	11/25/2012		8.8	13.7	1004	70.3	1.4	161	0.3
120	11/26/2012		8.9	9.8	997	83.3	0.3	150	5.9

Annex 6 **Ambient conditions from field test sites** **Page 5 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
121	11/27/2012	Cologne, winter	7.5	10.6	998	81.2	0.1	125	0.3
122	11/28/2012		6.0	7.4	997	81.3	1.8	84	0.0
123	11/29/2012		4.0	5.3	999	81.0	1.0	80	0.0
124	11/30/2012		1.6	4.7	1005	83.8	0.1	157	0.0
125	12/1/2012		2.9	5.8	1003	83.1	0.7	156	5.1
126	12/2/2012		3.9	5.3	1006	82.3	1.3	146	0.3
127	12/3/2012		3.7	5.8	997	87.7	0.5	158	7.2
128	12/4/2012		4.5	6.6	993	84.3	1.0	114	5.7
129	12/5/2012		2.1	4.2	999	85.7	0.8	120	4.2
130	12/6/2012		0.9	4.1	1005	79.9	0.7	151	0.0
131	12/7/2012		-2.6	0.0	1001	89.4	0.0	108	0.0
132	12/8/2012		-2.6	1.9	1016	86.2	0.0	125	0.9
134	12/9/2012		4.0	4.9	1002	87.0	1.8	149	16.1
134	12/10/2012		1.9	4.6	1010	81.4	2.6	78	1.8
135	12/11/2012		-0.2	1.4	1018	74.8	0.8	128	0.0
136	12/12/2012		-0.5	4.7	1010	71.4	0.5	136	0.0
137	12/13/2012		0.9	3.8	1000	75.6	0.5	148	0.0
138	12/14/2012		7.1	9.5	988	82.4	1.3	157	4.2
139	12/15/2012		8.7	12.1	995	78.6	1.2	173	4.7
140	12/16/2012		7.2	11.0	997	85.2	0.4	151	7.4
141	12/17/2012		7.2	10.1	999	85.4	0.1	141	3.0
142	12/18/2012		6.2	7.6	1011	88.1	0.0	145	0.9
143	12/19/2012		4.2	6.3	1014	85.6	0.3	154	0.0
144	12/20/2012		2.8	4.2	1003	85.8	1.4	150	7.2
145	12/21/2012		6.0	7.6	1007	91.2	0.0	153	2.1
146	12/22/2012		8.7	13.3	1001	89.0	1.0	148	25.7
147	12/23/2012		10.6	14.5	1001	87.5	0.8	139	8.4
148	12/24/2012		11.8	13.8	995	76.0	0.7	155	2.4
149	12/25/2012		9.4	11.8	996	77.1	2.1	162	4.2
150	12/26/2012		9.1	10.9	1000	76.1	2.3	165	4.2

Annex 6 **Ambient conditions from field test sites** **Page 6 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
151	12/27/2012	Cologne, winter	7.3	10.9	1004	86.2	0.5	129	9.8
152	12/28/2012		8.4	10.0	1015	85.1	0.5	157	1.8
153	12/29/2012		10.4	12.2	1005	72.7	2.2	168	0.3
154	12/30/2012		8.6	9.9	1009	72.5	2.6	171	3.3
155	12/31/2012		9.9	11.2	1000	71.3	3.3	177	2.1
156	1/1/2013		6.1	8.9	1006	82.0	0.7	143	3.0
157	1/2/2013		7.5	9.4	1020	79.6	0.8	155	1.8
158	1/3/2013		10.6	11.0	1026	88.3	0.6	126	2.4
159	1/4/2013		9.1	10.8	1027	89.3	0.7	120	0.9
160	1/5/2013		8.4	9.2	1025	86.1	0.3	126	0.0
161	1/6/2013		9.1	9.7	1022	86.6	0.4	115	0.0
162	1/7/2013		8.2	10.2	1020	80.0	0.3	143	0.0
163	1/8/2013		7.6	8.9	1017	78.6	0.3	141	0.0
164	1/9/2013		5.8	6.3	1010	87.0	0.2	136	6.3
165	1/10/2013		4.0	7.6	1006	80.2	0.7	129	2.4
166	1/11/2013		-1.4	2.3	1011	78.3	0.0	153	0.0
167	1/12/2013		-1.5	2.6	1010	70.1	0.1	141	0.0
168	1/13/2013		-0.6	2.7	1009	70.0	0.2	145	0.0
169	1/14/2013		-2.5	0.0	1003	77.5	0.6	140	0.0
170	1/15/2013		-1.5	-0.1	999	87.5	0.1	139	0.0
171	1/16/2013		-2.1	-1.3	1006	84.8	0.0	87	0.0
172	1/17/2013		-2.0	-1.2	1009	84.7	0.2	118	0.0
173	1/18/2013		-1.2	0.4	997	75.2	0.9	147	0.0
174	1/19/2013		-3.3	-1.4	990	73.9	0.7	147	0.0
175	1/20/2013		-0.9	-0.1	988	84.1	0.0	148	0.0
176	1/21/2013		-0.1	0.9	993	84.0	0.0	152	0.0
177	1/22/2013		0.2	1.3	999	80.4	0.0	149	0.0
178	1/23/2013		-0.5	1.8	1002	78.9	0.2	128	0.6
179	1/24/2013		-1.1	-0.3	1010	74.4	0.6	126	0.0
180	1/25/2013		-1.9	-0.7	1008	77.1	1.0	155	0.0

Annex 6 **Ambient conditions from field test sites** **Page 7 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
181	1/26/2013	Cologne, winter	-0.1	2.7	1004	81.5	0.9	148	0.6
182	1/27/2013		3.1	5.2	999	85.4	0.9	160	10.2
183	1/28/2013		6.9	10.2	1004	78.3	1.9	172	9.8
184	1/29/2013		11.9	15.0	1001	82.4	2.0	177	4.2
185	1/30/2013		10.9	15.8	1005	71.5	2.9	149	4.4
186	1/31/2013		8.6	10.1	1004	72.4	2.4	155	5.9
187	2/1/2013		5.0	7.5	990	88.1	0.9	127	11.7
188	2/2/2013		3.7	4.9	1006	78.8	1.8	94	0.9
189	2/3/2013		5.8	9.2	1006	82.0	2.0	144	3.0
190	2/4/2013		7.5	10.9	1000	76.2	1.9	149	3.3
191	2/5/2013		2.5	7.0	990	79.2	1.0	142	0.9
192	2/6/2013		2.4	3.6	997	84.5	0.9	112	5.4
193	2/27/2013	Bonn, winter	2.5	3.6	1021	78.9	0.9	185	0.0
194	2/28/2013		4.1	6.8	1017	71.8	1.2	250	0.0
195	3/1/2013		3.5	4.8	1016	72.0	1.7	249	0.0
196	3/2/2013		3.0	5.8	1015	67.4	1.2	238	0.0
197	3/3/2013		3.1	6.0	1014	72.8	0.5	196	0.0
198	3/4/2013		6.6	12.4	1007	57.8	1.4	140	0.0
199	3/5/2013		8.5	14.0	999	56.5	1.2	136	0.0
200	3/6/2013		11.5	18.7	993	48.5	0.4	143	0.0
201	3/7/2013		12.3	16.4	990	67.5	0.5	144	2.1
202	3/8/2013		13.7	18.3	990	72.1	1.4	138	1.5
203	3/9/2013		10.6	13.7	991	72.2	1.2	178	3.6
204	3/10/2013		1.6	5.7	993	81.8	3.6	273	2.4
205	3/11/2013		-1.4	0.4	996	78.7	1.9	241	0.0
206	3/12/2013		-3.4	-1.2	995	83.9	2.0	276	0.0
207	3/13/2013		-1.2	0.8	999	72.8	1.1	224	0.3
208	3/14/2013		-1.3	2.0	1004	75.3	1.1	209	2.1
209	3/15/2013		2.3	5.7	1006	58.8	1.0	132	2.1
210	3/16/2013		5.3	7.8	998	49.0	3.4	131	0.0

Annex 6 **Ambient conditions from field test sites** **Page 8 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
211	3/17/2013	Bonn, winter	4.7	6.1	988	78.3	2.2	131	0.9
212	3/18/2013		6.6	11.1	985	60.3	0.7	131	0.0
213	3/19/2013		5.8	10.0	991	74.5	0.6	157	1.2
214	3/20/2013		2.6	4.9	999	85.8	1.9	240	13.2
215	3/21/2013		0.6	3.3	1010	78.8	1.0	229	0.3
216	3/22/2013		2.9	7.3	1006	63.4	3.2	146	0.0
217	3/23/2013		1.1	3.4	1005	56.8	4.2	146	0.0
218	3/24/2013		1.0	4.7	1005	42.8	3.3	153	0.0
219	3/25/2013		0.9	4.6	1004	49.0	2.6	153	0.0
220	3/26/2013		1.6	6.1	1003	44.1	2.3	168	0.0
221	3/27/2013		2.6	6.4	1001	49.5	2.0	148	0.0
222	3/28/2013		3.0	6.7	999	58.9	1.2	243	0.0
223	3/29/2013		0.4	3.1	999	77.8	1.1	271	1.5
224	3/30/2013		1.8	4.4	1000	68.9	1.3	271	0.0
225	3/31/2013		1.7	4.0	1003	68.2	1.1	269	0.0
226	4/1/2013		3.2	7.3	1001	52.9	1.5	190	0.0
227	4/2/2013		3.6	8.5	1003	52.2	1.8	201	0.0
228	4/3/2013		3.0	6.6	1005	58.0	1.8	158	0.0
229	4/4/2013		4.4	8.7	1001	60.5	1.8	166	0.0
230	4/5/2013		3.8	4.7	1003	67.8	1.6	267	0.0
231	4/6/2013		3.6	6.2	1012	73.9	1.7	221	0.3
232	4/7/2013		6.4	11.4	1008	51.4	0.7	174	0.0
234	4/8/2013		7.0	11.5	996	63.9	1.4	130	0.9
234	4/9/2013		8.3	10.6	992	78.0	1.2	133	1.8
235	4/10/2013		9.7	13.2	996	77.3	1.4	154	6.0
236	4/11/2013		13.0	17.3	991	69.6	1.3	169	6.0
237	4/12/2013		12.2	16.8	997	69.0	1.1	154	4.4
238	4/13/2013		13.9	17.2	1011	56.8	1.4	152	0.6
239	4/14/2013		18.3	24.1	1011	57.0	1.5	136	0.0
240	4/15/2013		17.5	23.1	1011	67.0	1.5	214	2.7

Annex 6 **Ambient conditions from field test sites** **Page 9 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
241	4/16/2013	Bonn, winter	18.4	22.8	1011	54.4	0.9	149	0.0
242	4/17/2013		18.7	25.0	1009	54.3	0.6	141	0.0
243	4/18/2013		15.6	19.8	1009	46.2	3.1	210	0.0
244	4/19/2013		11.4	14.7	1017	57.7	3.5	260	0.0
245	4/20/2013		10.3	13.9	1018	51.5	3.3	274	0.0
246	4/21/2013		11.1	13.1	1009	57.4	1.1	253	0.0
247	4/22/2013		13.2	17.4	1009	46.5	1.4	217	0.0
248	4/23/2013		13.7	18.9	1014	63.6	1.7	187	0.0
249	4/24/2013		17.9	24.6	1016	56.5	1.0	167	0.0
250	4/25/2013		20.0	26.6	1010	51.5	0.4	146	0.0
251	4/26/2013		11.9	20.3	1000	77.3	2.2	230	9.9
252	4/27/2013		7.8	9.8	1003	70.3	3.2	293	0.0
253	4/28/2013		9.2	12.2	1007	68.3	0.7	169	0.0
254	4/29/2013		12.0	16.9	1010	56.1	1.9	209	0.0
255	4/30/2013		11.8	15.1	1014	57.9	1.0	214	0.0
256	5/1/2013		14.6	18.3	1011	62.8	0.9	173	0.3
257	5/2/2013		16.5	21.6	1009	60.4	1.1	200	0.0
258	5/3/2013		16.0	20.6	1007	60.0	1.5	253	0.0
259	5/4/2013		15.7	21.0	1011	54.5	2.4	238	0.0
260	5/5/2013		16.4	22.1	1013	55.9	1.3	190	0.0
261	5/14/2013	Bornheim, summer	No weather data available						
262	5/15/2013								
263	5/16/2013		12.6	16.7	989	85.5	0.7	263	8.6
264	5/17/2013		10.0	10.6	995	89.1	0.8	265	2.4
265	5/18/2013		12.0	17.8	1000	77.7	0.4	216	0.0
266	5/19/2013		16.7	22.4	998	66.5	2.7	273	7.4
267	5/20/2013		11.9	15.0	1000	83,,1	0.3	175	6.2
268	5/21/2013		12.9	18.2	1001	78.8	1.8	239	13.1
269	5/22/2013		8.8	11.1	1004	82.4	2.4	258	7.4
270	5/23/2013		6.4	10.6	1000	81.9	1.8	255	2.4

Annex 6 **Ambient conditions from field test sites** **Page 10 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
271	5/24/2013	Bornheim, summer	8.3	14.6	1003	69.9	0.7	192	0.9
272	5/25/2013		10.5	15.0	1005	70.9	2.8	270	3.0
273	5/26/2013		9.8	11.8	1002	79.9	3.2	271	5.7
274	5/27/2013		14.0	20.5	1000	61.4	1.6	244	0.0
275	5/28/2013		17.2	23.9	993	60.4	2.0	179	1.2
276	5/29/2013		9.7	11.1	995	88.4	0.6	207	15.0
277	5/30/2013		13.5	16.6	999	69.6	1.7	237	2.4
278	5/31/2013		16.1	22.0	1001	73.0	4.7	299	0.9
279	6/1/2013		11.9	14.7	1009	79.4	4.4	290	0.3
280	6/2/2013		13.3	18.6	1016	57.6	4.0	288	0.0
281	6/3/2013		12.9	17.9	1017	61.6	3.6	269	0.0
282	6/4/2013		15.6	21.6	1012	64.5	1.7	237	0.0
283	6/5/2013		19.9	26.6	1009	54.2	0.6	197	0.0
284	6/6/2013		20.9	28.3	1010	52.6	0.8	168	0.0
285	6/7/2013		21.7	29.1	1010	55.5	1.0	211	0.0
286	6/8/2013		21.1	26.8	1005	62.3	2.1	243	0.0
287	6/9/2013		15.6	19.2	1001	78.7	1.8	273	4.5
288	6/10/2013		14.4	18.1	1005	75.9	1.2	253	0.6
289	6/11/2013		18.8	23.8	1008	61.5	0.6	198	0.0
290	6/12/2013		21.1	23.7	1008	67.1	1.0	181	0.0
291	6/13/2013		17.0	27.6	1007	77.9	1.3	209	22.5
292	6/14/2013		16.1	21.2	1009	65.4	0.6	181	0.0
293	6/15/2013		17.2	22.6	1005	63.1	1.4	209	0.0
294	6/16/2013		17.7	23.7	1007	63.9	0.7	226	0.0
295	6/17/2013		23.3	29.7	1004	64.7	0.9	185	0.0
296	6/18/2013		27.2	34.8	1005	61.3	0.4	178	0.0
297	6/19/2013		26.9	35.0	1003	67.8	1.9	244	0.0
298	6/20/2013		20.5	25.1	1003	78.5	1.0	187	34.6
299	6/21/2013		19.0	23.4	1005	69.8	1.6	196	0.3
300	6/22/2013		19.0	23.7	1004	67.8	1.8	198	1.5

Annex 6 **Ambient conditions from field test sites** **Page 11 of 11**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
301	6/23/2013	Bornheim, summer	16.2	19.2	1005	69.9	1.6	216	0.9
302	6/24/2013		14.2	17.4	1013	76.9	1.8	255	1.5
303	6/25/2013		13.4	16.8	1018	71.1	1.8	259	0.3
304	6/26/2013		13.9	16.7	1018	70.9	1.1	250	9.8
305	6/27/2013		13.2	17.1	1014	78.5	0.7	230	3.9
306	6/28/2013		14.1	16.7	1010	86.1	0.3	174	16.4
307	6/29/2013		14.8	18.8	1012	73.9	2.6	269	1.8
308	6/30/2013		17.7	22.4	1012	66.4	0.6	198	0.0
309	7/1/2013		18.8	25.4	1008	74.9	0.7	215	21.0
310	7/2/2013		21.6	27.1	1003	62.7	0.6	183	0.3
311	7/3/2013		17.5	20.1	1004	85.6	0.2	213	16.0
312	7/4/2013		20.0	24.7	1014	71.1	0.9	232	0.0
313	7/5/2013		19.8	24.8	1020	74.4	0.3	222	0.0
314	7/6/2013		22.4	29.3	1020	65.4	1.0	191	0.0
315	7/7/2013		23.1	29.7	1020	58.8	1.2	218	0.0
316	7/8/2013		23.0	29.8	1019	59.6	1.4	214	0.0
317	7/9/2013		23.4	29.9	1014	59.4	1.4	237	0.0
318	7/10/2013		19.5	24.2	1012	62.6	3.5	261	0.0
319	7/11/2013		15.7	19.7	1013	70.1	1.7	215	0.0
320	7/12/2013		16.5	21.9	1013	70.8	1.2	250	0.0
321	7/13/2013		17.7	22.9	1014	68.3	1.1	241	0.0
322	7/14/2013		18.9	24.2	1014	69.1	1.7	249	0.0

Annex 7 **Measured values from UK field test sites, related to actual conditions** **Page 1 of 4**

Manufacturer	PALAS	PM10 and PM2.5 Measured values in µg/m³ (ACT)
Type of instrument	FIDAS 200 S	
Serial-No.	SN 0111 / SN 0112	

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
1	27.02.2014	7,0	7,4	12,7	12,2	57,4	6,7	6,7	10,9	10,6		Teddington, Winter
2	28.02.2014	12,4	13,6	19,3	18,5	68,7	13,1	13,7	15,8	16,4		
3	01.03.2014	13,7	14,0	19,8	19,7	70,3	14,2	14,5	17,8	18,0		
4	02.03.2014	3,9	4,2	7,9	7,7	52,3	4,4	4,4	7,4	7,1		
5	03.03.2014	8,9	9,4	12,5	13,1	71,4	8,5	8,7	10,7	10,8		
6	04.03.2014	14,7	15,4	21,7	21,4	69,8	14,1	14,4	18,3	18,4		
7	05.03.2014	9,6	11,3	21,3	20,9	49,5	11,3	10,9	16,4	15,4		
8	06.03.2014	10,5	10,7	17,2	17,5	61,1	10,8	10,5	14,6	13,8		
9	07.03.2014	11,3	11,4	16,5	16,2	69,3	10,8	10,4	14,5	13,7		
10	08.03.2014	41,7	42,2	47,0	46,1	90,0	44,1	43,0	48,2	46,9		
11	09.03.2014	28,6	29,1	34,2	33,5	85,2	28,5	27,6	32,9	31,7		
12	10.03.2014	10,0	10,4	17,5	17,4	58,4	12,4	12,0	18,3	17,3		
13	11.03.2014	19,2	20,5	31,1	30,5	64,5	19,0	18,6	26,7	25,7		
14	12.03.2014	44,5	45,7	60,2	59,7	75,2	47,6	46,5	55,2	53,3		
15	13.03.2014			68,0	67,1		58,3	56,4	67,7	65,2	Outlier Ref. PM2,5	
16	14.03.2014	40,1	40,6	48,7	47,9	83,7	42,5	39,7	49,7	46,0		
17	15.03.2014	9,3	9,3	14,2	13,4	67,1	9,0	8,3	13,1	12,0		
18	16.03.2014	11,1	11,5	14,8	14,3	77,8	10,8	10,1	13,8	12,8		
19	17.03.2014	12,0	12,5	18,4	18,0	67,3	13,1	12,1	18,6	16,9		
20	18.03.2014	7,3	7,6	16,0	15,4	47,4	8,1	7,5	13,7	12,2		
21	19.03.2014	13,4	14,2	27,0	25,7	52,4	16,3	15,1	23,3	21,1		
22	20.03.2014	6,2	6,9	13,5	12,7	50,2	7,9	7,5	13,0	12,2		
23	21.03.2014	3,4	3,9	10,0	9,7	37,0	4,4	4,4	8,7	8,4		
24	22.03.2014	3,9	4,2	8,0	7,7	51,7	4,2	4,4	7,0	7,1		
25	23.03.2014	7,6	7,6	10,6	10,4	72,7	6,8	7,2	9,0	9,4		
26	24.03.2014	8,1	8,2	11,8	11,6	69,7	7,5	7,8	9,7	10,0		
27	25.03.2014	19,5	19,9	28,1	27,5	70,8	18,2	19,3	22,2	23,2		
28	26.03.2014											
29	27.03.2014											
30	28.03.2014											

Annex 7 **Measured values from UK field test sites, related to actual conditions** **Page 2 of 4**

Manufacturer	PALAS	PM10 and PM2.5
Type of instrument	FIDAS 200 S	Measured values in µg/m³ (ACT)
Serial-No.	SN 0111 / SN 0112	

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
31	29.03.2014											Teddington, Winter
32	30.03.2014											
33	31.03.2014											
34	01.04.2014	33,9	32,7	44,5	42,9	76,2	32,2	32,7	41,1	41,3		
35	02.04.2014	58,6	57,7				58,0	59,9	80,6	81,8	Outlier Ref. PM10	
36	03.04.2014	35,6	35,6	51,6	49,9	70,1	37,7	39,0	49,8	50,4		
37	04.04.2014	6,8	6,6	10,6	10,6	63,3	6,5	6,6	9,2	9,1		
38	05.04.2014	4,2	4,1	6,1	6,0	68,9	4,2	4,4	5,6	5,8		
39	06.04.2014	3,1	2,8	5,6	5,3	53,6	2,9	2,9	4,6	4,5		
40	07.04.2014	3,4	3,2	7,2	6,7	47,8	3,9	3,9	6,7	6,8		
41	08.04.2014	5,8	5,8	13,5	12,8	44,1	7,3	7,4	11,4	11,4		
42	09.04.2014	8,4	8,5	15,5	14,8	56,0	8,9	8,8	13,4	12,9		
43	10.04.2014	9,1	8,9	14,8	14,5	61,4	8,2	8,0	13,2	12,8		
44	11.04.2014	14,3	14,3	19,9	19,3	73,1	13,2	13,3	17,6	17,5		
45	12.04.2014	8,3	8,2	13,9	13,0	61,4	9,2	9,0	13,1	12,7		
46	13.04.2014	8,0	7,5	14,5	13,8	54,8	7,9	7,7	12,8	12,1		
47	14.04.2014	7,5	7,4	15,6	15,0	49,0	6,9	6,7	13,1	12,4		
48	15.04.2014	9,0	8,4	21,4	20,5	41,4	9,4	9,3	17,8	17,2		
49	16.04.2014	16,1	15,6	28,4	28,0	56,2	15,3	14,8	23,2	22,0		
50	17.04.2014	9,6	9,1	18,1	17,5	52,5	10,6	10,1	17,7	16,5		
51	18.04.2014	5,3	5,0	12,5	11,8	42,1	5,7	5,5	10,6	10,2		
52	19.04.2014	18,5	18,5	26,6	26,2	70,0	18,9	18,8	23,3	22,8		Teddington, Summer
53	20.04.2014	39,0	39,1	45,7	44,7	86,3	39,4	38,5	43,1	41,9		
54	21.04.2014	20,7	20,8	28,0	26,9	75,5	22,3	21,0	26,2	24,3		
55	22.04.2014	8,9	9,8	14,6	14,0	65,5	9,7	9,1	12,6	11,6		
56	23.04.2014	7,2	7,4	10,9	10,4	68,1	7,6	7,1	9,7	8,7		
57	24.04.2014	13,2	12,8	16,8	16,0	79,3	11,3	10,6	13,5	12,5		
58	25.04.2014	9,0	9,0	13,5	12,8	68,8	9,3	9,1	11,5	11,4		
59	26.04.2014	4,1	4,2	9,2	8,9	46,1	4,4	4,2	7,9	7,2		
60	27.04.2014	17,9	17,6	25,1	24,4	71,5	16,4	15,7	19,6	18,4		

Annex 7 **Measured values from UK field test sites, related to actual conditions** **Page 3 of 4**

Manufacturer	PALAS	PM10 and PM2.5
Type of instrument	FIDAS 200 S	Measured values in µg/m³ (ACT)
Serial-No.	SN 0111 / SN 0112	

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
61	28.04.2014	18,7	18,9	24,3	23,3	78,8	18,2	19,2	22,0	22,8		Teddington, Summer
62	29.04.2014	17,5	16,8	23,5	22,8	74,1	18,5	19,2	21,5	22,1		
63	30.04.2014	12,5	12,1	15,6	15,3	79,6	12,0	12,3	13,8	14,1		
64	01.05.2014	13,0	12,8	17,8	17,8	72,5	12,4	12,8	14,9	15,1		
65	02.05.2014	5,4	5,8	12,3	12,2	45,4	6,3	6,5	11,3	11,5		
66	03.05.2014	8,9	9,0	14,3	14,3	62,5	9,1	9,0	12,4	12,0		
67	04.05.2014	13,1	13,4	20,3	19,7	66,3	13,1	12,9	16,4	15,8		
68	05.05.2014	10,7	11,2	15,4	15,2	71,8	13,1	12,5	17,2	16,1		
69	06.05.2014	4,2	4,4	10,8	10,5	40,6	5,0	4,8	9,4	9,0		
70	07.05.2014	3,1	3,0	7,7	7,4	40,6	3,5	3,4	7,3	7,0		
71	08.05.2014	3,4	3,1	7,3	7,1	45,4	4,4	4,2	7,9	7,4		
72	09.05.2014	5,1	4,6	12,3	11,7	40,2	6,2	5,8	12,1	10,6		
73	10.05.2014	3,8	3,3	10,6	10,1	34,3	5,8	5,5	11,5	10,4		
74	11.05.2014	4,1	3,7	11,0	10,1	37,1	5,8	5,4	11,4	10,2		
75	12.05.2014	4,4	4,6	8,4	8,0	54,8	4,5	4,3	7,7	7,0		
76	13.05.2014	6,3	6,2	9,7	9,1	66,7	6,9	6,7	9,5	9,1		
77	14.05.2014	8,7	9,1	13,5	12,9	67,8	8,8	9,4	12,7	13,3		
78	15.05.2014	9,7	9,8	14,8	14,4	66,9	9,8	10,3	13,6	14,0		
79	16.05.2014	15,3	14,8	22,4	21,7	68,1	15,6	16,3	21,6	22,2		
80	17.05.2014	13,9	13,6	18,6	18,3	74,4	14,6	15,0	19,5	19,7		
81	18.05.2014			25,4	25,4		20,6	21,3	26,7	27,2	Outlier Ref. PM2,5	
82	19.05.2014	11,8	11,3	17,7	17,1	66,5	11,0	11,1	16,4	16,4		
83	20.05.2014	7,2	6,6	10,7	10,0	66,4	7,5	7,7	10,6	10,6		
84	21.05.2014	6,7	6,4	10,6	10,3	62,3	6,9	6,8	10,8	10,7		
85	22.05.2014	4,4	3,8	9,8	8,9	43,7	4,3	4,3	8,6	8,4		
86	23.05.2014	5,6	5,3	9,9	9,1	57,1	5,0	5,1	7,5	7,5		
87	24.05.2014	3,9	3,7	9,0	8,3	43,9	4,5	4,5	7,9	7,6		
88	25.05.2014	8,1	7,9	13,1	12,6	62,1	7,7	7,6	10,7	10,3		
89	26.05.2014	9,2	9,1	14,2	13,0	67,2	8,4	8,4	11,5	11,4		
90	27.05.2014	6,0	6,2	8,4	8,0	74,7	4,9	4,9	6,8	6,5		

Annex 7 **Measured values from UK field test sites, related to actual conditions** **Page 4 of 4**

Manufacturer	PALAS		
Type of instrument	FIDAS 200 S		PM10 and PM2.5 Measured values in µg/m³ (ACT)
Serial-No.	SN 0111 / SN 0112		

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	SN 0111 PM10 [µg/m³]	SN 0112 PM10 [µg/m³]	Remark	Test site
91	28.05.2014	6,7	7,0	10,5	10,2	66,2	6,6	6,3	9,3	8,6		Teddington, Summer
92	29.05.2014	8,6	9,1	13,2	12,9	67,7	9,6	9,1	12,4	11,5		
93	30.05.2014	9,7	9,8	15,0	14,2	66,5	10,9	10,4	15,3	14,3		
94	31.05.2014	11,3	11,7	17,0	16,1	69,4	13,4	12,2	17,3	15,5		
95	01.06.2014	8,7	8,7	13,1	12,2	68,6	9,8	8,9	13,0	11,7		
96	02.06.2014	5,5	6,0	9,5	8,3	64,9	6,7	6,6	9,3	9,1		
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Annex 8 **Ambient conditions from field test sites, UK** **Page 1 of 4**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	27.02.2014	Teddington, Winter	6,4	12,6	984	80,6	0,2	109	2,5
2	28.02.2014		4,8	9,6	984	89,3	0,8	8	5,1
3	01.03.2014		4,9	10,6	983	83,7	0,1	189	0,0
4	02.03.2014		6,9	11,4	969	88,1	1,1	162	10,2
5	03.03.2014		4,4	8,9	976	92,1	0,1	116	10,2
6	04.03.2014		4,8	12,2	992	85,6	0,0	188	0,0
7	05.03.2014		8,5	15,1	1005	76,0	0,1	199	0,0
8	06.03.2014		9,2	14,4	1004	80,5	0,4	177	0,0
9	07.03.2014		11,0	17,1	1007	77,5	0,4	131	0,0
10	08.03.2014		11,5	16,7	1004	64,2	0,5	156	0,0
11	09.03.2014		10,7	19,5	1005	68,2	0,4	155	0,0
12	10.03.2014		9,1	14,4	1013	75,6	2,3	14	0,0
13	11.03.2014		7,4	12,4	1015	84,2	1,0	27	0,0
14	12.03.2014		9,4	17,5	1012	76,7	0,3	40	0,0
15	13.03.2014		9,8	19,6	1011	74,5	0,2	21	0,0
16	14.03.2014		11,4	18,9	1007	71,5	0,0	266	0,0
17	15.03.2014		11,4	18,9	1006	69,7	0,2	307	0,0
18	16.03.2014		12,2	20,6	1004	69,2	0,2	294	0,0
19	17.03.2014		10,4	15,9	1000	73,7	0,1	250	0,0
20	18.03.2014		10,3	14,4	1000	74,6	0,2	239	0,0
21	19.03.2014		10,9	18,5	1000	75,7	0,3	188	0,0
22	20.03.2014		10,1	14,4	987	79,5	0,5	200	2,5
23	21.03.2014		8,3	13,8	984	73,2	0,6	187	7,6
24	22.03.2014		6,2	12,8	984	76,6	0,2	224	0,0
25	23.03.2014		5,5	11,1	994	72,3	0,7	309	0,0
26	24.03.2014		7,9	12,0	991	70,6	1,3	139	5,1
27	25.03.2014		6,2	9,4	996	81,3	0,6	40	0,0
28	26.03.2014		8,8	10,2	999	59,6	1,7	359	0,0
29	27.03.2014								
30	28.03.2014								

Annex 8 **Ambient conditions from field test sites, UK** **Page 2 of 4**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	29.03.2014	Teddington, Winter							
32	30.03.2014		14,1	15,0	994	67,3	0,8	119	0,0
33	31.03.2014		15,5	17,3	993	60,3	0,7	127	0,0
34	01.04.2014		14,5	21,1	988	71,7	0,3	26	0,0
35	02.04.2014		14,7	19,6	982	73,4	0,9	49	0,0
36	03.04.2014		13,8	18,9	983	77,1	0,5	112	0,0
37	04.04.2014		10,8	17,2	993	77,6	0,1	157	0,0
38	05.04.2014		13,7	16,1	994	86,5	0,6	173	2,5
39	06.04.2014		13,7	15,6	993	88,0	0,6	178	0,0
40	07.04.2014		10,3	15,0	991	86,5	0,2	194	2,5
41	08.04.2014		9,2	16,2	1005	70,7	0,3	299	0,0
42	09.04.2014		12,0	20,0	1005	69,0	0,0	222	0,0
43	10.04.2014		13,5	18,2	1002	56,2	0,3	329	0,0
44	11.04.2014		11,1	17,6	1002	63,8	0,3	351	0,0
45	12.04.2014		11,3	16,1	1001	70,3	0,2	275	0,0
46	13.04.2014		11,6	18,0	1003	64,8	0,5	312	0,0
47	14.04.2014		10,9	17,7	1009	59,0	0,8	354	0,0
48	15.04.2014		9,8	16,6	1011	60,2	0,5	75	0,0
49	16.04.2014		10,9	19,4	1005	59,7	0,3	123	0,0
50	17.04.2014		12,3	19,4	1000	60,1	1,0	332	0,0
51	18.04.2014		9,3	13,8	1002	57,5	1,4	13	0,0
52	19.04.2014	Teddington, Summer	10,7	15,1	995	68,0	1,5	34	0,0
53	20.04.2014		9,9	17,8	986	90,0	0,4	38	7,6
54	21.04.2014		13,8	20,8	986	80,0	0,2	348	22,9
55	22.04.2014		11,7	16,7	994	81,9	0,3	165	0,0
56	23.04.2014		12,8	17,4	1000	81,2	0,3	164	2,5
57	24.04.2014		13,4	19,4	996	71,8	0,4	16	0,0
58	25.04.2014		10,2	14,3	989	93,3	0,5	138	5,1
59	26.04.2014		12,2	16,7	984	70,4	1,4	138	0,0
60	27.04.2014		12,3	15,4	987	77,1	0,8	58	0,0

Annex 8 **Ambient conditions from field test sites, UK** **Page 3 of 4**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	28.04.2014	Teddington, Summer	13,0	18,4	993	75,8	0,6	49	0,0
62	29.04.2014		11,6	17,7	994	79,4	0,4	59	0,0
63	30.04.2014		13,6	21,6	992	74,4	0,3	180	5,1
64	01.05.2014		11,5	13,9	995	90,2	0,7	358	12,7
65	02.05.2014		8,5	13,1	1009	69,6	1,0	16	0,0
66	03.05.2014		10,6	17,0	1008	58,7	0,3	16	0,0
67	04.05.2014		11,9	19,4	1000	66,3	0,3	161	0,0
68	05.05.2014		15,3	19,1	988	61,6	0,6	158	0,0
69	06.05.2014		15,0	21,7	987	63,2	0,2	201	0,0
70	07.05.2014		13,4	17,2	991	69,4	0,2	208	2,5
71	08.05.2014		13,5	16,4	988	83,9	0,2	211	2,5
72	09.05.2014		14,2	18,9	991	68,0	0,3	209	2,5
73	10.05.2014		12,1	18,5	983	71,6	0,5	198	2,5
74	11.05.2014		11,9	16,1	988	66,8	0,2	242	0,0
75	12.05.2014		12,0	19,4	994	74,9	0,2	309	5,1
76	13.05.2014		11,6	17,2	1006	76,2	0,4	331	0,0
77	14.05.2014		14,2	20,4	1014	62,1	0,6	346	0,0
78	15.05.2014		15,3	22,6	1015	65,2	0,1	59	0,0
79	16.05.2014		17,1	24,4	1008	64,4	0,1	55	0,0
80	17.05.2014		18,5	26,5	999	67,4	0,2	150	0,0
81	18.05.2014		18,7	24,5	987	57,2	0,7	142	0,0
82	19.05.2014		20,0	25,3	983	56,9	1,3	124	0,0
83	20.05.2014		14,9	20,3	990	75,0	0,3	158	0,0
84	21.05.2014		16,0	20,1	984	71,4	0,7	49	7,6
85	22.05.2014		14,6	18,3	983	70,7	1,4	138	5,1
86	23.05.2014		13,7	17,6	988	74,1	0,7	145	10,2
87	24.05.2014		12,7	17,1	994	75,1	0,6	163	0,0
88	25.05.2014		13,1	19,6	1000	69,9	0,3	161	5,1
89	26.05.2014		11,9	13,3	997	93,2	0,5	324	2,5
90	27.05.2014		11,2	13,4	994	94,4	0,8	318	15,2

Annex 8 **Ambient conditions from field test sites, UK** **Page 4 of 4**

No.	Date	Test site	Amb. temperature (AVG) [°C]	Amb. temperature (MAX) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	28.05.2014	Teddington, Summer	13,9	16,8	993	89,4	0,1	46	0,0
92	29.05.2014		15,6	19,3	999	76,3	0,8	54	0,0
93	30.05.2014		13,2	19,3	1006	71,0	0,5	40	0,0
94	31.05.2014		16,1	20,7	1004	65,3	0,3	333	0,0
95	01.06.2014		18,1	24,9	1000	60,5	0,1	351	0,0
96	02.06.2014		16,4	23,2	996	74,3	0,1	174	0,0

Appendix 2

Filter weighing procedure

A.1 Carrying out the weighing

All weighings are done in an air-conditioned weighing room. Ambient conditions are 20 °C ±1 °C and 50 % ±5 % relative humidity, which conforms to the requirements of Standard EN 14907.

The filters used in the field test are weighed manually. In order to condition the filters (including control filters), they are placed on sieves to avoid overlap.
The specifications for pre- and post-weighing are specified beforehand and conform to the Standard.

Before sampling = pre-weighing	After sampling = post-weighing
Conditioning 48 h + 2 h	Conditioning 48 h + 2 h
Filter weighing	Filter weighing
Re-conditioning 24 h +2 h	Re-conditioning 24 h + 2 h
Filter weighing and immediate packaging	Filter weighing

The balance is always ready for use. An internal calibration process is started prior to each weighing series. The standard weight of 200 mg is weighed as reference and the boundary conditions are noted down if nothing out of the ordinary results from the calibration process. Deviations of prior weighings conform to the Standard and do not exceed 20 µg (refer to Figure 134). All six control filters are weighed afterwards and a warning is displayed for control filters with deviations > 40 µg during evaluation. These control filters are not used for post-weighing. Instead, the first three acceptable control filters are used while the others remain in the protective jar in order to replace a defective or deviating filter, if necessary. Figure 135 shows an exemplary process over a period of more than four months.

All filters which display a difference of more than 40 µg between the first and second weighing are excluded from the pre-weighing process. Filters exhibiting deviations of more than 60 µg are not considered for evaluation after post-weighing, as conforming to standards.

Weighed filters are packed in separate polystyrene jars for transport and storage. These jars remain closed until the filter is inserted. Virgin filters can be stored in the weighing room for up to 28 days before sampling. Another pre-weighing is carried out if this period is exceeded.

Sampled filters can be stored for up to 15 days at a temperature of 23 °C or less. The filters are stored at 7 °C in a refrigerator.

A2 Filter evaluation

The filters are evaluated with the help of a corrective term in order to minimise relative mass changes caused by the weighing room conditions.

Equation:

$$\text{Dust} = MF_{post} - (M_{Tara} \times (MKon_{post} / MKon_{pre})) \qquad \text{(F1)}$$

$MKon_{pre}$ = mean mass of the 3 control filters after 48 h and 72 h pre-weighing

$MKon_{post}$ = mean mass of the 3 control filters after 48 h and 72 h post-weighing

M_{Tara} = mean mass of the filter after 48 h and 72 h pre-weighing

MF_{post} = mean mass of the loaded filter after 48 h and 72 h post-weighing

Dust = corrected dust mass of the filter

This shows that the method becomes independent from weighing room conditions due to the corrective calculation. Influence due to the water content of the filter mass between virgin and loaded filter can be controlled and do not change the dust content of sampled filters. Hence, point 9.3.2.5 of EN 14907 is fulfilled.

The example of the standard weight between November 2008 and February 2009 shows that the permissible difference of max. 20 µg from the previous measurement is not exceeded.

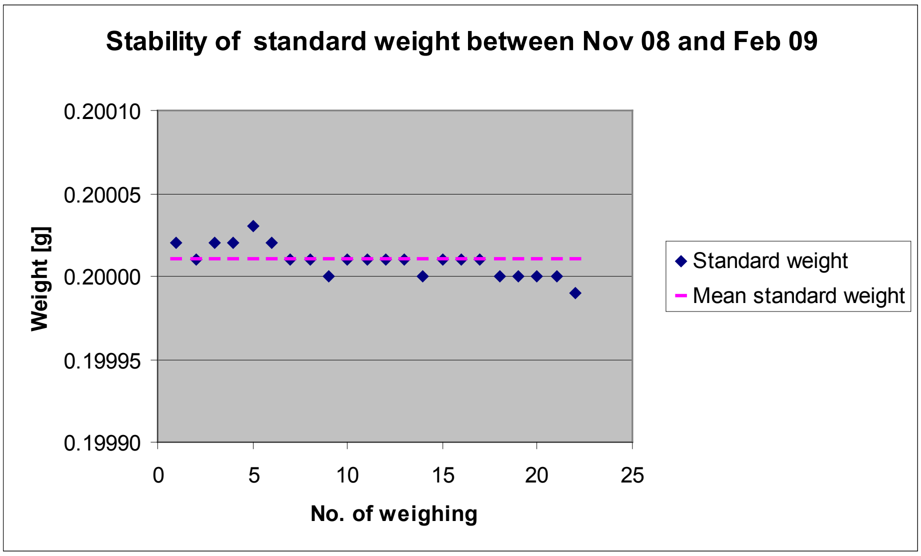

Figure 134: Stability of standard weight

Table 64: Stability of standard weight

Date	Weighing No.	Standard weight	Difference to the previous weighing
		g	µg
12.11.2008	1	0.20002	
13.11.2008	2	0.20001	-10
10.12.2008	3	0.20002	10
11.12.2008	4	0.20002	0
17.12.2008	5	0.20003	10
18.12.2008	6	0.20002	-10
07.01.2009	7	0.20001	-10
08.01.2009	8	0.20001	0
14.01.2009	9	0.20000	-10
15.01.2009	10	0.20001	10
21.01.2009	11	0.20001	0
22.01.2009	12	0.20001	0
29.01.2009	13	0.20001	0
30.01.2009	14	0.20000	-10
04.02.2008	15	0.20001	10
05.02.2009	16	0.20001	0
11.02.2009	17	0.20001	0
12.02.2009	18	0.20000	-10
18.02.2009	19	0.20000	0
19.02.2009	20	0.20000	0
26.02.2009	21	0.20000	0
27.02.2009	22	0.19999	-10

Marked in yellow = average value

Marked in green = lowest value

Marked in blue = highest value

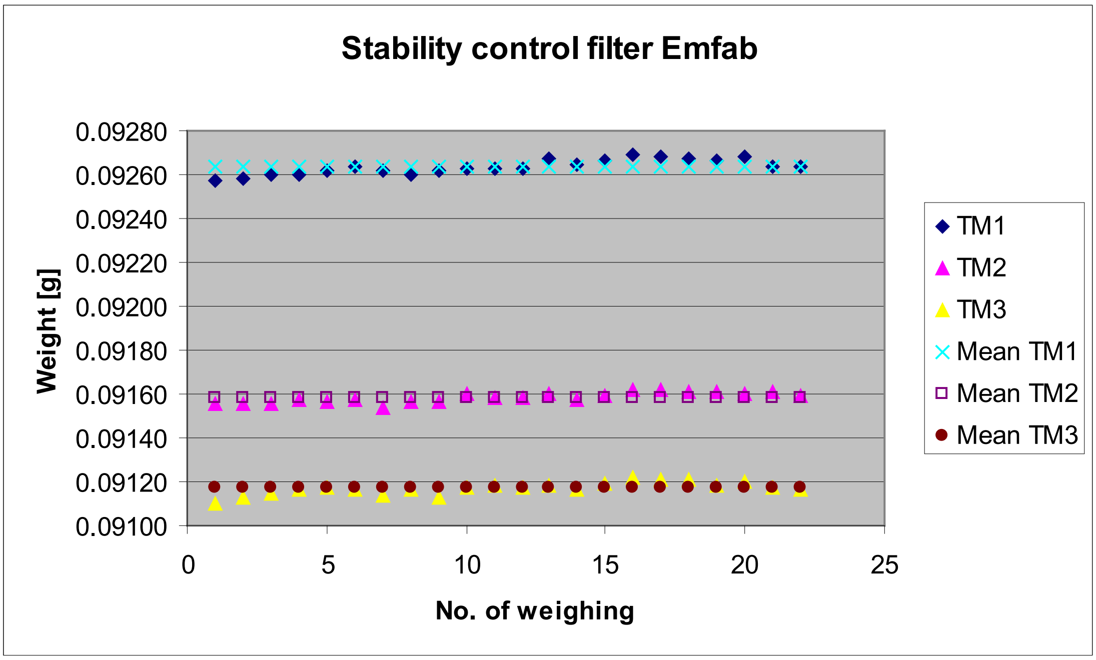

Figure 135: Stability of the control filters

Table 65: Stability of the control filters

	Control filter no.		
Weighing no.	TM1	TM2	TM3
1	0.09257	0.09155	0.09110
2	0.09258	0.09155	0.09113
3	0.09260	0.09155	0.09115
4	0.09260	0.09157	0.09116
5	0.09262	0.09156	0.09117
6	0.09264	0.09157	0.09116
7	0.09262	0.09154	0.09114
8	0.09260	0.09156	0.09116
9	0.09262	0.09156	0.09113
10	0.09263	0.09160	0.09117
11	0.09263	0.09158	0.09118
12	0.09263	0.09158	0.09117
13	0.09267	0.09160	0.09118
14	0.09265	0.09157	0.09116
15	0.09266	0.09159	0.09119
16	0.09269	0.09162	0.09122
17	0.09268	0.09162	0.09121
18	0.09267	0.09161	0.09121
19	0.09266	0.09161	0.09118
20	0.09268	0.09160	0.09120
21	0.09264	0.09161	0.09117
22	0.09264	0.09159	0.09116
Mean value	0.09264	0.09158	0.09117
Standard deviation.	3.2911E-05	2.4937E-05	2.8558E-05
Rel. standard deviation.	0.036	0.027	0.031
Median	0.09264	0.09158	0.09117
Lowest value	0.09257	0.09154	0.09110
Highest value	0.09269	0.09162	0.09122

Marked in yellow = average value

Marked in green = lowest value

Marked in blue = highest value

Appendix 3

Manuals

Notification as regards the Fidas® 200 S air quality measuring system for suspended particulate matter, PM_{10} and $PM_{2,5}$ fractions, manufactured by PALAS GmbH

Notification

Notification as regards Federal Environment Agency (UBA) notices of 27 February 2014 (BAnz AT 01.04.2014 B12, chapter IV number 5.1)

The Fidas® 200 S measuring system for suspended particulate matter, PM_{10} and $PM_{2,5}$ fractions, manufactured by PALAS GmbH is also available as an indoor version for installation at temperature controlled sites. This version is called Fidas® 200 for suspended particulate matter, PM_{10} and $PM_{2,5}$ fractions.

An additional socket for a digital out put is provided on the rear panel of the measuring system.

The Osram Ostar Projection LED, art. no. LE B H3W, used in the Fidas® sensor was discontinued and replaced by an Osram Ostar Stage LED, art. no. LE ATB S2W.

The software version has been revised.

The software version most recently published was:

100327.0007.0001.0001.0011

The current software version of the measuring system is:

100380.0014.0001.0001.0011

Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 27 September 2014

TÜV RHEINLAND ENERGY GMBH

Deutsche Akkreditierungsstelle D-PL-11120-02-00

Addendum to Report No. 936/21226418/C dated 7 December 2016 on the performance test of the APDA-372 and APDA-372E ambient air quality measuring systems manufactured by HORIBA Europe GmbH for the PM_{10} and $PM_{2,5}$ fractions of suspended particulate matter

TÜV Report No.: 936/21243705/A
Cologne, 7 September 2018

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: 0221 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-372 and APDA-372E ambient air quality measuring systems for suspended particulate matter, PM_{10} and $PM_{2,5}$ in accordance with the following standards and requirements:

- VDI standard 4202, part 1, “Automated measuring systems for air quality monitoring – Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants” September 2010 and 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 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 dated 1998
- European standard EN 14907, “Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter”, German version EN 14907: 2005
- Guideline “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of January 2010

The APDA-372 and APDA-372E measuring systems determine the dust concentrations by means of scattered light measurement with a combination of a polychromatic LED and a 90° scattered light detection. With the aid of a pump, ambient air is drawn in via a Sigma2 sampling head (4.8 l/min @ 25 °C and 1013 hPa) and reaches the actual measuring instrument via the sampling tube. The sampling tube contains a heater for the IADS (Intelligent Aerosol Drying System), which serves to avoid condensation effects on the particles. The aerosol passes directly through the aerosol sensor downstream of the sampling tube. With the aid of scattered light measurement technology, both the particle number and the particle size are measured simultaneously but separately in real time.

The tested certification range was:

Component	Certification range
PM_{10}	0–10,000 µg/m³
$PM_{2,5}$	0–10,000 µg/m³

With the exception of a modified front design (“Horiba” replaces “Palas” and “APDA-372” replaces “Fidas® 200”) and an adapted software, the APDA-372 ambient dust monitor is absolutely identical to the Fidas® 200 and Fidas® 200 E measuring systems designed and completely manufactured by PALAS GmbH. PALAS GmbH manufacture the two system versions simultaneously under the exact same conditions including personnel and materials employed. Inspections of the relevant drawings and audits of the production site in Karlsruhe demonstrated that the instrument versions are completely identical.

Given the identical design, the APDA-372 and APDA-372 E measuring system had not been physically tested before their initial publication as performance tested. All tests were performed on the instruments of the Fidas® 200 Series manufactured by PALAS GmbH, the original equipment manufacturer. Only a document inspection was carried out and the production site is audited regularly.

The publication history for the APDA-372 and APDA-372E measuring systems for suspended particulate matter, PM_{10} and $PM_{2,5}$, distributed by HORIBA Europe GmbH is provided below.

- APDA-372 for suspended particulate matter PM_{10} and $PM_{2,5}$, Federal Environment Agency notice of 25 February 2015 (BAnz AT 02.04.2015 B5,) – initial announcement of suitability.

- APDA-372 and APDA-372E for suspended particulate matter PM_{10} and $PM_{2,5}$, Federal Environment Agency notice of 18 February 2016 (BAnz AT 14.03.2016 B7, chapter V 5th notification) – Notification regarding the correction of a mistake in the test report and manual, approval of an alternative weather station, type WS300-UMB, approval of an alternative longer IADS, new instrument version APDA-372E (external sensor), new software version

- APDA-372 for suspended particulate matter PM_{10} and $PM_{2,5}$, Federal Environment Agency notice of 14 July 2016 (BAnz AT 01.08.2016 B11, chapter V 34th notification)

– Notification regarding the IADS temperature during the test of the particle sensor's sensitivity, presentation instrument, new software version

- APDA-372 for suspended particulate matter PM_{10} and $PM_{2,5}$, Federal Environment Agency notice of22 February 2017 (BAnz AT 15.03.2017 B6, chapter V 9th notification) – Notification regarding the presentation of design changes, correction of mistakes in the test report and new software version

- APDA-372 for suspended particulate matter PM_{10} and $PM_{2,5}$, Federal Environment Agency notice of 13 July 2017 (BAnz AT 31.07.2017 B12, chapter II 31st notification) – Notification regarding a new software version

- APDA-372 for suspended particulate matter PM_{10} and $PM_{2,5}$, Federal Environment Agency notice of 21 February 2018 (BAnz AT 26.03.2018 B8, chapter V 7th notification) – Notification regarding a new software version

- APDA-372 for suspended particulate matter PM_{10} and $PM_{2,5}$, Federal Environment Agency notice of 3 July 2018 (BAnz AT 17.07.2018 B9, chapter III 29th notification) – Notification regarding the changed criterion for leak tightness tests and design changes

Since July 2017, the new European 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. For the first time, this standard contains uniform requirements for the performance testing of automated measuring systems for determining suspended particulate matter (PM_{10}; $PM_{2.5}$) at a European level and will serve as the basis for the approval of automated dust measuring systems.

The present addendum now contains an assessment of the APDA-372 measuring system (versions APDA-372 and APDA-372E) with regard to compliance with the requirements of standard EN 16450 (July 2017).

Given the identical design, the assessment of the APDA-372 measuring system (versions APDA-372 and APDA-372E) with regard to compliance with the requirements of standard EN 16450 (July 2017) does not include physical tests of the measuring systems. All necessary tests (re-assessment and re-testing) for the indoor versions APDA-372 and APDA-372E are taken directly from the tests of the measuring systems of the Fidas® 200 series manufactured by the PALAS GmbH as the original equipment manufacturer, where relevant. Results of these tests were presented in an "Addendum to the report on performance testing of the Fidas® 200S, Fidas® 200 and Fidas® 200 E ambient air quality monitor for suspended particulate matter PM_{10} and $PM_{2,5}$ manufactured by PALAS GmbH", TÜV Report no. 936/21239834/B dated 7 September 2018. Alongside the test report, this basic addendum aimed at the initial approval (TÜV Report no. 936/21226418/Cdated 7 December 2016) served as appendix to this report.

All test results obtained as well as the conclusions drawn and statements made fully apply to both instrument versions.

Only for two test criteria did we have to modify this addendum compared to the basic addendum.

1. The equivalence test carried out (Chapters 6.1 16 to 6.1 17, page13 of this report) must again be evaluated separately for the APDA-372 measuring system (version APDA-372 and APDA-372E), since in this case only the original equivalence test of the Fidas® 200 S with 4 comparison campaigns is still available, but not the extended equivalence test with 6 comparison campaigns, which is shown in the basic addendum of the original equipment manufacturer PALAS GmbH.

2. The criterion "maintenance interval" (Chapter 6.1 18, from page 58 of this report) must be adjusted, since the maintenance interval (determined by the regular inspection of the particle sensor with CalDust 1100 or MonoDust 1500) for the APDA-372 measuring system (variants APDA-372 and APDA-372E) is one month according to the current version of the announcement.

The assessment of these two test criteria is presented in the appendix of this report.

It was demonstrated that the
APDA-372 measuring system (APDA-372E and APDA-372) fully satisfies the requirements of standard EN 16450:2017.

On its publication, this addendum becomes an integral part of TÜV Rheinland test report no. 936/21226418/C dated 7 December 2016 and will be available at www.qal1.de.

Environmental Protection/Air Pollution Control

Dipl.-Ing. Guido Baum	Dipl.-Ing. Karsten Pletscher

Cologne, 7 September 2018
936/21243705/A

3 Schwebstaub ($PM_{2,5}$- und PM_{10}-Fraktion)

3.1 APDA-372 für Schwebstaub PM_{10} und $PM_{2,5}$

Hersteller:
HORIBA Europe GmbH, Oberursel

Eignung:
Zur kontinuierlichen parallelen Immissionsmessung der PM_{10}- und der $PM_{2,5}$-Fraktion im Schwebstaub im stationären Einsatz

Messbereiche in der Eignungsprüfung:

Komponente	Zertifizierungsbereich	Einheit
PM_{10}	0 – 10 000	µg/m³
$PM_{2,5}$	0 – 10 000	µg/m³

Softwareversionen:	Messsystem:	100380.0014.0001.0001.0011
	Implementierter Auswertealgorithmus:	PM_ENVIRO_0011
	Auswertesoftware PDAnalyze:	1.010

Einschränkungen:
Keine

Hinweise:

1. Die Anforderungen gemäß des Leitfadens „Demonstration of Equivalence of Ambient Air Monitoring Methods" werden für die Messkomponenten PM_{10} und $PM_{2,5}$ eingehalten.
2. Die Anforderungen an den Variationskoeffizienten R^2 gemäß Richtlinie EN 12341 wurden für den Standort Köln, Sommer für einen der beiden Prüflinge nicht eingehalten.
3. Die Messeinrichtung ist als Indoor-Variante zur Installation an temperaturkontrollierten Orten konzipiert.
4. Die Empfindlichkeit des Partikelsensors muss monatlich mit CalDust 1100 überprüft werden.
5. Die Messeinrichtung ist mit dem gravimetrischen PM_{10}-Referenzverfahren nach DIN EN 12341 regelmäßig am Standort zu kalibrieren.
6. Die Messeinrichtung ist mit dem gravimetrischen $PM_{2,5}$-Referenzverfahren nach DIN EN 14907 regelmäßig am Standort zu kalibrieren.
7. Der Prüfbericht über die Eignungsprüfung ist im Internet unter www.qal1.de einsehbar.

Prüfinstitut: TÜV Rheinland Energie und Umwelt GmbH, Köln

Bericht-Nr.: 936/21226418/A vom 29. September 2014

Figure 1: Original publication BAnz AT 02.04.2015 B5, chapter III number 3.1

5 Mitteilung zu der Bekanntmachung des Umweltbundesamtes vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel III Nummer 3.1)

Im Handbuch der Messeinrichtung APDA-372 für PM_{10} und $PM_{2,5}$ der Firma HORIBA Europe GmbH wurde ein Fehler hinsichtlich der Beschreibung der Funktionalität der IADS-Regelung festgestellt. Die Beschreibung muss richtig lauten wie folgt:

„Die Temperatur des IADS wird geregelt in Abhängigkeit von der Umgebungstemperatur und Luftfeuchtigkeit (gemessen mit Wetterstation). Die Minimaltemperatur beträgt 23 °C. Die Feuchtekompensation erfolgt dabei durch eine dynamische Anpassung der IADS-Temperatur bis zu einer maximalen Heizleistung von 90 Watt."

Der Hersteller hat ab Handbuchversion HE0141015 diesen Fehler korrigiert. Der Prüfbericht 936/21226418/A vom 29. September 2014 der TÜV Rheinland Energie und Umwelt GmbH wurde ebenfalls korrigiert und wird durch den Prüfbericht 936/21226418/B vom 15. Oktober 2015 ersetzt.

Die Messeinrichtung kann zukünftig alternativ mit der Wetterstation Typ WS300-UMB betrieben werden. Für die Messeinrichtung steht eine verlängerte IADS zur Verfügung, anpassbar für einen Längenbereich von 1,20 m bis 2,10 m. Außerdem ist die Geräteversion APDA-372E mit externem Sensor einsetzbar.

Die aktuelle Softwareversion lautet:

100396.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 6. November 2015

Figure 2: Public notice BAnz AT 14.03.2016 B7, chapter V 5th notification

34 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel III Nummer 3.1) und vom 18. Februar 2016 (BAnz AT 14.03.2016 B7, Kapitel V 4. Mitteilung)

Bei der Messeinrichtung APDA 372 für PM_{10} und $PM_{2,5}$ der Firma Horiba Europe GmbH kann die Überprüfung der Empfindlichkeit des Partikelsensors der Messeinrichtung(en) APDA 372 mit MonoDust 1500 bei einer IADS-Temperatur von 35 °C oder 50 °C durchgeführt werden.

Die Messeinrichtung kann auf der Geräterückseite zwei zusätzliche Buchsen für die Ansteuerung einer externen Pumpe/Durchflussregelung (nicht relevant für die eignungsgeprüfte Geräteversion) enthalten.

Die aktuelle Softwareversion der Messeinrichtung lautet:

100408.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 24. Februar 2016

Figure 3: Public notice BAnz AT 01.08.2016 B11, chapter V 34th notification

9 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel III Nummer 3.1) und vom 14. Juli 2016 (BAnz AT 01.08.2016 B11, Kapitel V 34. Mitteilung)

Bei der Messeinrichtung APDA-372 für PM_{10} und $PM_{2,5}$ der Firma Horiba Europe GmbH kann alternativ der neue Flowsensor vom Typ Siargo FS4008-10-O6-CV-A statt der bisher verwendeten Variante Honeywell AWM5102VN genutzt werden.

Die neuen Temperaturkompensationsfaktoren lauten für die jeweiligen Geräte wie folgt: 0.19 (APDA-372E) und 0.17 (APDA-372).

Ein Fehler im Prüfbericht 936/21226418/B vom 15. Oktober 2015 der TÜV Rheinland Energie und Umwelt GmbH wurde korrigiert. Die Immissionsmesseinrichtung APDA-372 für PM_{10} und $PM_{2,5}$ arbeitet mit einem gleitenden Mittelwert über 900 s (15 Minuten) anstatt wie an zwei Stellen im Bericht dargestellt mit einem gleitenden 30-Minuten-Mittelwert. Der oben genannte Bericht wird durch den Prüfbericht 936/21226418/C vom 7. Dezember 2016 der TÜV Rheinland Energy GmbH ersetzt.

Die aktuelle Softwareversion der Messeinrichtung lautet: 100417.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energy GmbH vom 13. Dezember 2016

Figure 4: Public notice BAnz AT 15.03.2017 B6, chapter V 9th notification

31 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel III Nummer 3.1) und vom 22. Februar 2017 (BAnz AT 15.03.2017 B6, Kapitel V 9. Mitteilung)

Die aktuelle Softwareversion für die Messeinrichtungen APDA-372 bzw. APDA-372E für PM_{10} und $PM_{2,5}$ der Firma HORIBA Europe GmbH lautet:

100427.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energy GmbH vom 7. März 2017

Figure 5: Public notice BAnz AT 31.07.2017 B12, chapter II 31st notification

7 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel III Nummer 3.1) und vom 13. Juli 2017 (BAnz AT 31.07.2017 B12, Kapitel II 31. Mitteilung)

Die aktuellen Softwareversionen für die Messeinrichtungen APDA-372 bzw. APDA-372E für PM_{10} und $PM_{2,5}$ der Firma HORIBA Europe GmbH lauten:

100430.0014.0001.0001.0011
100431.0014.0001.0001.0011
100434.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energy GmbH vom 2. Oktober 2017

Figure 6: Public notice BAnz AT 26.03.2018 B8, chapter V 7th notification

29 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel III Nummer 3.1) und vom 21. Februar 2018 (BAnz AT 26.03.2018 B8, Kapitel V 7. Mitteilung)

Um eine praxisgerechtere Durchführung der Dichtigkeitsprüfung für die Messeinrichtungen APDA-372 bzw. APDA-372E für PM_{10} und $PM_{2,5}$ der Firma HORIBA Europe GmbH zu ermöglichen, wird das Kriterium zum Bestehen der Dichtigkeitsprüfung bei blockiertem Geräteeinlass auf 0 ± 0,5 l/min (Gesamtsystem ohne Sigma-2 Probenahmekopf) sowie 0 ± 0,08 l/min (APDA-372-Steuereinheit alleine) geändert.

Die Messeinrichtung wird zukünftig mit einem LED-Lichtschutzkragen ausgerüstet. Die Nachrüstung bestehender Geräte ist möglich.

Stellungnahme der TÜV Rheinland Energy GmbH vom 2. Mai 2018

Figure 7: Public notice BAnz AT 17.07.2018 B9, chapter III 29th notification

Appendices:

- Report on the performance test of the APDA-372 ambient air monitor for suspended particulate matter PM_{10} and $PM_{2,5}$ manufactured by HORIBA Europe GmbH, TÜV Report no. 936/21226418/C dated 7 December 2016
- Addendum to TÜV test report no. 936/21227195/C dated 12 October 2016 on performance testing of the Fidas® 200 S, Fidas® 200 and Fidas® 200 E for suspended particulate matter $PM_{2.5}$ and PM_{10} fractions manufactured by PALAS GmbH, TÜV Report no. 936/21239834/B dated 07 September 2018

Appendix

6.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8)

The January 2010 Guideline (GDE 2010) requires compliance with the following five criteria in order to recognise equivalence:

1. Of the full data set, at least 20% of the concentration values (determined with the reference method) shall be greater than the upper assessment threshold specified in 2008/50/EC [8], i.e. 28 µg/m³ for PM_{10} and 17 µg/m³ for $PM_{2.5}$.
   Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.
2. Between-AMS uncertainty shall remain below 2.5 µg/m³ for the overall data and for data sets with data larger than/equal to 30 µg/m³ PM_{10} and 18 µg/m³ $PM_{2.5}$.
3. The uncertainty between reference systems shall not exceed 2.0 µg/m³.
4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and at 30 µg/m³ for $PM_{2.5}$ for every individual test specimen and checked against the average of the reference method. For each of the following cases, the expanded uncertainty shall not exceed 25%:
   - Full data set:
   - datasets representing PM concentrations greater than/equal to 30 µg/m³ for PM_{10}, or concentrations greater than/equal to 18 µg/m³ for $PM_{2.5}$, provided that the set contains 40 or more valid data pairs
   - Datasets for each individual site
5. Preconditions for acceptance of the full dataset are that the slope b is insignificantly different from $|b-1| \leq 2 \cdot u(b)$ 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.

The following chapter address the issue of verifying compliance with the five criteria.

Chapter 16 Between-AMS uncertainty $u_{bs,AMS}$ (7.5.8.4) addresses verification of criteria 1 and 2.

Verification of criteria 3, 4 and 5 is reported on in chapter 6.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8)

Chapter 6.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8) contains an assessment for the case that criterion 5 is not complied with without applying correction factors.

6.116 Between-AMS uncertainty $u_{bs,AMS}$ (7.5.8.4)

The between-AMS uncertainty u_{bs} shall be ≤ 2.5 µg/m³.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

The test was performed as part of the field test with four separate comparison campaigns. Different seasons as well as different concentrations of $PM_{2.5}$ and PM_{10} were taken into consideration.

In the full dataset, at least 20% of the results obtained using the reference method should be greater than the upper assessment threshold of the annual limit value specified in 2008/50/EC. The assessment threshold for $PM_{2.5}$ is 17 µg/m³, for PM_{10} it is 28 µg/m³.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full data set (4 comparisons, for PM_{10}: 229 valid pairs of measured values for SN 0111, 229 valid pairs of measured values for SN 0112; for $PM_{2,5}$: 227 valid pairs of measured values for SN 0111, 227 valid pairs of measured values for SN 0112), 27.1% of the measured values are above the upper assessment threshold of 17 µg/m³ for $PM_{2.5}$ and 20.3% of the measured values are above the upper assessment threshold of 28 µg/m³ for PM_{10}. The concentrations measured were related to the ambient conditions.

6.4 Evaluation

Chapter 7.5.8.4 of standard EN 16450 specifies that:

The between-AMS uncertainty u_{bs} shall be ≤ 2.5 µg/m³. A between-AMS uncertainty > 2.5 µg/m³ is an indication of unsuitable performance of one or both instruments, and equivalence should not be stated.

Uncertainty is determined for:

- All locations or comparisons together (full data set)
- 1 data set with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values ≥ 30 µg/m³ for PM_{10} (basis: averages reference measurement)

Furthermore, this report also covers an evaluation of the following data sets:

- Every location or comparison separately
- 1 data set with measured values < 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values < 30 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)

The between-AMS uncertainty u_{bs} is calculated from the differences of all daily averages (24h-values) of the AMS which are operated simultaneously as:

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

Where: $y_{i,1}$ and $y_{i,2}$ = Results of the parallel measurements of individual 24h-values i

n = Number of 24h-values

6.5 Assessment

At no more than 0.84 µg/m³ for $PM_{2.5}$ and no more than 1.17 µg/m³ for PM_{10}, the uncertainty between the test specimen u_{bs} remains well below the permissible maximum of 2.5 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 1 and Table 2 list the calculated values for the between-AMS uncertainties u_{bs}. A corresponding chart is provided in Figure 8 to Figure 21.

Table 1: Between-AMS uncertainty u_{bs} for systems SN 0111 and SN 0112, measured component $PM_{2.5}$

Tested instruments	**Location**	**Number of measurements**	**Uncertainty u_{bs}**
SN			µg/m³
0111 / 0112	**All locations**	**285**	**0.48**
Individual locations			
0111 / 0112	Cologne, summer	101	0.12
0111 / 0112	Cologne, Winter	66	0.55
0111 / 0112	Bonn, winter	60	0.70
0111 / 0112	Bornheim, Summer	58	0.50
Classing over reference values			
0111 / 0112	**Values ≥ 18 µg/m³**	**54**	**0.84**
0111 / 0112	Values < 18 µg/m³	171	0.33

Table 2: Between-AMS uncertainty u_{bs} for systems SN 0111 and SN 0112, measured component PM_{10}

Tested instruments	**Location**	**Number of measurements**	**Uncertainty u_{bs}**
SN			µg/m³
0111 / 0112	**All locations**	**285**	**0.67**
Individual locations			
0111 / 0112	Cologne, summer	101	0.27
0111 / 0112	Cologne, Winter	66	0.67
0111 / 0112	Bonn, winter	60	0.90
0111 / 0112	Bornheim, Summer	58	0.87
Classing over reference values			
0111 / 0112	**Values ≥ 30 µg/m³**	**54**	**1.17**
0111 / 0112	Values < 30 µg/m³	171	0.58

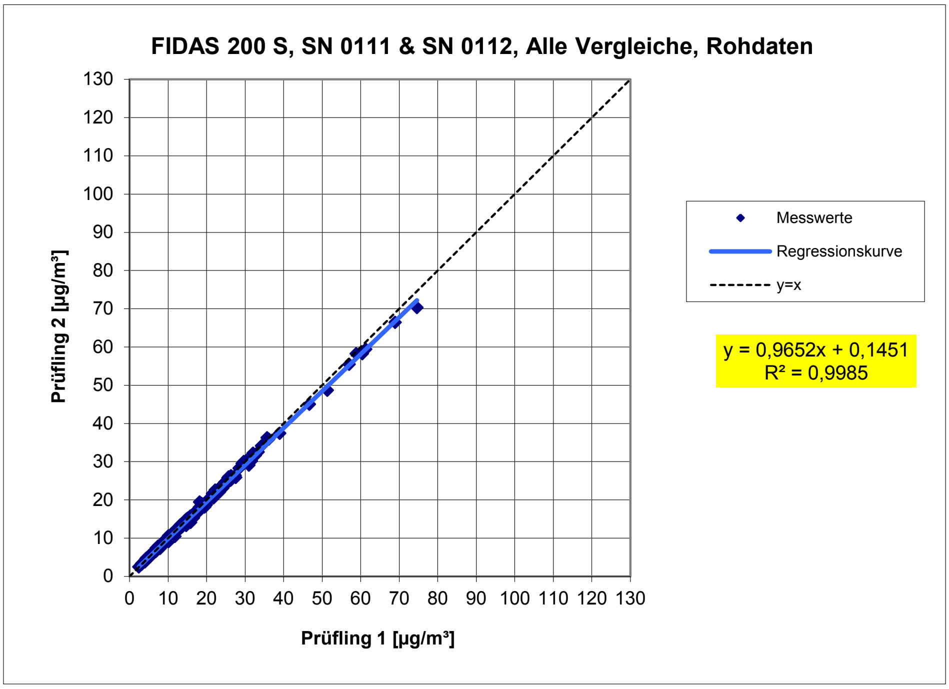

Figure 8: *Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, all test sites*

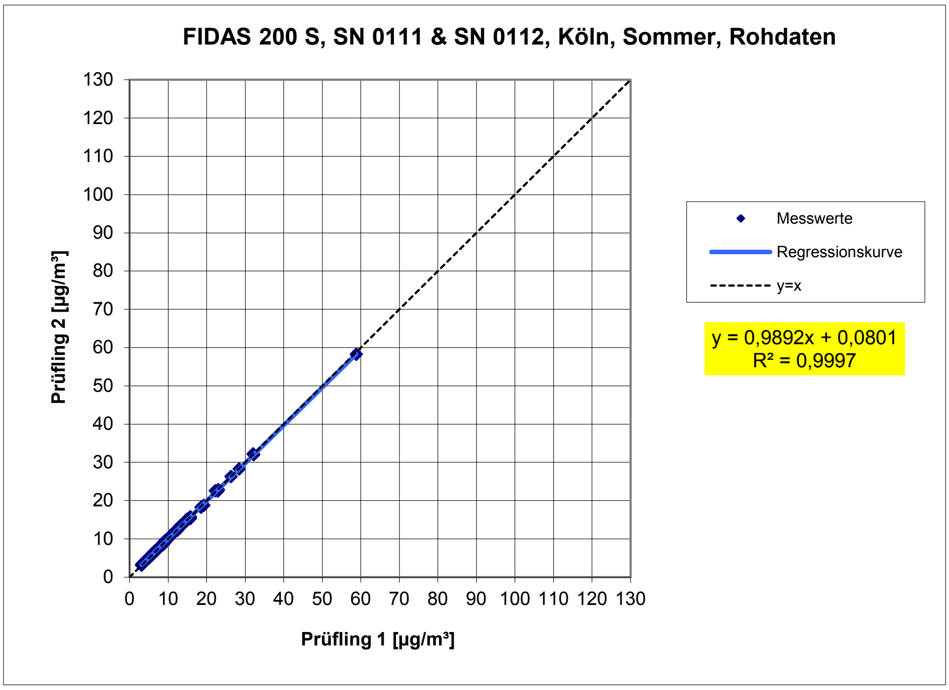

Figure 9: *Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2,5}$, Cologne, summer*

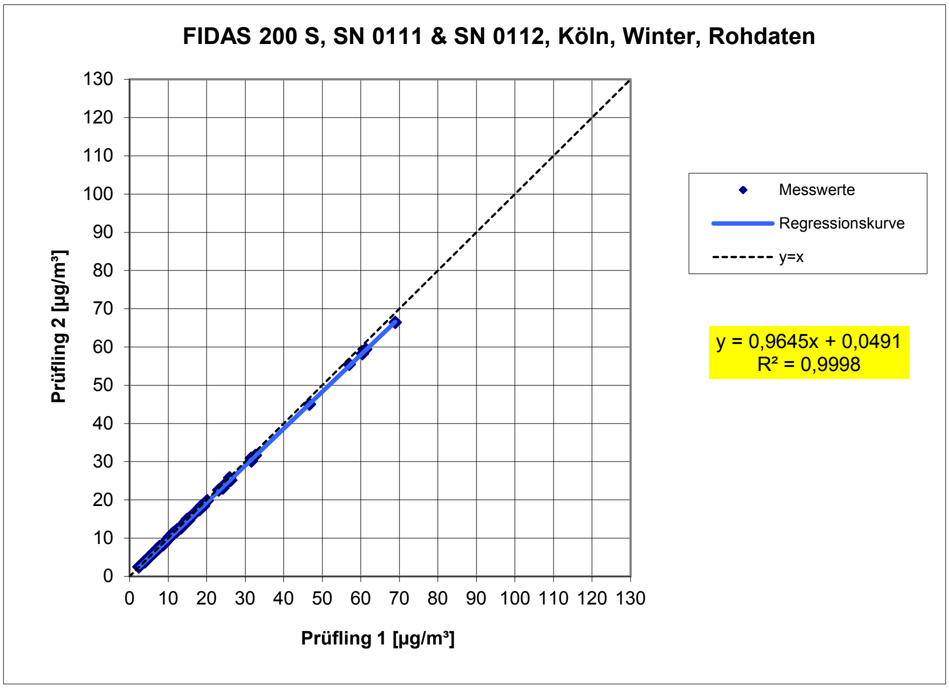

Figure 10: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, Cologne, winter

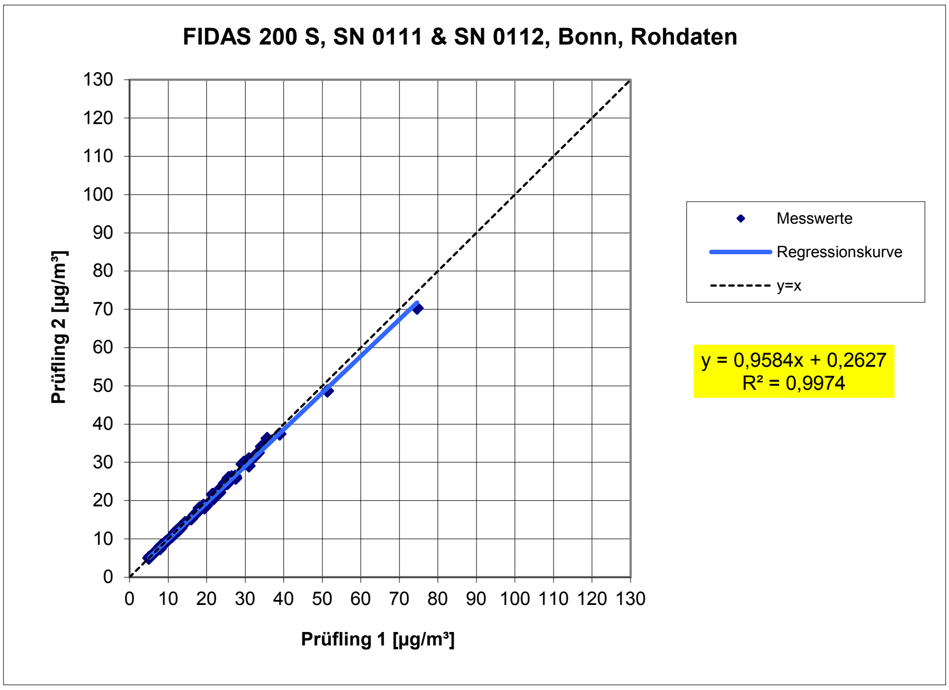

Figure 11: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, Bonn, winter

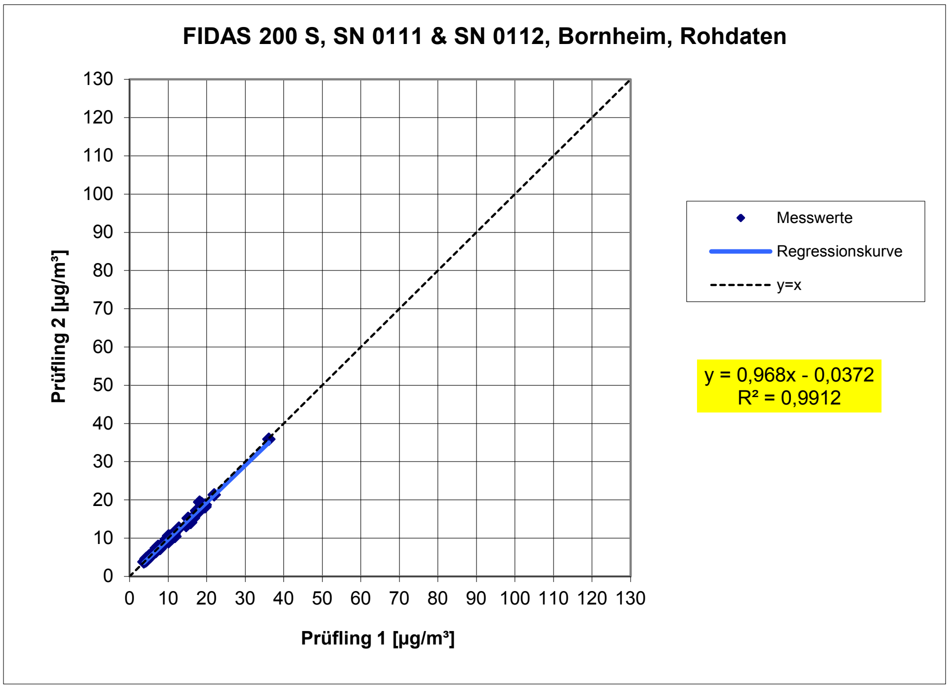

Figure 12: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, Bornheim, summer

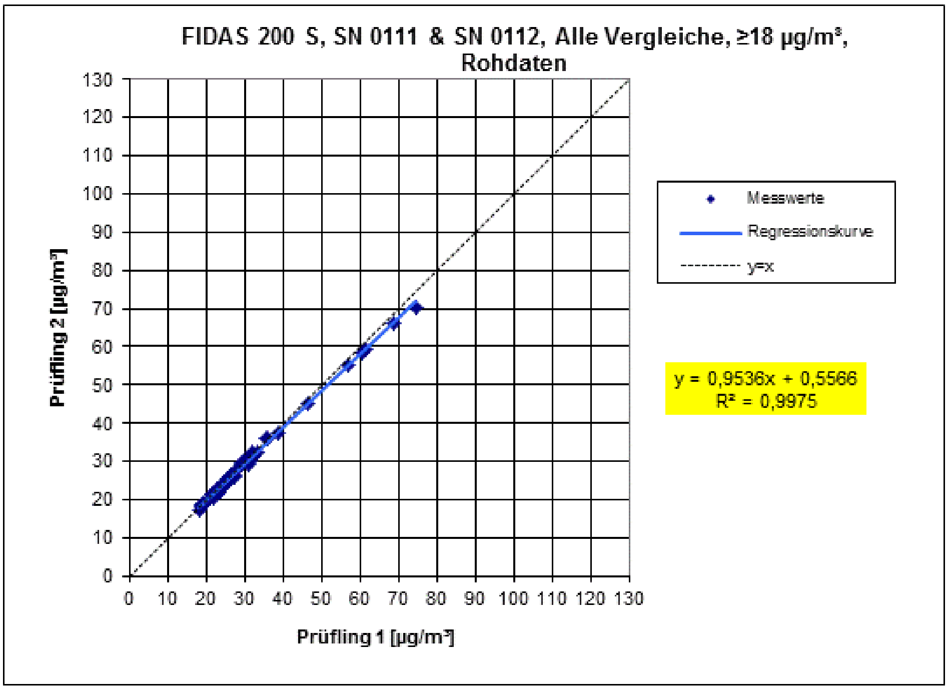

Figure 13: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2,5}$, all field test sites, values ≥ 18 µg/m³

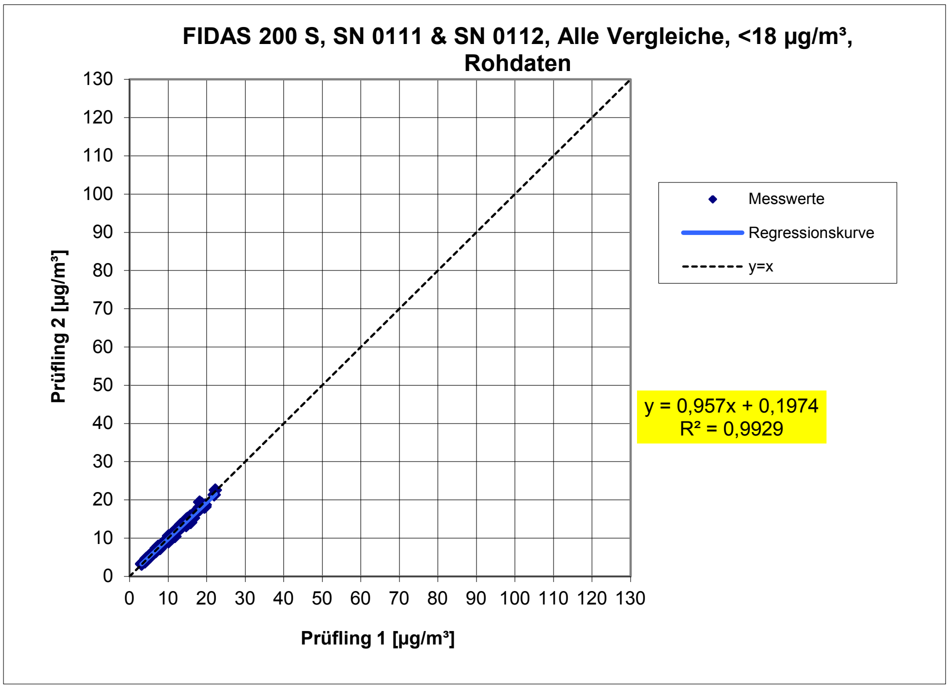

Figure 14: *Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, all field test sites, values < 18 µg/m³*

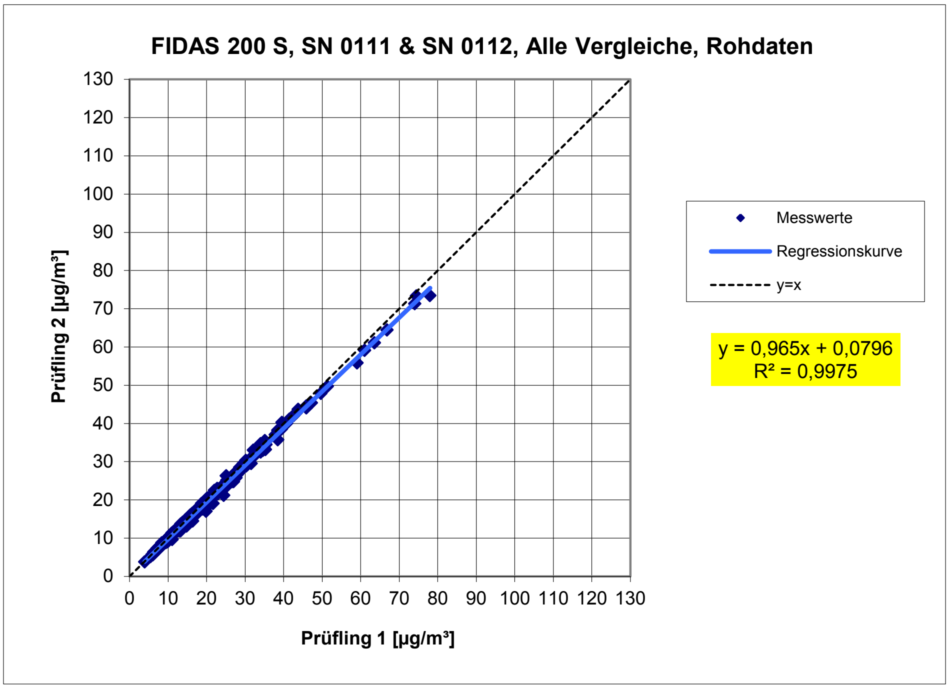

Figure 15: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component PM_{10}, all field test sites

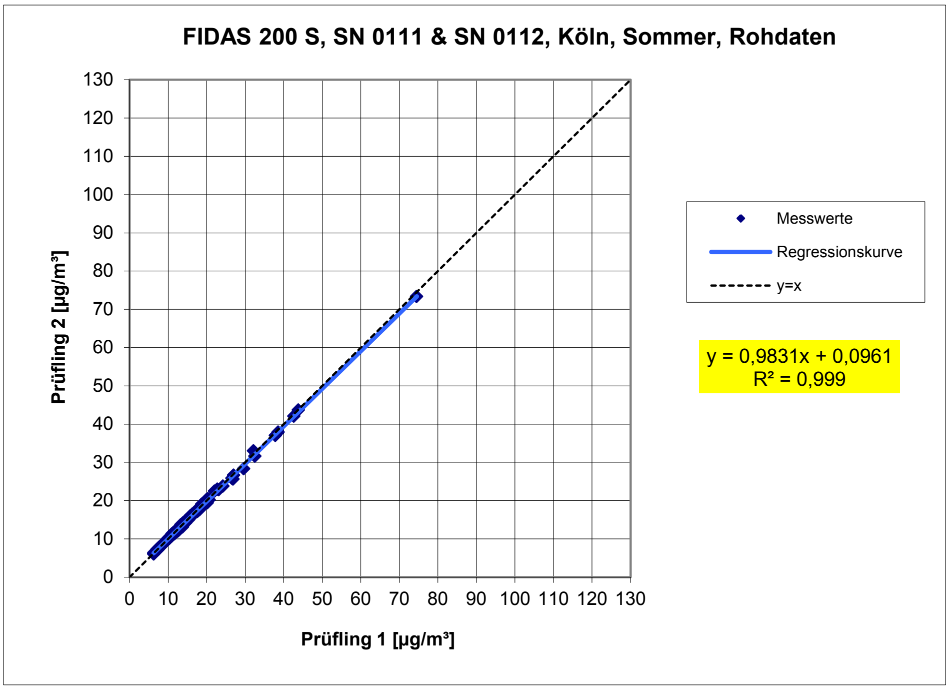

Figure 16: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component PM_{10}, Cologne, summer

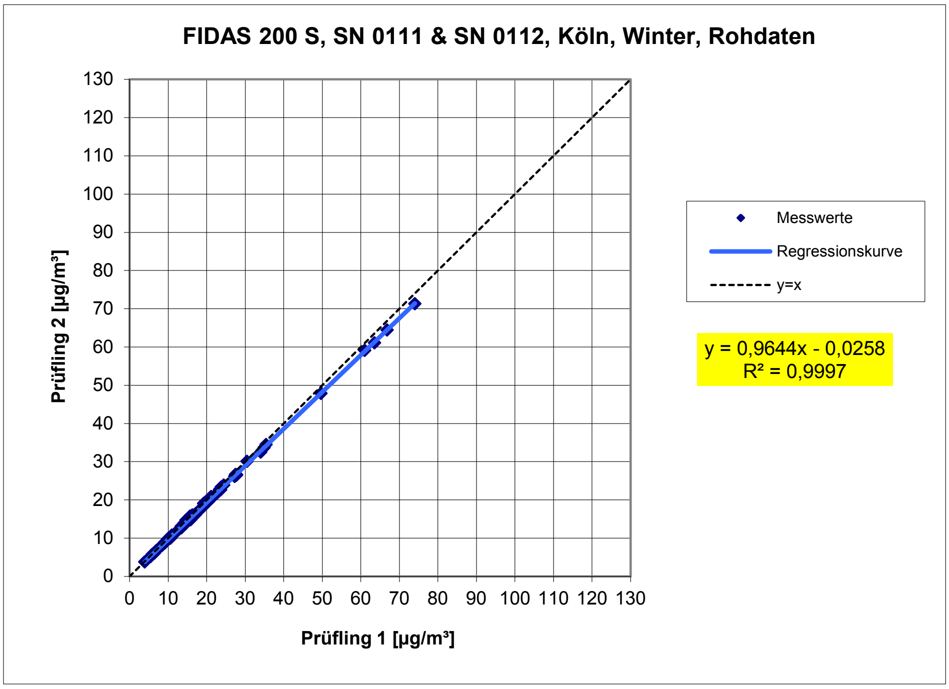

Figure 17: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component PM_{10}, Cologne, winter

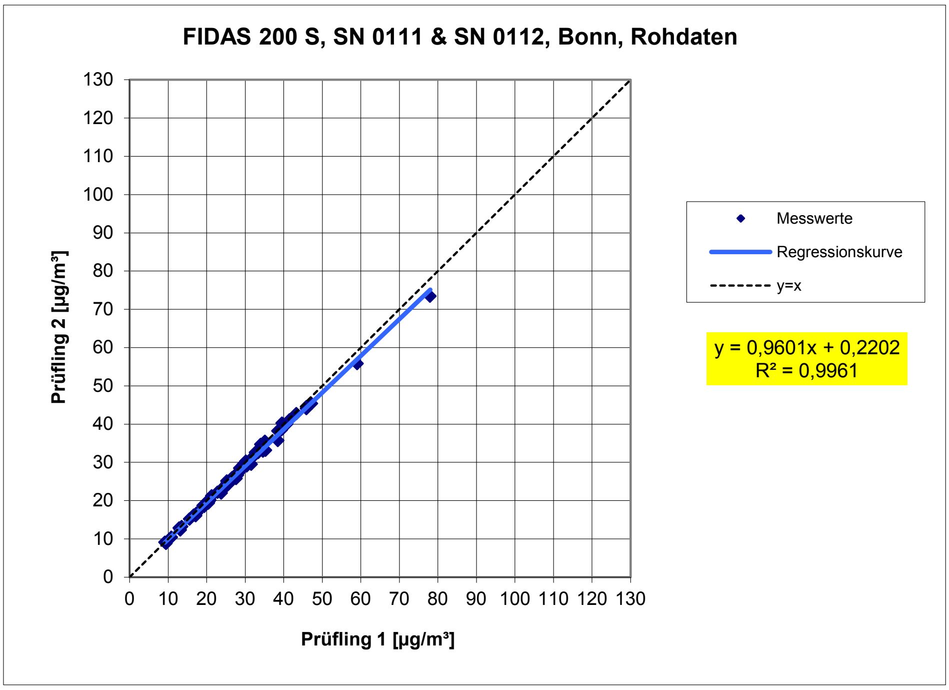

Figure 18: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component PM_{10}, Bonn, winter

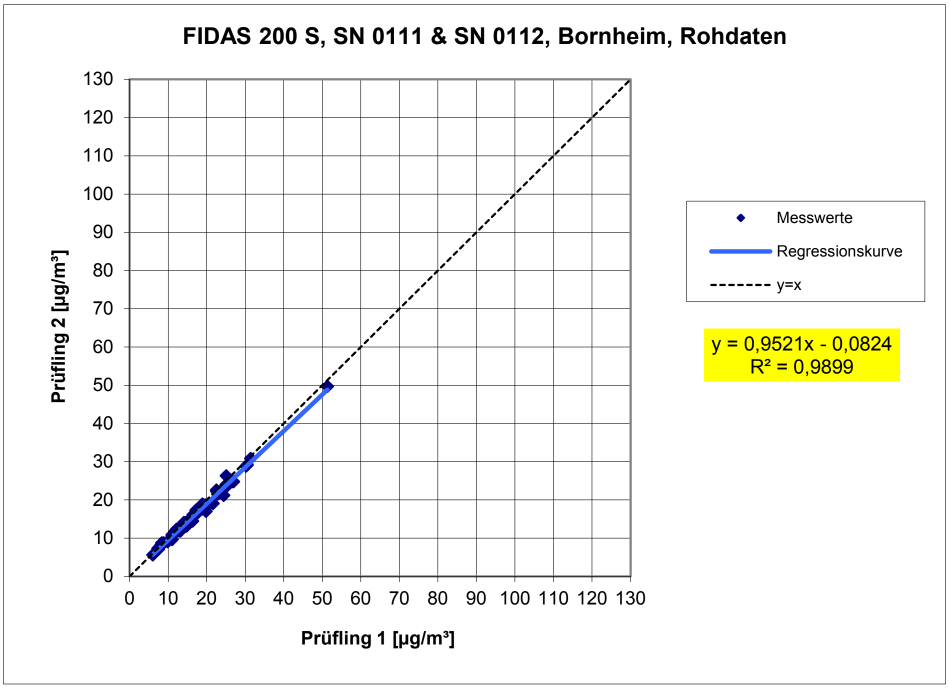

Figure 19: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component PM_{10}, Bornheim, summer

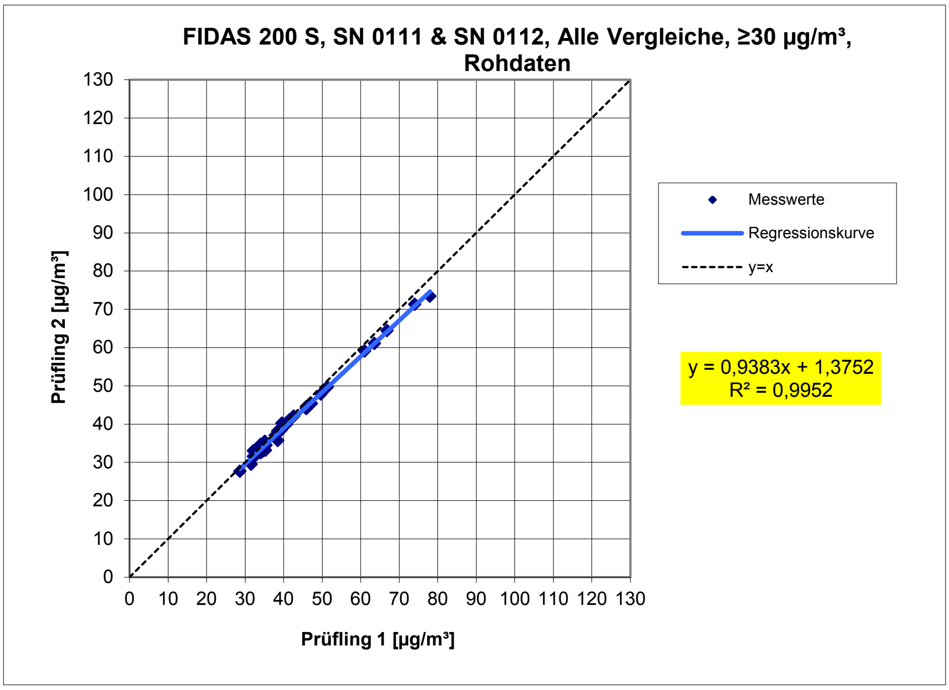

Figure 20: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component PM10, all field test sites, values ≥ 30 µg/m³

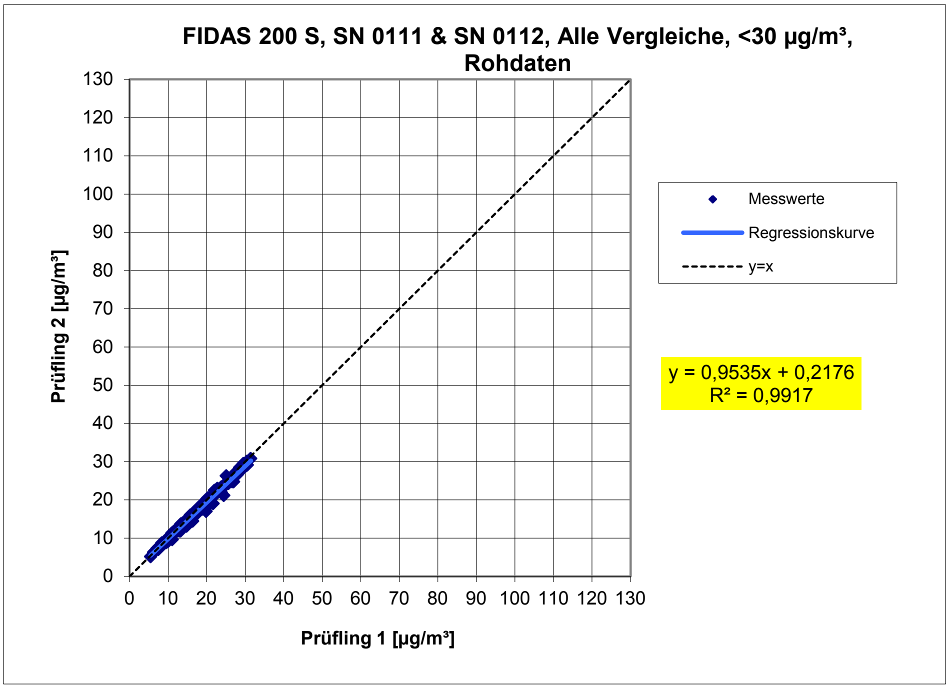

Figure 21: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component PM_{10}, all field test sites, values < 30 µg/m³

6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

The expanded uncertainty shall be ≤ 25% at the level of the relevant limit value related to the 24-hour average results – after a calibration where necessary.

6.2 Equipment

For this criterion, the instruments as described in Chapter 5 of the "Addendum to the report on performance testing of the Fidas® 200S, Fidas® 200 and Fidas® 200 E ambient air quality monitor for suspended particulate matter PM_{10} and $PM_{2,5}$ manufactured by PALAS GmbH", TÜV Report no. 936/21239834/A dated 1 September 2017 were used additionally.

6.3 Testing

The test was performed as part of the field test with four separate comparison campaigns. Different seasons as well as different concentrations of $PM_{2.5}$ and PM_{10} were taken into consideration.

In the full dataset, at least 20% of the results obtained using the reference method should be greater than the upper assessment threshold of the annual limit value specified in 2008/50/EC. The assessment threshold for $PM_{2.5}$ is 17 µg/m³, for PM_{10} it is 28 µg/m³.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full data set (4 comparisons, for PM_{10}: 229 valid pairs of measured values for SN 0111, 229 valid pairs of measured values for SN 0112; for $PM_{2,5}$: 227 valid pairs of measured values for SN 0111, 227 valid pairs of measured values for SN 0112), 27.1% of the measured values are above the upper assessment threshold of 17 µg/m³ for $PM_{2.5}$ and 20.3% of the measured values are above the upper assessment threshold of 28 µg/m³ for PM_{10}. The concentrations measured were related to the ambient conditions.

6.4 Evaluation

[EN 16450, 7.5.8.3]

Before calculating the expanded uncertainty of the test specimens, uncertainties were established between the simultaneously operated reference measuring systems (u_{ref})

Uncertainties between the simultaneously operated reference measuring systems $u_{bs,RM}$ were established similar to the between-AMS uncertainties and shall be ≤ 2.0 µg/m³.

Results of the evaluation are summarised in section 6.6.

[EN 16450, 7.5.8.5 & 7.5.8.6]

In order to assess comparability of the tested instruments y with the reference method x, a linear relationship $y_i = a + bx_i$ between the measured values of both methods is assumed. The association between the means of the reference systems and each individual test specimen to be assessed is established by means of orthogonal regression.

The regression is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- 1 data set with measured values $PM_{2.5}$ ≥ 18 µg/m³ (basis: averages of reference measurement)
- 1 data set with measured values PM_{10} ≥ 30 µg/m³ (basis: averages of reference measurement)

For further assessment, the uncertainty u_{c_s} resulting from a comparison of the test specimens with the reference method is described in the following equation which defines u_{CR} as a function of the fine dust concentration x_i.

$$u_{yi}^2 = \frac{RSS}{(n-2)} - u_{RM}{}^2 + \left[a + (b-1)L\right]^2$$

Where RSS is the sum of the (relative) residuals from orthogonal regression

u_{RM} = random uncertainty of the reference method; u_{RM} is calculated as $u_{bs,RM}/\sqrt{2}$, where $u_{bs,RM}$ is the between RM uncertainty of two reference instruments operated in parallel.

The algorithms for calculating axis intercept a and slope b as well as their variance by means of orthogonal regression are described in detail in the annex to standard 16450: 2017.

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

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

Uncertainty u_{CR} is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- 1 data set with measured values $PM_{2.5}$ ≥ 18 µg/m³ (basis: averages of reference measurement)
- 1 data set with measured values PM_{10} ≥ 30 µg/m³ (basis: averages of reference measurement)

The Guideline states the following prerequisite for accepting the full data set:

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

and

- The axis intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$, where u(a) and u(b) describe the standard uncertainty of the slope and the axis intercept calculated as the square root of the variance. If the prerequisites are not met, it is possible to calibrate the measuring systems in accordance with section 9.7 of the Guideline (also see 6.1 17 Use of correction factors/terms). The calibration may only be performed for the full data set.

[EN 16450, 7.5.8.7] For all datasets the combined relative uncertainty of the AMS $w_{c,CM}$ is calculated from a combination of contributions from 9.5.3.1 and 9.5.3.2 in accordance with the following equation:

$$w_{AMS}^2 = \frac{u_{yi=L}^2}{L^2}$$

For each data set the uncertainty w_{AMS} is calculated at a level of L = 30 µg/m³ for $PM_{2.5}$ as well as L = 50 µg/m³ for PM_{10}.

[EN 16450 7.5.8.8] For each data set the expanded relative uncertainty of the results measured with the test specimen is calculated by multiplying w_{AMS} by an coverage factor k according to the following equation:

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

In practice, k is specified at k=2 for large n.

[Item 9.6]

The largest resulting uncertainty W_{AMS} is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive 2008/50/EC. Two situations are conceivable:

1. $W_{AMS} \leq W_{dqo}$ → The test is deemed equivalent to the reference method.

2. $W_{AMS} > W_{dqo}$ → The tested instrument is not deemed equivalent to the reference method.

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

7.5 Assessment

Without the need for any correction factors, the expanded uncertainties W_{CM} were below the expanded, relative uncertainty W_{dqo} defined for fine dust at 25% for $PM_{2.5}$ and PM_{10} for all data sets observed. The uncertainties W_{CM} determined for $PM_{2.5}$ remained below the expanded, relative uncertainty W_{dqo} specified for fine dust at 25% for all data sets observed with the exception of Bornheim, summer. Correction factors shall be applied in accordance with item 6.1 17 Use of correction factors/terms (7.5.8.5 – 7.5.8.8).

Criterion satisfied? no

Correction factors in accordance with chapter 6.1 17 Use of correction factors/terms (7.5.8.5 – 7.5.8.8) were applied given excessive uncertainty at the test site “Bornheim, summer” for $PM_{2,5}$, the significant slope (SN 0111 & SN 0112) and intercept (SN 0111) the full data set for $PM_{2.5}$ as well as a significant slope and intercept for PM_{10}.

Table 3 and Table 4 below summarise all results for the equivalence tests of the Fidas® 200 S for $PM_{2.5}$ and PM_{10}. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 3: Overview of equivalence test results for the Fidas® 200 S for $PM_{2.5}$

Vergleich Testgerät mit Referenzgerät gemäß Richtlinie DIN EN 16450:2017					
Prüfling	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Grenzwert	30	µg/m³
Status Messwerte	Rohdaten		erlaubte Unsicherheit	25	%
Alle Vergleiche					
Unsicherheit zwischen Referenz	**0,58**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,48**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**225**				
Steigung b	**1,076**	**signifikant**			
Unsicherheit von b	**0,011**				
Achsabschnitt a	**-0,339**	**nicht signifikant**			
Unsicherheit von a	**0,192**				
Erweiterte Messunsicherheit W_{CM}	**17,06**	**%**			
Alle Vergleiche, ≥18 µg/m³					
Unsicherheit zwischen Referenz	**0,63**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,84**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**54**				
Steigung b	**1,046**				
Unsicherheit von b	**0,025**				
Achsabschnitt a	**0,458**				
Unsicherheit von a	**0,769**				
Erweiterte Messunsicherheit W_{CM}	**18,58**	**%**			
Alle Vergleiche, <18 µg/m³					
Unsicherheit zwischen Referenz	**0,57**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,33**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**171**				
Steigung b	**1,198**				
Unsicherheit von b	**0,032**				
Achsabschnitt a	**-1,482**				
Unsicherheit von a	**0,327**				
Erweiterte Messunsicherheit W_{CM}	**31,44**	**%**			

Vergleich Testgerät mit Referenzgerät gemäß Richtlinie DIN EN 16450:2017					
Prüfling	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Grenzwert	30	µg/m³
Status Messwerte	Rohdaten		erlaubte Unsicherheit	25	%
Köln, Sommer					
Unsicherheit zwischen Referenz	**0,66**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,12**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**81**			**82**	
Steigung b	**1,119**			**1,116**	
Unsicherheit von b	**0,034**			**0,035**	
Achsabschnitt a	**-0,925**			**-0,885**	
Unsicherheit von a	**0,363**			**0,378**	
Erweiterte Messunsicherheit W_{CM}	**20,35**	**%**		**20,37**	**%**
Köln, Winter					
Unsicherheit zwischen Referenz	**0,54**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,55**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**51**			**50**	
Steigung b	**1,051**			**1,014**	
Unsicherheit von b	**0,014**			**0,014**	
Achsabschnitt a	**0,691**			**0,679**	
Unsicherheit von a	**0,313**			**0,326**	
Erweiterte Messunsicherheit W_{CM}	**17,24**	**%**		**11,70**	**%**
Bonn					
Unsicherheit zwischen Referenz	**0,62**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,70**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**50**			**50**	
Steigung b	**1,114**			**1,070**	
Unsicherheit von b	**0,025**			**0,027**	
Achsabschnitt a	**-0,783**			**-0,519**	
Unsicherheit von a	**0,571**			**0,619**	
Erweiterte Messunsicherheit W_{CM}	**21,42**	**%**		**16,89**	**%**
Bornheim					
Unsicherheit zwischen Referenz	**0,42**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,50**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**45**			**45**	
Steigung b	**1,214**			**1,186**	
Unsicherheit von b	**0,054**			**0,054**	
Achsabschnitt a	**-1,487**			**-1,606**	
Unsicherheit von a	**0,644**			**0,643**	
Erweiterte Messunsicherheit W_{CM}	**35,08**	**%**		**29,18**	**%**
Alle Vergleiche, ≥18 µg/m³					
Unsicherheit zwischen Referenz	**0,63**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,84**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**54**			**54**	
Steigung b	**1,071**			**1,022**	
Unsicherheit von b	**0,025**			**0,026**	
Achsabschnitt a	**0,185**			**0,713**	
Unsicherheit von a	**0,754**			**0,80**	
Erweiterte Messunsicherheit W_{CM}	**20,59**	**%**		**17,15**	**%**
Alle Vergleiche, <18 µg/m³					
Unsicherheit zwischen Referenz	**0,57**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,33**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**173**			**173**	
Steigung b	**1,222**			**1,180**	
Unsicherheit von b	**0,032**			**0,032**	
Achsabschnitt a	**-1,573**			**-1,399**	
Unsicherheit von a	**0,328**			**0,331**	
Erweiterte Messunsicherheit W_{CM}	**35,38**	**%**		**28,53**	**%**
Alle Vergleiche					
Unsicherheit zwischen Referenz	**0,58**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,48**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**227**			**227**	
Steigung b	**1,096**	**signifikant**		**1,056**	**signifikant**
Unsicherheit von b	**0,011**			**0,011**	
Achsabschnitt a	**-0,408**	**signifikant**		**-0,234**	**nicht signifikant**
Unsicherheit von a	**0,190**			**0,196**	
Erweiterte Messunsicherheit W_{CM}	**19,75**	**%**		**14,94**	**%**

Results for testing the five criteria from chapter 6.1 Method used for equivalence testing (7.5.8.4 - 7.5.8.8) were as follows:

Criterion 1: More than 20% of the data exceed 17 µg/m³.

Criterion 2: Between-AMS uncertainty of the AMS tested did not exceed 2.5 µg/m³.

Criterion 3: Uncertainty between reference instruments did not exceed 2.0 µg/m³.

Criterion 4: Except for Bornheim, summer, all expanded uncertainties remained below 25%.

Criterion 5: For both tested systems, the slope determined when assessing the full data set exceeded permissible limits.
Moreover when assessing the full data set, the intercept for SN 0111 proved significantly higher than permitted.

Additional: The slope determined for the full data set regarding both test specimens combined was at 1.076, the axis intercept was at -0.339 at a total expanded uncertainty of 17.06%.

Table 4: Overview of equivalence test results for the Fidas® 200 S for PM_{10}

Vergleich Testgerät mit Referenzgerät gemäß Richtlinie DIN EN 16450:2017					
Prüfling	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Grenzwert	50	µg/m³
Status Messwerte	Rohdaten		erlaubte Unsicherheit	25	%
Alle Vergleiche					
Unsicherheit zwischen Referenz	**0,62**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,67**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**227**				
Steigung b	**1,058**	signifikant			
Unsicherheit von b	**0,011**				
Achsabschnitt a	**-1,505**	signifikant			
Unsicherheit von a	**0,264**				
Erweiterte Messunsicherheit W_{CM}	**9,27**	**%**			
Alle Vergleiche, ≥30 µg/m³					
Unsicherheit zwischen Referenz	**0,67**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**1,17**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**35**				
Steigung b	**1,005**				
Unsicherheit von b	**0,038**				
Achsabschnitt a	**0,746**				
Unsicherheit von a	**1,619**				
Erweiterte Messunsicherheit W_{CM}	**11,25**	**%**			
Alle Vergleiche, <30 µg/m³					
Unsicherheit zwischen Referenz	**0,61**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,58**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**192**				
Steigung b	**1,085**				
Unsicherheit von b	**0,022**				
Achsabschnitt a	**-1,979**				
Unsicherheit von a	**0,386**				
Erweiterte Messunsicherheit W_{CM}	**11,31**	**%**			

Vergleich Testgerät mit Referenzgerät gemäß Richtlinie DIN EN 16450:2017					
Prüfling	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Grenzwert	50	µg/m³
Status Messwerte	Rohdaten		erlaubte Unsicherheit	25	%
Köln, Sommer					
Unsicherheit zwischen Referenz	**0,80**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,27**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**81**			**82**	
Steigung b	**1,045**			**1,028**	
Unsicherheit von b	**0,028**			**0,028**	
Achsabschnitt a	**-1,637**			**-1,524**	
Unsicherheit von a	**0,490**			**0,489**	
Erweiterte Messunsicherheit W_{CM}	**7,34**	**%**		**6,93**	**%**
Köln, Winter					
Unsicherheit zwischen Referenz	**0,53**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,67**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**51**			**50**	
Steigung b	**1,064**			**1,027**	
Unsicherheit von b	**0,015**			**0,015**	
Achsabschnitt a	**-1,260**			**-1,284**	
Unsicherheit von a	**0,399**			**0,398**	
Erweiterte Messunsicherheit W_{CM}	**9,78**	**%**		**5,73**	**%**
Bonn					
Unsicherheit zwischen Referenz	**0,38**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,90**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**50**			**50**	
Steigung b	**1,043**			**1,004**	
Unsicherheit von b	**0,027**			**0,029**	
Achsabschnitt a	**-0,082**			**0,061**	
Unsicherheit von a	**0,821**			**0,865**	
Erweiterte Messunsicherheit W_{CM}	**12,03**	**%**		**9,36**	**%**
Bornheim					
Unsicherheit zwischen Referenz	**0,54**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,87**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**47**			**47**	
Steigung b	**1,128**			**1,083**	
Unsicherheit von b	**0,040**			**0,039**	
Achsabschnitt a	**-1,986**			**-2,169**	
Unsicherheit von a	**0,733**			**0,720**	
Erweiterte Messunsicherheit W_{CM}	**19,11**	**%**		**10,74**	**%**
Alle Vergleiche, ≥30 µg/m³					
Unsicherheit zwischen Referenz	**0,67**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**1,17**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**35**			**35**	
Steigung b	**1,037**			**0,974**	
Unsicherheit von b	**0,038**			**0,039**	
Achsabschnitt a	**0,054**			**1,391**	
Unsicherheit von a	**1,628**			**1,65**	
Erweiterte Messunsicherheit W_{CM}	**13,06**	**%**		**10,72**	**%**
Alle Vergleiche, <30 µg/m³					
Unsicherheit zwischen Referenz	**0,61**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,58**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**194**			**194**	
Steigung b	**1,109**			**1,063**	
Unsicherheit von b	**0,022**			**0,021**	
Achsabschnitt a	**-2,089**			**-1,870**	
Unsicherheit von a	**0,394**			**0,378**	
Erweiterte Messunsicherheit W_{CM}	**15,08**	**%**		**8,35**	**%**
Alle Vergleiche					
Unsicherheit zwischen Referenz	**0,62**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,67**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**229**			**229**	
Steigung b	**1,077**	signifikant		**1,039**	signifikant
Unsicherheit von b	**0,011**			**0,011**	
Achsabschnitt a	**-1,561**	signifikant		**-1,436**	signifikant
Unsicherheit von a	**0,266**			**0,264**	
Erweiterte Messunsicherheit W_{CM}	**11,87**	**%**		**7,73**	**%**

Results for testing the five criteria from chapter 6.1 Method used for equivalence testing (7.5.8.4 - 7.5.8.8) were as follows:

Criterion 1:	More than 20% of the data exceed 28 µg/m³.
Criterion 2:	Between-AMS uncertainty of the AMS tested did not exceed 2.5 µg/m³.
Criterion 3:	Uncertainty between reference instruments did not exceed 2.0 µg/m³.
Criterion 4:	All expanded uncertainties remained below 25%.
Criterion 5:	For both candidate systems, the evaluation showed that the slope and the axis intercept significantly exceeded the permissible thresholds.
Additional:	The slope determined for the full data set regarding both test specimens combined was at 1.058, the axis intercept was at -1.505 at a total expanded uncertainty of 9.27%.

The January 2010 version of the Guideline does not specify clearly which axis intercept and which slope to use for correcting test specimens if a test specimen does not meet the requirements for equivalence testing. After double-checking with the chair of the EU working group responsible for issuing the Guideline (Mr Theo Hafkenscheid), we decided to apply the requirements of the November 2005 version of the Guideline and to use the slope and the intercept determined by means of orthogonal regression for the full data set. These are listed for each criterion under “Additional”

As a consequence of the data presented in Table 3 regarding the excessive uncertainty W_{CM} at the site in Bornheim (summer) and the significance determined, the slope and intercept of $PM_{2,5}$ had to be corrected. Given the significance determined for PM_{10} as presented in Table 4, the slope and the intercept for PM_{10} had to be corrected as well.

It should be noted here that the uncertainty W_{CM} determined without applying correction factors for all observed data sets is below the determined expanded relative uncertainty W_{dqo} of 25% for PM_{10}.

For $PM_{2.5}$:

The slope for the entire data set is 1.076. The intercept for the full data set is -0.339. This is why chapter 6.1 17 Use of correction factors/terms (7.5.8.5 – 7.5.8.8) contains an additional assessment for which the corresponding calibration factors were applied to the data sets.

For PM_{10}:

The slope for the entire data set is 1.058. The intercept for the full data set is -1.505. This is why chapter 6.1 17 Use of correction factors/terms (7.5.8.5 – 7.5.8.8) contains an additional assessment for which the corresponding calibration factors were applied to the data sets.

For compliant monitoring, the revised version of the January 2010 Guideline requires continuous random checks of a certain number of instruments in a measurement grid and specify the number of measurement sites to be checked as a function of the expanded uncertainty of a measuring system. The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation. However, TÜV Rheinland recommend that the expanded uncertainty of the entire data set (in the present case, the uncorrected raw data) be used for this purpose: 17.1% for $PM_{2.5}$, implying annual checks at four measurement sites and 9.3% for PM_{10} implying checks a year at two measurement sites (Guideline GDE 2010, Chapter 9.9.2, Table 2010 or EN 16450 [9], Chapter 9.9.2, Table 6). As a result of the necessary use of calibration factors, this assessment should be based on the evaluation of the corrected data sets (see chapter 6.1 17 Use of correction factors/terms (7.5.8.5 – 7.5.8.8)).

6.6 Detailed presentation of test results

Table 5 and Table 6 provide an overview of the Between RM uncertainty u_{ref} determined in the field test.

Table 5: Between RM uncertainty u_{ref} for $PM_{2,5}$

Reference instruments	Location	Number of measurements	Uncertainty u_{bs}
No.			µg/m³
1 / 2	Cologne, summer	82	0.66
1 / 2	Cologne, Winter	52	0.54
1 / 2	Bonn, winter	50	0.62
1 / 2	Bornheim, Summer	47	0.42
1 / 2	All locations	231	0.58

Table 6: Between RM uncertainty u_{ref} for PM_{10}

Reference instruments	Location	Number of measurements	Uncertainty u_{bs}
No.			µg/m³
1 / 2	Cologne, summer	82	0.80
1 / 2	Cologne, Winter	52	0.53
1 / 2	Bonn, winter	50	0.38
1 / 2	Bornheim, Summer	49	0.54
1 / 2	All locations	233	0.62

Between RM uncertainty u_{ref} remained < 2 µg/m³ at all test sites.

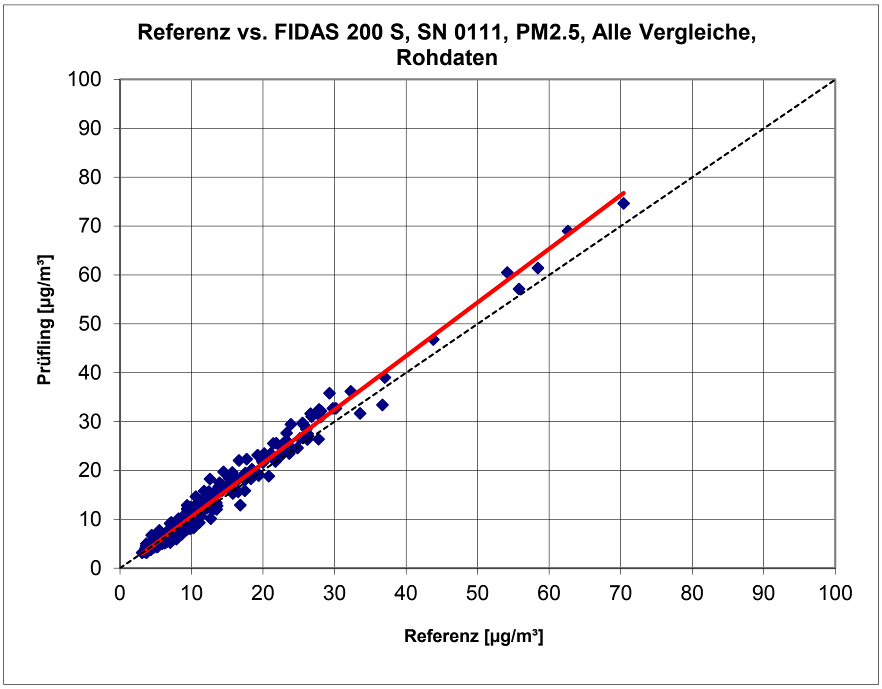

Figure 22: Reference vs. tested instrument, SN 0111, $PM_{2,5}$, all tested sites

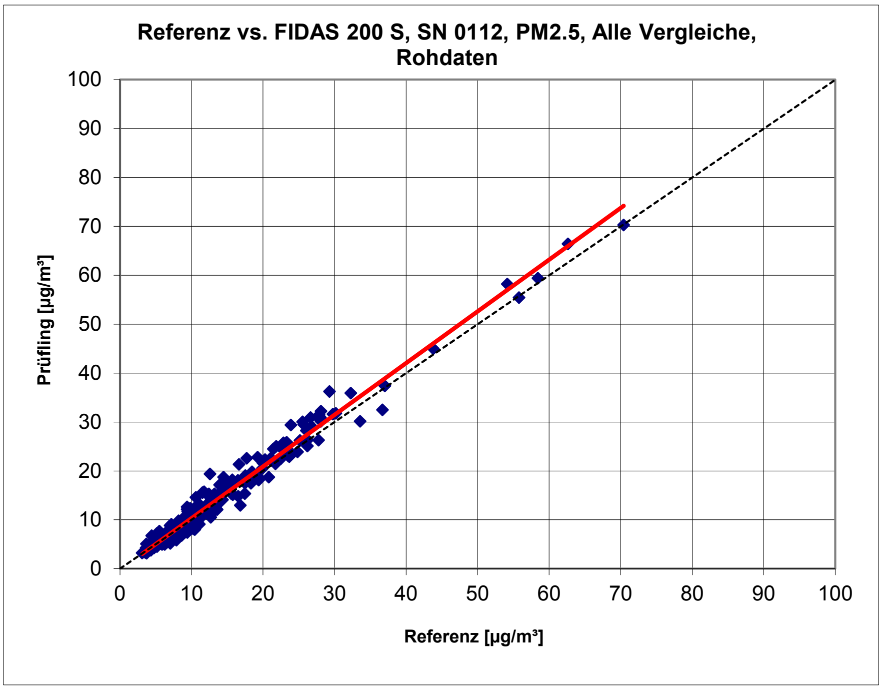

Figure 23: Reference vs. tested instrument, SN 0112, $PM_{2,5}$, all tested sites

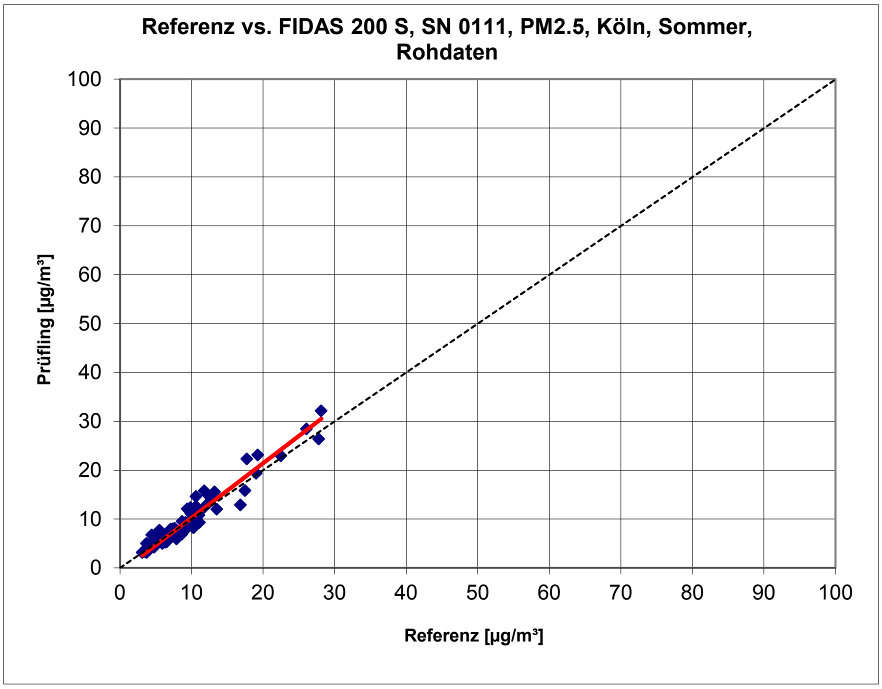

Figure 24: Reference vs. tested instrument, SN 0111, $PM_{2.5}$, Cologne, summer

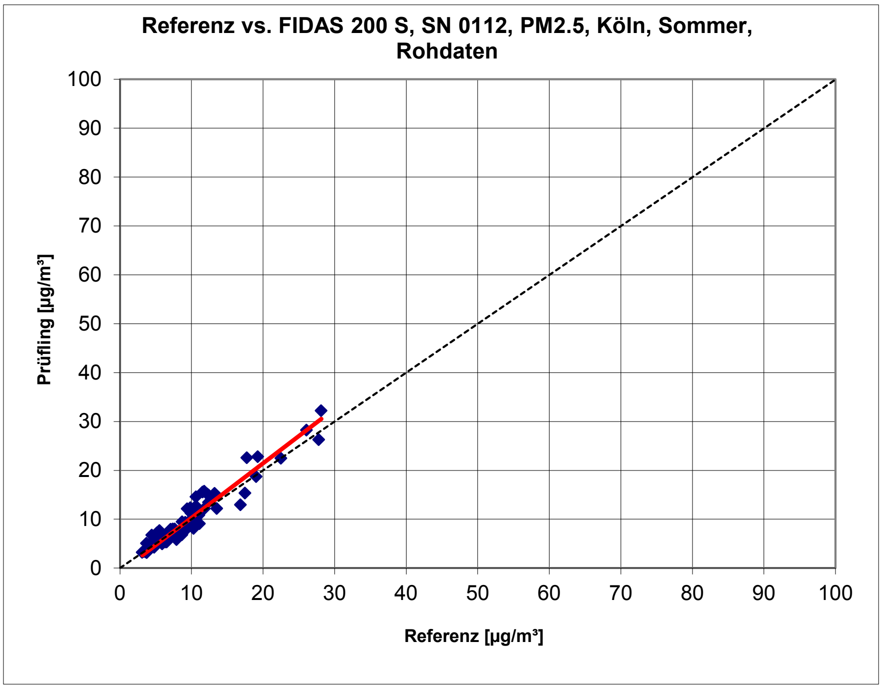

Figure 25: Reference vs. tested instrument, SN 0112, $PM_{2.5}$, Cologne, summer

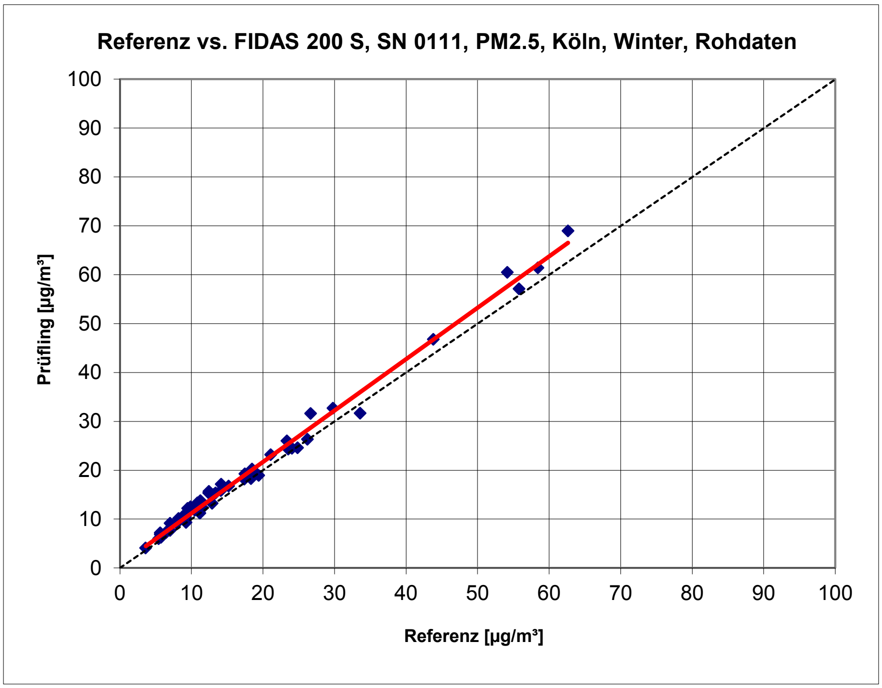

Figure 26: *Reference vs. tested instrument, SN 0111, $PM_{2.5}$, Cologne, winter*

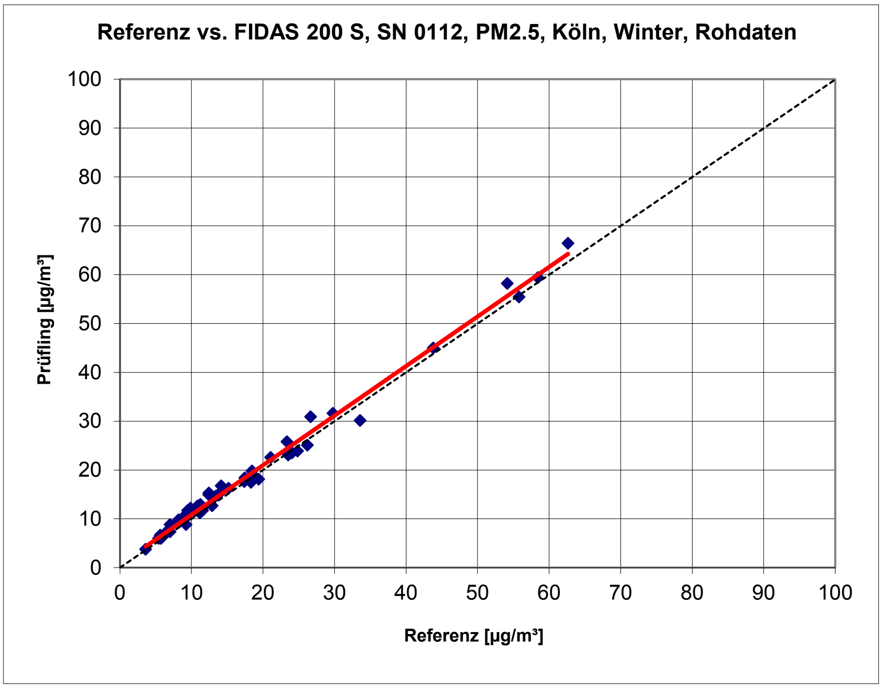

Figure 27: *Reference vs. tested instrument, SN 0112, $PM_{2.5}$, Cologne, winter*

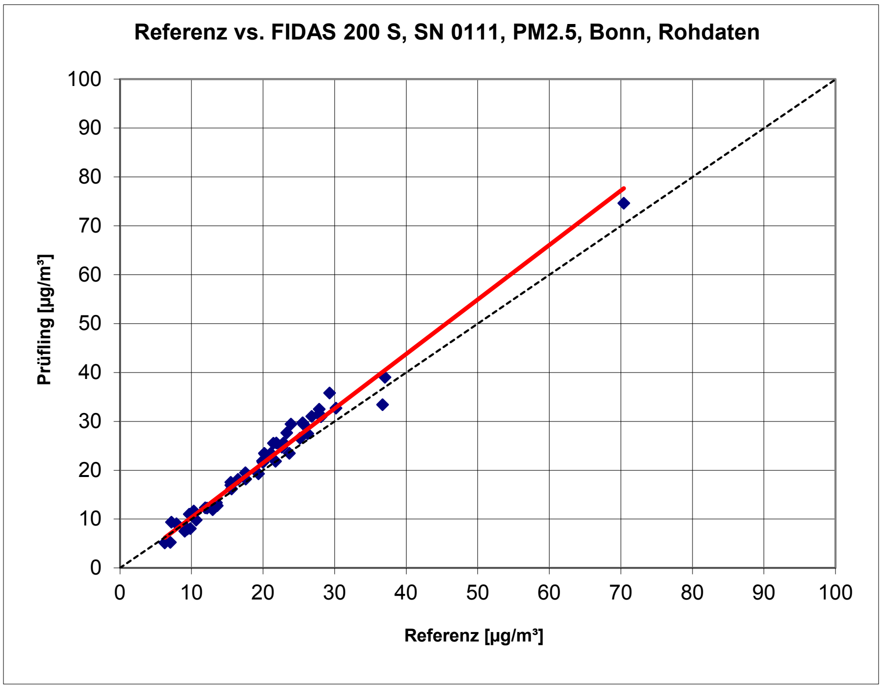

Figure 28: *Reference vs. tested instrument, SN 0111, $PM_{2.5}$, Bonn, winter*

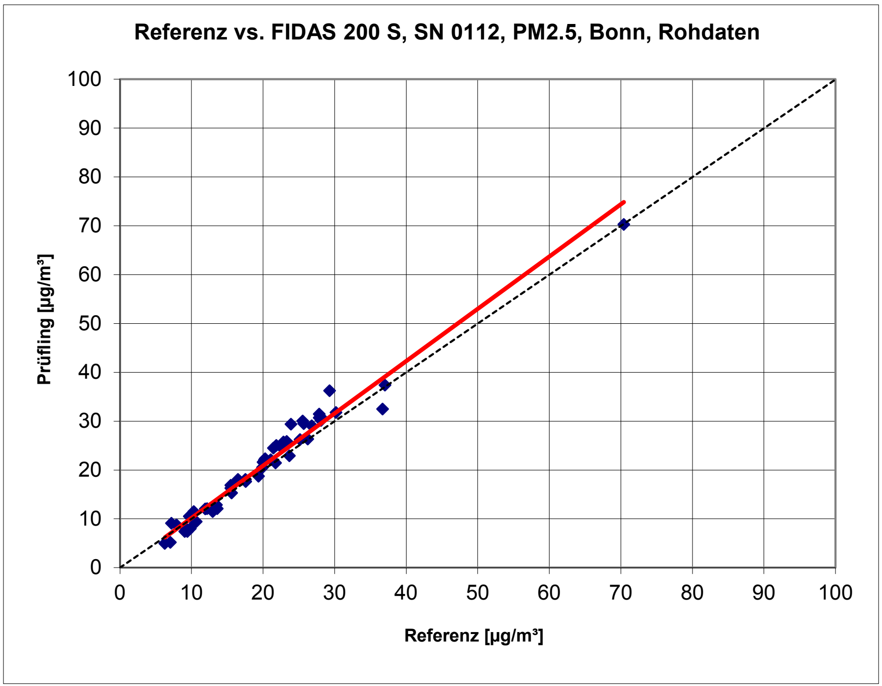

Figure 29: *Reference vs. tested instrument, SN 0112, $PM_{2.5}$, Bonn, winter*

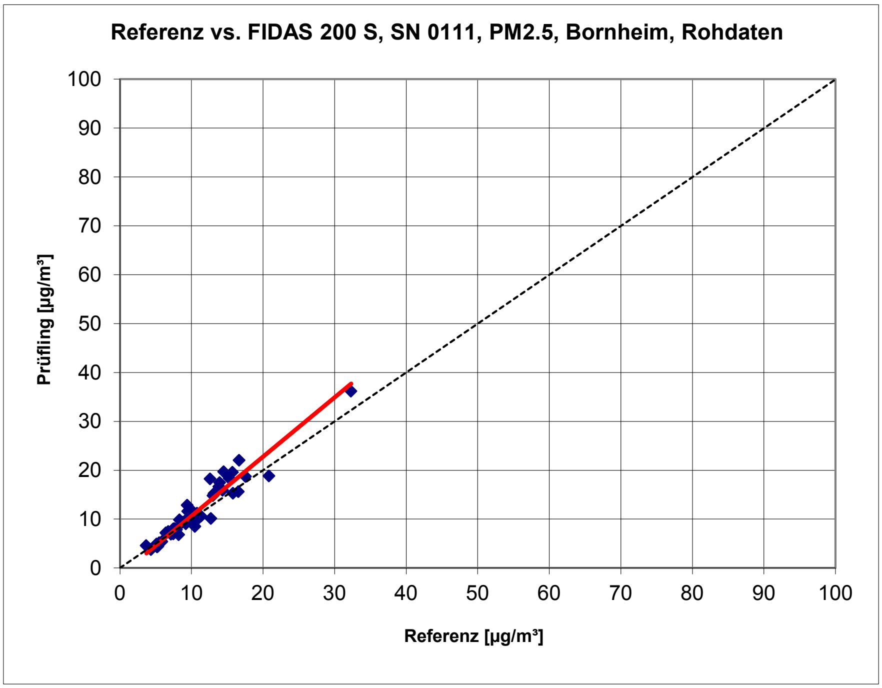

Figure 30: Reference vs. tested instrument, SN 0111, $PM_{2.5}$, Bornheim, summer

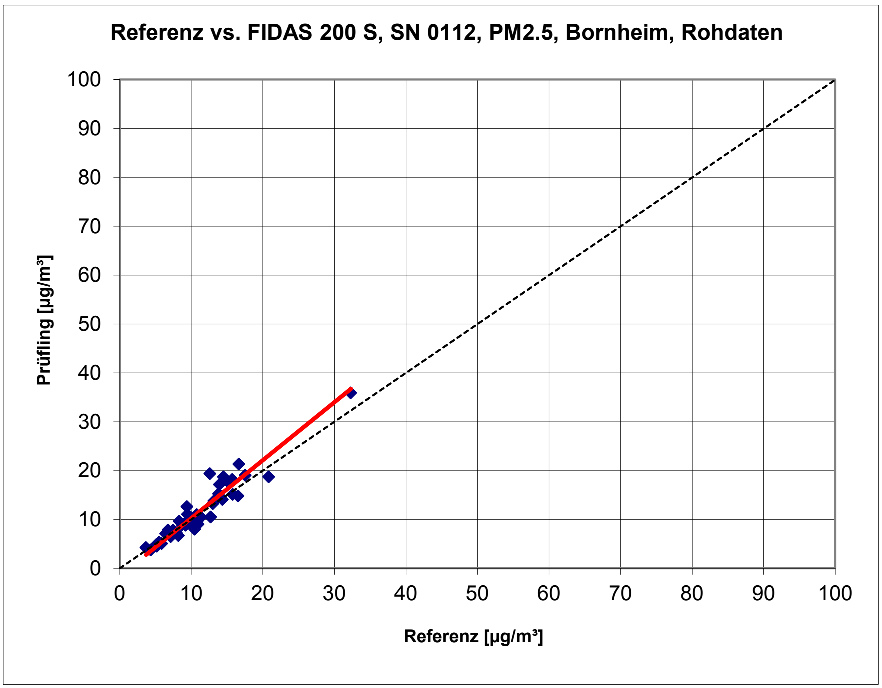

Figure 31: Reference vs. tested instrument, SN 0112, $PM_{2.5}$, Bornheim, summer

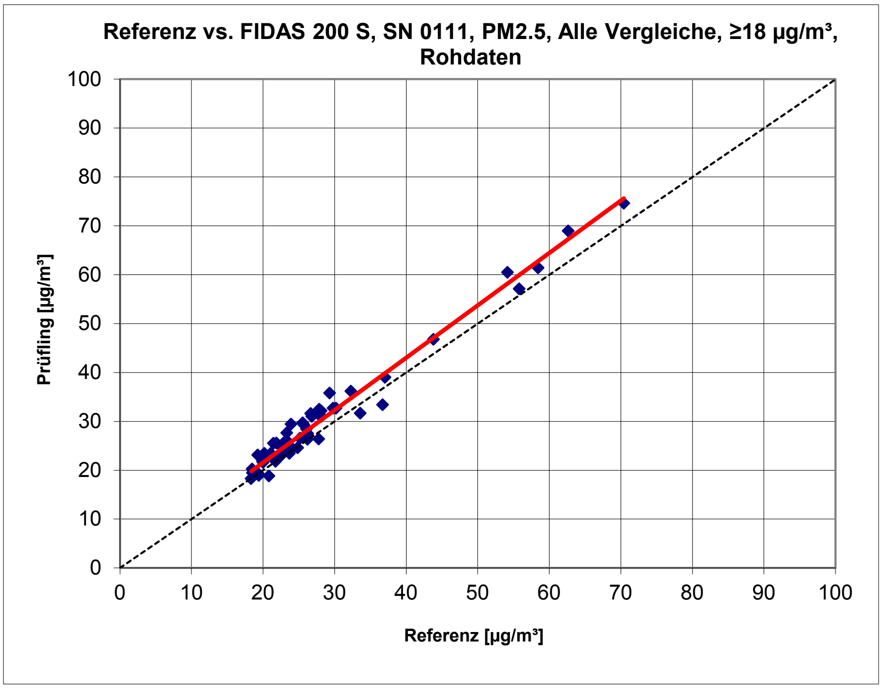

Figure 32: Reference vs. tested instrument, SN 0111, $PM_{2.5}$, values ≥ 18 µg/m³

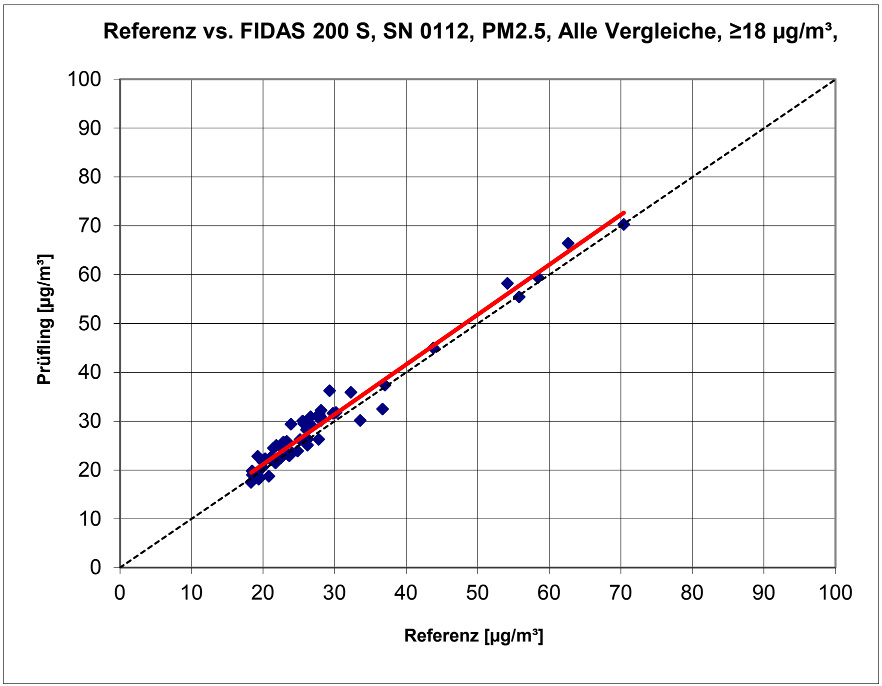

Figure 33: Reference vs. tested instrument, SN 0112, $PM_{2.5}$, values ≥ 18 µg/m³

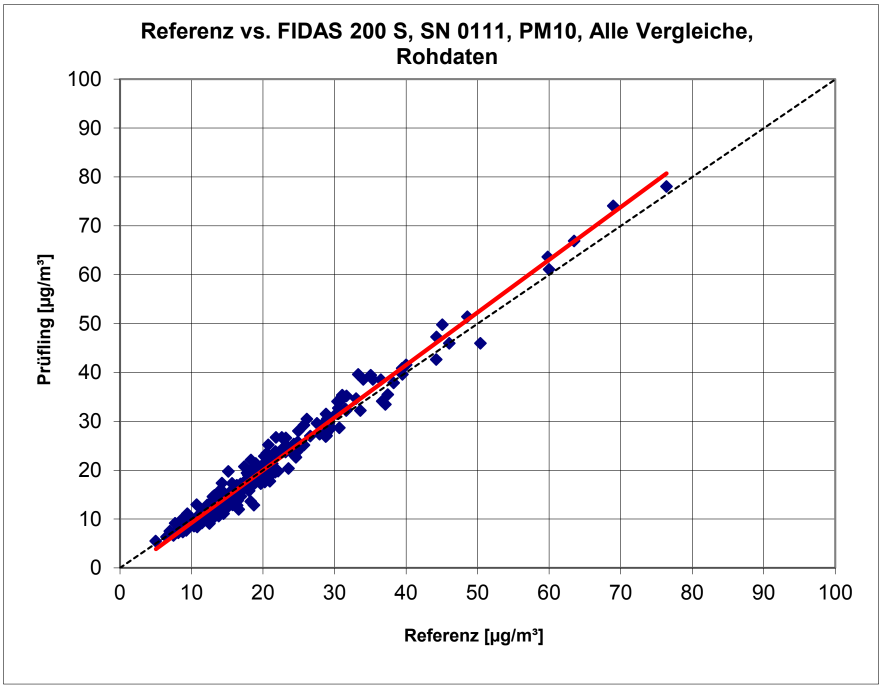

Figure 34: Reference vs. tested instrument SN 0111, PM_{10}, all sites

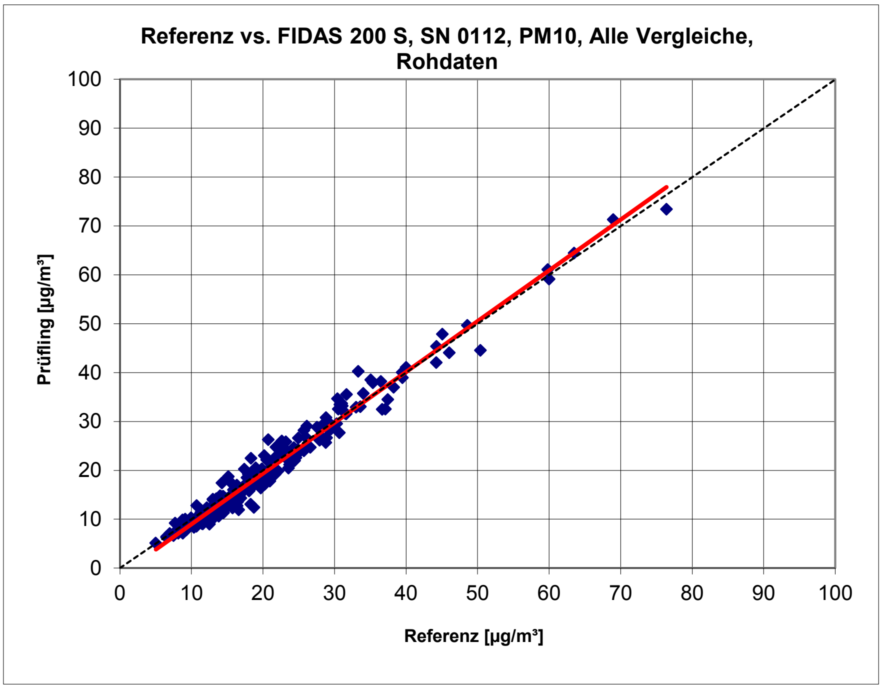

Figure 35: Reference vs. tested instrument SN 0112, PM_{10}, all sites

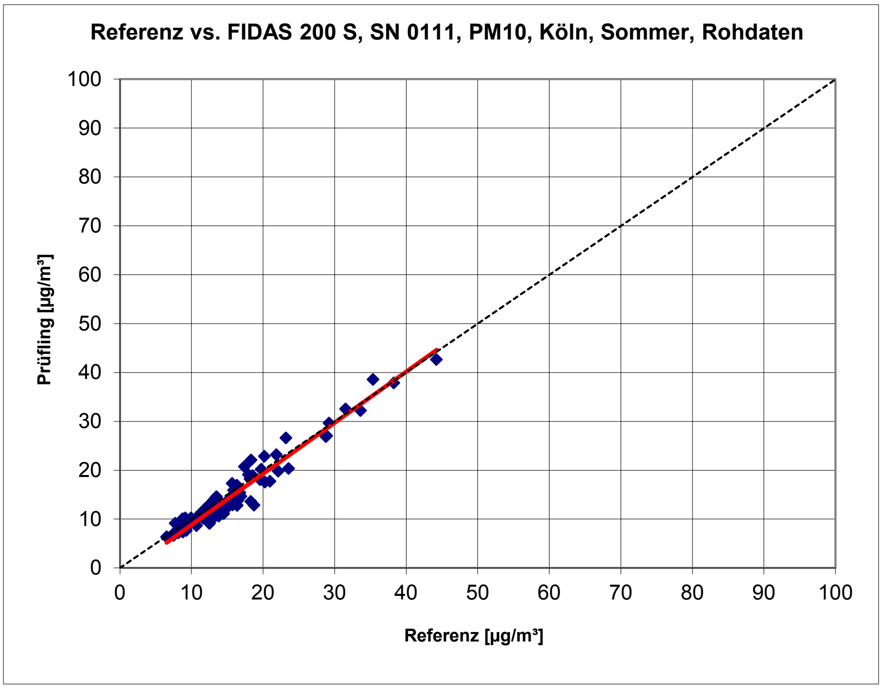

Figure 36: Reference vs. tested instrument SN 0111, measured component PM_{10}, Cologne, summer

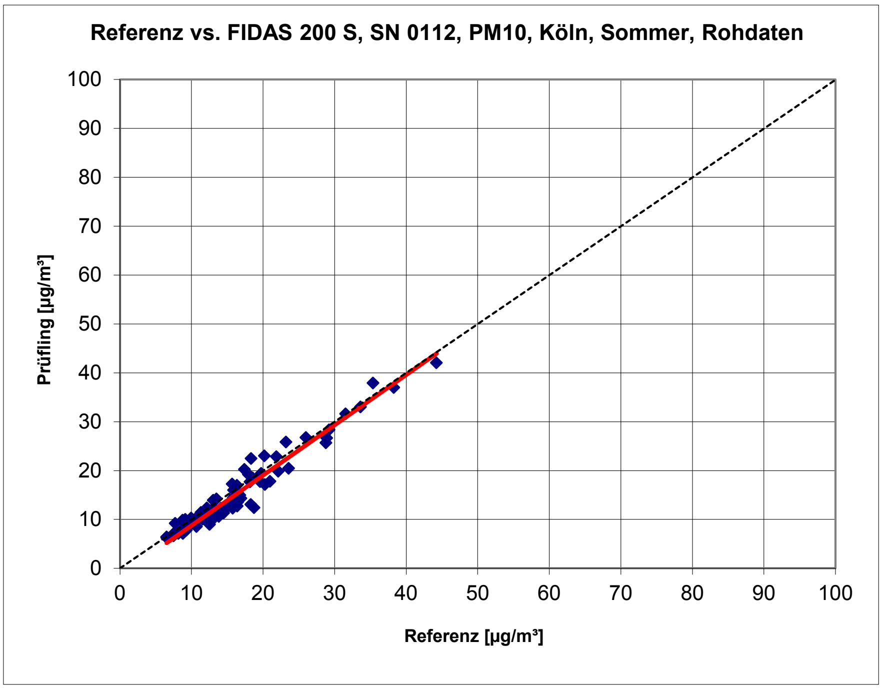

Figure 37: Reference vs. tested instrument SN 0112, PM_{10}, Cologne, summer

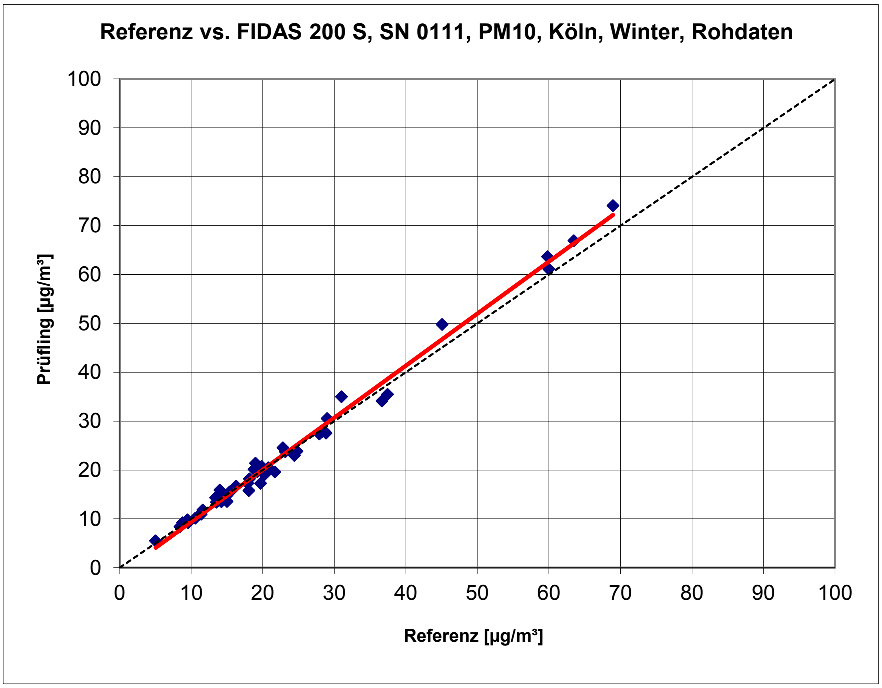

Figure 38: Reference vs. Tested instrument SN 0111, PM_{10}, Cologne, winter

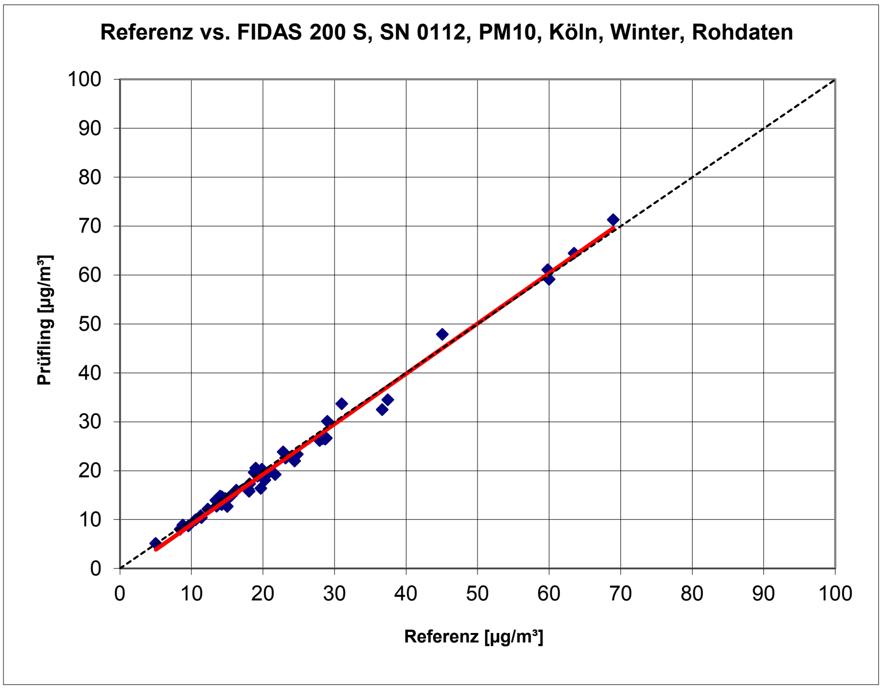

Figure 39: Reference vs. Tested instrument SN 0112, PM_{10}, Cologne, winter

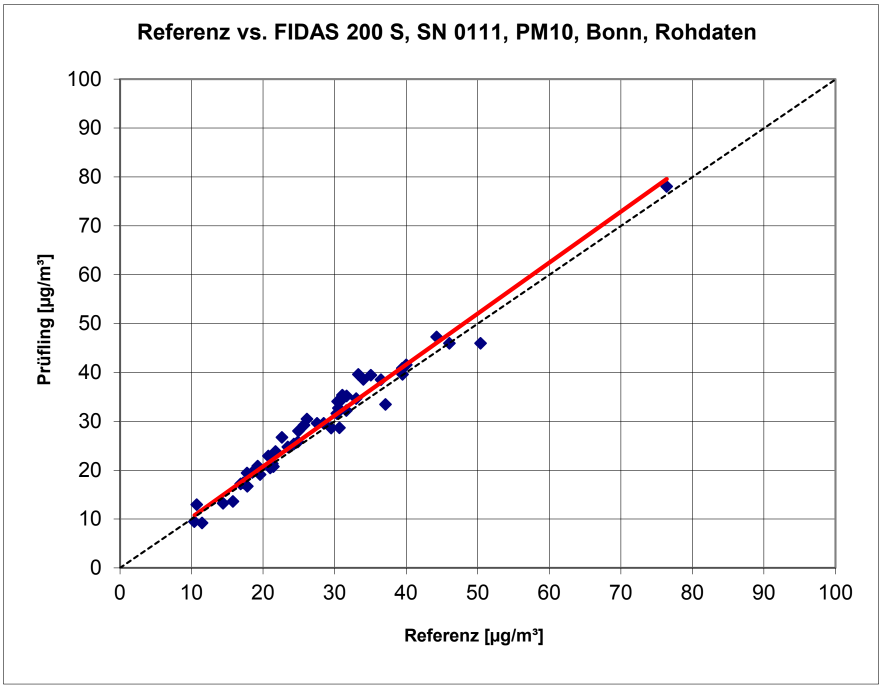

Figure 40: Reference vs. tested instrument SN 0111, PM_{10}, Bonn, winter,

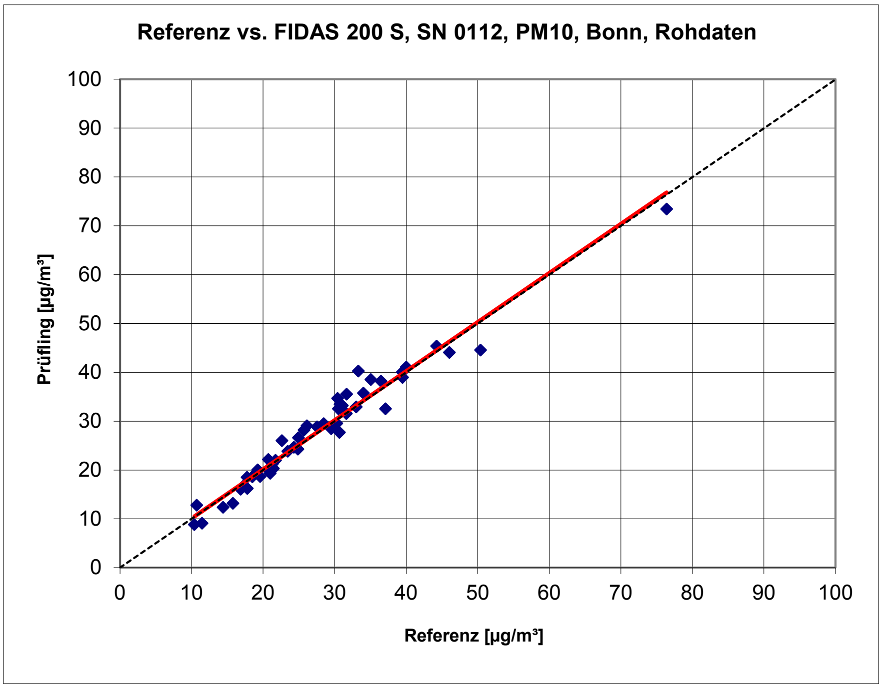

Figure 41: Reference vs. tested instrument SN 0112, PM_{10}, Bonn, winter

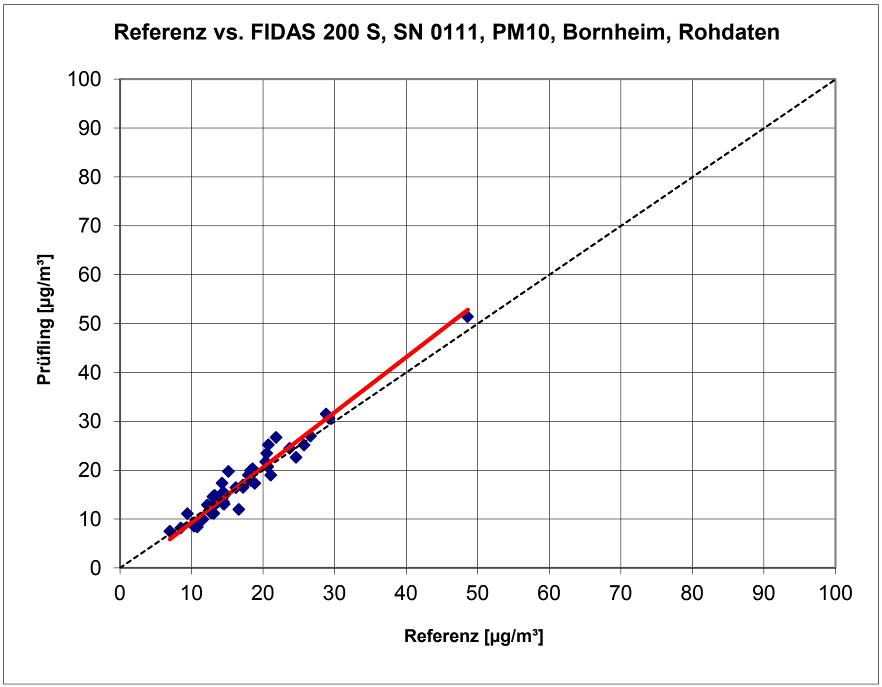

Figure 42: *Reference vs. tested instrument SN 0111, PM_{10}, Bornheim, summer*

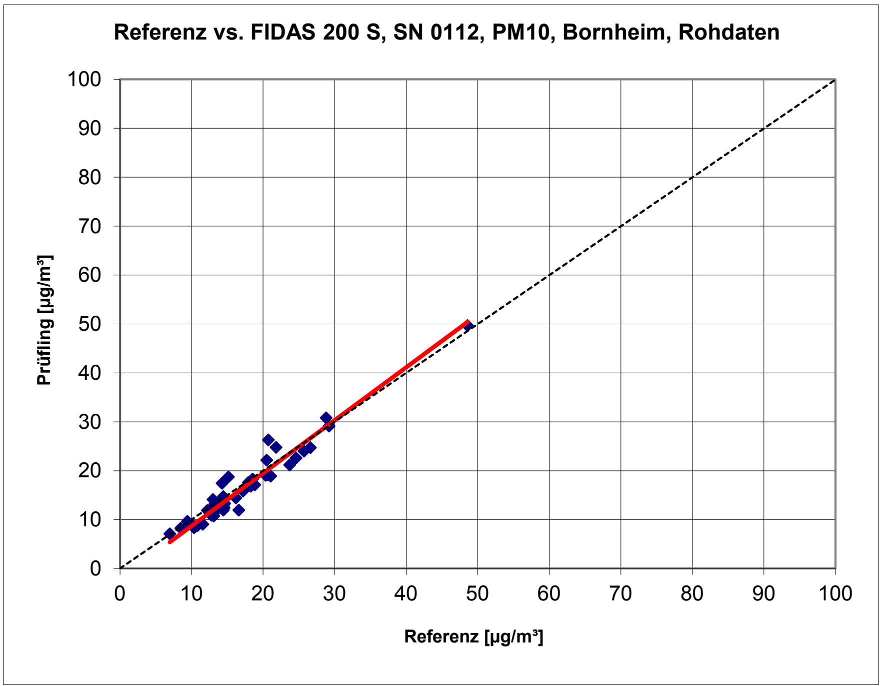

Figure 43: *Reference vs. tested instrument SN 0112, PM_{10}, Bornheim, summer*

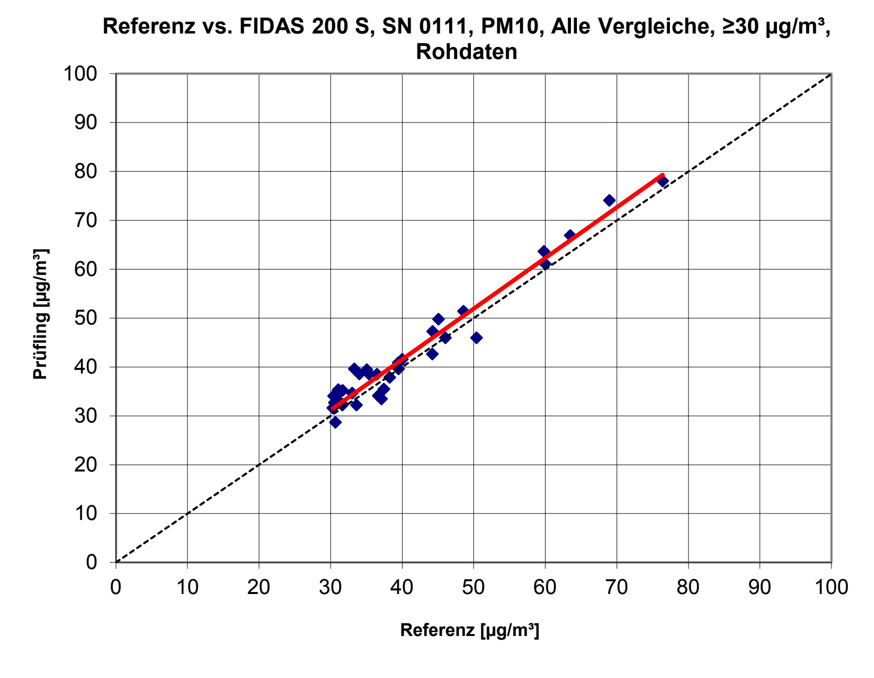

Figure 44: Reference vs. tested instrument, SN 0111, PM_{10}, values ≥ 30 µg/m³

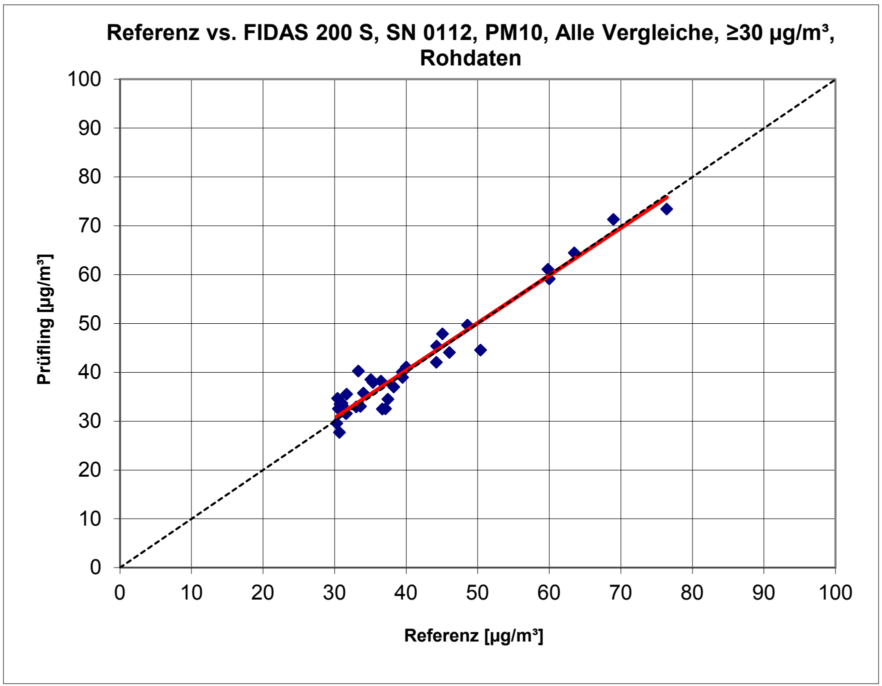

Figure 45: Reference vs. tested instrument, SN 0112, PM_{10}, values ≥ 30 µg/m³

6.117 Use of correction factors/terms (7.5.8.5–7.5.8.8)

Correction factors/terms (=calibration) shall be applied in the event the highest expanded uncertainty calculated for the tested instruments exceeds the relative expanded uncertainty specified under requirements for data quality or the test demonstrates that the slope is significantly different from 1 and/or the ordinate intercept is significantly different from 0.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

See item 6.1. 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

6.4 Evaluation

If it emerges from the evaluation of raw data in accordance with 6.1. 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8) that $W_{AMS} > W_{dqo}$, i.e. the tested instrument is not found to be equivalent with the reference method, then it is permissible to use a correction factor or term which results from the regression equation for <u>the full data set</u>. The corrected values have to meet the requirements for all data sets or sub data sets. Moreover, a correction may also be used for the case that $W_{AMS} \leq W_{dqo}$ in order to improve the accuracy of the tested instruments.

Three different situations may occur:

a) Slope b is not significantly different from 1: $|b-1| \leq 2u(b)$

Axis intercept a is significantly different from 0: $|a| > 2u(a)$

b) Slope b is significantly different from 1: $|b-1| > 2u(b)$

axis intercept a is not significantly different from 0: $|a| \leq 2u(a)$

b) Slope b is significantly different from 1: $|b-1| > 2u(b)$

Axis intercept a is significantly different from 0: $|a| > 2u(a)$

concerning a)

The value of the axis 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 corrected values $y_{i,corr}$ may then serve to calculate the following new terms using linear regression:

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

and

$$u_{yi,corr}^2 = \frac{RSS}{(n-2)} - u_{RM}{}^2 + \left[c + (d-1)L\right]^2 + u^2(a)$$

where u(a) = uncertainty of the axis intercept a, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to standard EN 16450: 2017.

concerning b)

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

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

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using a new linear regression:

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

and

$$u_{yi,corr}^2 = \frac{RSS}{(n-2)} - u_{RM}{}^2 + \left[c + (d-1)L\right]^2 + L^2u^2(b)$$

where u(b) = uncertainty of the original slope b, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to standard EN 16450: 2017.

concerning c)

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

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

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using a new linear regression:

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

and

$$u^2_{yi,corr} = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [c + (d-1)L]^2 + L^2 u^2(b) + u^2(a)$$

where u(b) = uncertainty of the original slope b, whose value was used to determine $y_{i,corr}$ and u(a) = uncertainty of the original axis intercept a, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to standard EN 16450: 2017.

The values for $u_{c\_s,corr}$ are then used to calculate the combined relative uncertainty of the AMS after correction in accordance with the following equation:

$$w^2_{AMS,corr} = \frac{u^2_{corr,yi=L}}{L^2}$$

The uncertainty $w_{AMS,corr}$ for the corrected data set is calculated at the 24h limit value using y_i as concentration at the limit value.

The relative expanded uncertainty $W_{AMS,corr}$ is calculated using the following equation:

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

In practice, k is specified at k=2 for large n.

The largest resulting uncertainty $W_{AMS,corr}$ is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive 2008/50/EC. Two situations are conceivable:

1. $W_{AMS,corr} \leq W_{dqo}$ → The tested instrument is deemed equivalent to the reference method.

2. $W_{AMS,corr} > W_{dqo}$ → The tested instrument is not deemed equivalent to the reference method.

The expanded relative uncertainty W_{dqo} specified is 25% (2008/50/EC).

6.5 Assessment

After the use of correction factors, the candidate systems met the requirements for data quality of air quality monitors for all data sets, both for $PM_{2.5}$ and for PM_{10}. Requirements for PM_{10} have been met without the need for a correction factor. The correction of the slope and the axis intercept however, have led to a further (slight) improvement of the expanded uncertainty.

Criterion satisfied? yes

The evaluation of the full dataset for both test candidates resulted in a significant slope and axis intercept for both measured components PM_{10} and $PM_{2,5}$ (SN 0111 only in the case of $PM_{2,5}$).

For $PM_{2.5}$:

The slope for the entire data set is 1.076. The intercept for the full data set is -0.339 (see Table 3)

For PM_{10}:

The slope for the entire data set is 1.058. The intercept for the full data set is -1.505 (see Table 4)

For both components, the full data set was corrected in terms of the slope and intercept. All data sets were re-evaluated using the corrected values.

After applying the correction, all datasets comply with the requirements for data quality and measurement uncertainty improved considerably for some sites.

When a measuring system is operated in the context of a measurement grid, the January 2010 version of the Guideline and standard EN 16450 require that the instruments are tested annually at a number of sites which in turn depends on the highest's expanded uncertainty determined during equivalence testing. The criterion used for specifying the number of sites for annual testing is grouped into 5% steps (Guideline GDE2010, Chapter 9.9.2, Table 6 and/or EN 16450:2017, Chapter 8.6.2, Table 5). It should be noted that the highest expanded uncertainty determined for $PM_{2.5}$ after applying the correction was in the range 20% to 25 %. For PM_{10}, the highest expanded uncertainty after applying the correction factor was in the range between 10% and 15%.

The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation of the requirements for regular tests as described above. TÜV Rheinland recommends the use of the expanded uncertainty of the full dataset for this purpose: 17.1% ($PM_{2.5}$ uncorrected data set) and 10.5% ($PM_{2.5}$ dataset after correcting slope/intercept). This would imply annual tests at 4 sites (uncorrected) or 3 sites (corrected); 9.3% (PM_{10} uncorrected data set) and 7.4% (PM_{10} data set after correction of the slope/intercept). This would imply annual tests at 2 (uncorrected or corrected) sites.

6.6 Detailed presentation of test results

Table 7 and Table 8 show the results of evaluating the equivalence test after applying the correction factor for the slope and axis intercept to the entire dataset.

Table 7: Overview of results of the equivalence test, SN 0111 & SN 0112, $PM_{2.5}$ after slope/intercept correction

Vergleich Testgerät mit Referenzgerät gemäß Richtlinie DIN EN 16450:2017					
Prüfling	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Grenzwert	30	µg/m³
Status Messwerte	Korrektur Steigung & Offset		erlaubte Unsicherheit	25	%
Alle Vergleiche					
Unsicherheit zwischen Referenz	**0,58**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,44**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**225**				
Steigung b	**0,999**	**nicht signifikant**			
Unsicherheit von b	**0,010**				
Achsabschnitt a	**0,012**	**nicht signifikant**			
Unsicherheit von a	**0,178**				
Erweiterte Messunsicherheit W_{CM}	**10,53**	**%**			
Alle Vergleiche, ≥18 µg/m³					
Unsicherheit zwischen Referenz	**0,63**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,78**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**54**				
Steigung b	**0,971**				
Unsicherheit von b	**0,023**				
Achsabschnitt a	**0,771**				
Unsicherheit von a	**0,715**				
Erweiterte Messunsicherheit W_{CM}	**13,21**	**%**			
Alle Vergleiche, <18 µg/m³					
Unsicherheit zwischen Referenz	**0,57**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,31**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**171**				
Steigung b	**1,108**				
Unsicherheit von b	**0,030**				
Achsabschnitt a	**-1,010**				
Unsicherheit von a	**0,304**				
Erweiterte Messunsicherheit W_{CM}	**17,70**	**%**			

Vergleich Testgerät mit Referenzgerät gemäß Richtlinie DIN EN 16450:2017					
Prüfling	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Grenzwert	30	µg/m³
Status Messwerte	Korrektur Steigung & Offset		erlaubte Unsicherheit	25	%
Köln, Sommer					
Unsicherheit zwischen Referenz	0,66	µg/m³			
Unsicherheit zwischen Prüflingen	0,11	µg/m³			
	SN 0111			SN 0112	
Anzahl Wertepaare	81			82	
Steigung b	1,036			1,034	
Unsicherheit von b	0,031			0,033	
Achsabschnitt a	-0,518			-0,478	
Unsicherheit von a	0,337			0,351	
Erweiterte Messunsicherheit W_{CM}	10,54	%		10,86	%
Köln, Winter					
Unsicherheit zwischen Referenz	0,54	µg/m³			
Unsicherheit zwischen Prüflingen	0,51	µg/m³			
	SN 0111			SN 0112	
Anzahl Wertepaare	51			50	
Steigung b	0,976			0,942	
Unsicherheit von b	0,013			0,013	
Achsabschnitt a	0,962			0,951	
Unsicherheit von a	0,291			0,303	
Erweiterte Messunsicherheit W_{CM}	8,73	%		10,22	%
Bonn					
Unsicherheit zwischen Referenz	0,62	µg/m³			
Unsicherheit zwischen Prüflingen	0,65	µg/m³			
	SN 0111			SN 0112	
Anzahl Wertepaare	50			50	
Steigung b	1,034			0,993	
Unsicherheit von b	0,023			0,025	
Achsabschnitt a	-0,394			-0,144	
Unsicherheit von a	0,531			0,575	
Erweiterte Messunsicherheit W_{CM}	12,29	%		12,76	%
Bornheim					
Unsicherheit zwischen Referenz	0,42	µg/m³			
Unsicherheit zwischen Prüflingen	0,46	µg/m³			
	SN 0111			SN 0112	
Anzahl Wertepaare	45			45	
Steigung b	1,124			1,098	
Unsicherheit von b	0,050			0,050	
Achsabschnitt a	-1,027			-1,137	
Unsicherheit von a	0,598			0,598	
Erweiterte Messunsicherheit W_{CM}	21,43	%		16,74	%
Alle Vergleiche, ≥18 µg/m³					
Unsicherheit zwischen Referenz	0,63	µg/m³			
Unsicherheit zwischen Prüflingen	0,78	µg/m³			
	SN 0111			SN 0112	
Anzahl Wertepaare	54			54	
Steigung b	0,994			0,948	
Unsicherheit von b	0,023			0,024	
Achsabschnitt a	0,515			1,011	
Unsicherheit von a	0,701			0,74	
Erweiterte Messunsicherheit W_{CM}	13,11	%		14,17	%
Alle Vergleiche, <18 µg/m³					
Unsicherheit zwischen Referenz	0,57	µg/m³			
Unsicherheit zwischen Prüflingen	0,31	µg/m³			
	SN 0111			SN 0112	
Anzahl Wertepaare	173			173	
Steigung b	1,130			1,090	
Unsicherheit von b	0,030			0,030	
Achsabschnitt a	-1,095			-0,929	
Unsicherheit von a	0,304			0,308	
Erweiterte Messunsicherheit W_{CM}	21,05	%		15,38	%
Alle Vergleiche					
Unsicherheit zwischen Referenz	0,58	µg/m³			
Unsicherheit zwischen Prüflingen	0,44	µg/m³			
	SN 0111			SN 0112	
Anzahl Wertepaare	227			227	
Steigung b	1,017	nicht signifikant		0,981	nicht signifikant
Unsicherheit von b	0,010			0,010	
Achsabschnitt a	-0,053	nicht signifikant		0,111	nicht signifikant
Unsicherheit von a	0,176			0,182	
Erweiterte Messunsicherheit W_{CM}	10,92	%		11,23	%

Table 8: Overview of results of the equivalence test, SN 0111 & SN 0112, PM_{10} after slope/intercept correction

Vergleich Testgerät mit Referenzgerät gemäß Richtlinie DIN EN 16450:2017					
Prüfling	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Grenzwert	50	µg/m³
Status Messwerte	Korrektur Steigung & Offset		erlaubte Unsicherheit	25	%
Alle Vergleiche					
Unsicherheit zwischen Referenz	**0,62**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,64**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**227**				
Steigung b	**0,999**	**nicht signifikant**			
Unsicherheit von b	**0,011**				
Achsabschnitt a	**0,015**	**nicht signifikant**			
Unsicherheit von a	**0,249**				
Erweiterte Messunsicherheit W_{CM}	**7,43**	**%**			
Alle Vergleiche, ≥30 µg/m³					
Unsicherheit zwischen Referenz	**0,67**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**1,10**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**35**				
Steigung b	**0,949**				
Unsicherheit von b	**0,036**				
Achsabschnitt a	**2,181**				
Unsicherheit von a	**1,530**				
Erweiterte Messunsicherheit W_{CM}	**10,34**	**%**			
Alle Vergleiche, <30 µg/m³					
Unsicherheit zwischen Referenz	**0,61**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,55**	**µg/m³**			
	SN 0111 & SN 0112				
Anzahl Wertepaare	**192**				
Steigung b	**1,023**				
Unsicherheit von b	**0,021**				
Achsabschnitt a	**-0,408**				
Unsicherheit von a	**0,364**				
Erweiterte Messunsicherheit W_{CM}	**7,43**	**%**			

Vergleich Testgerät mit Referenzgerät gemäß Richtlinie DIN EN 16450:2017					
Prüfling	FIDAS 200 S		SN	SN 0111 & SN 0112	
			Grenzwert	50	µg/m³
Status Messwerte	Korrektur Steigung & Offset		erlaubte Unsicherheit	25	%
Köln, Sommer					
Unsicherheit zwischen Referenz	**0,80**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,26**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**81**			**82**	
Steigung b	**0,986**			**0,970**	
Unsicherheit von b	**0,026**			**0,026**	
Achsabschnitt a	**-0,098**			**0,009**	
Unsicherheit von a	**0,463**			**0,462**	
Erweiterte Messunsicherheit W_{CM}	**7,63**	**%**		**9,14**	**%**
Köln, Winter					
Unsicherheit zwischen Referenz	**0,53**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,63**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**51**			**50**	
Steigung b	**1,006**			**0,971**	
Unsicherheit von b	**0,014**			**0,014**	
Achsabschnitt a	**0,238**			**0,216**	
Unsicherheit von a	**0,378**			**0,377**	
Erweiterte Messunsicherheit W_{CM}	**6,41**	**%**		**7,77**	**%**
Bonn					
Unsicherheit zwischen Referenz	**0,38**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,85**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**50**			**50**	
Steigung b	**0,985**			**0,948**	
Unsicherheit von b	**0,026**			**0,027**	
Achsabschnitt a	**1,372**			**1,510**	
Unsicherheit von a	**0,776**			**0,817**	
Erweiterte Messunsicherheit W_{CM}	**9,01**	**%**		**10,07**	**%**
Bornheim					
Unsicherheit zwischen Referenz	**0,54**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,82**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**47**			**47**	
Steigung b	**1,064**			**1,022**	
Unsicherheit von b	**0,037**			**0,037**	
Achsabschnitt a	**-0,425**			**-0,597**	
Unsicherheit von a	**0,693**			**0,681**	
Erweiterte Messunsicherheit W_{CM}	**13,42**	**%**		**7,60**	**%**
Alle Vergleiche, ≥30 µg/m³					
Unsicherheit zwischen Referenz	**0,67**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**1,10**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**35**			**35**	
Steigung b	**0,979**			**0,919**	
Unsicherheit von b	**0,036**			**0,037**	
Achsabschnitt a	**1,526**			**2,795**	
Unsicherheit von a	**1,539**			**1,56**	
Erweiterte Messunsicherheit W_{CM}	**10,47**	**%**		**11,52**	**%**
Alle Vergleiche, <30 µg/m³					
Unsicherheit zwischen Referenz	**0,61**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,55**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**194**			**194**	
Steigung b	**1,046**			**1,002**	
Unsicherheit von b	**0,021**			**0,020**	
Achsabschnitt a	**-0,510**			**-0,305**	
Unsicherheit von a	**0,372**			**0,358**	
Erweiterte Messunsicherheit W_{CM}	**9,94**	**%**		**6,74**	**%**
Alle Vergleiche					
Unsicherheit zwischen Referenz	**0,62**	**µg/m³**			
Unsicherheit zwischen Prüflingen	**0,64**	**µg/m³**			
	SN 0111			**SN 0112**	
Anzahl Wertepaare	**229**			**229**	
Steigung b	**1,017**	**nicht signifikant**		**0,981**	**nicht signifikant**
Unsicherheit von b	**0,011**			**0,011**	
Achsabschnitt a	**-0,037**	**nicht signifikant**		**0,081**	**nicht signifikant**
Unsicherheit von a	**0,252**			**0,249**	
Erweiterte Messunsicherheit W_{CM}	**8,24**	**%**		**8,19**	**%**

6.1 18 Maintenance interval (7.5.7)

The maintenance interval shall be at least 2 weeks.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

With regard to this minimum requirement, the maintenance tasks required in a specific period and the length of that period for the correct functioning of the measuring system were identified. Furthermore, in determining the maintenance interval, the drift determined for zero and reference point ave been taken into consideration.

6.4 Evaluation

Over the entire period of the field test (four comparison campaigns), no unacceptable drift was observed. Regular reference point checks as part of the original field test with test standard CalDust 1100 demonstrated that permissible deviations of 130 ± 1.5 channels cannot be ensured within the test interval proposed by the manufacturer and that tests should consequently be performed on a monthly basis.

The maintenance interval is thus determined by regular checks of the particle sensor on a test bench.

During operation times, maintenance is generally limited to contamination and plausibility checks and potential status/error messages.

On this basis, the maintenance interval was determined at 4 weeks for the initial publication (Notification as regards Federal Environment Agency (UBA) notice of 25 February 2015 (BAnz AT 02.04.2015 B5, chapter III number 3.1).

Drift effects determined were the result of adhesive gases which had deposited on the optical surfaces. This problem was solved as part of the change procedure in compliance with standard EN 15267-2. The implemented change (additional bore hole) potentially reduced the number or necessary comparisons with CalDust 1100 or MonoDust 1500.

6.5 Assessment

The maintenance interval is defined by the need for regular inspections of the particle sensor using CalDust 1100 or MonoDust 1500 and is at four weeks.

Criterion satisfied? yes

6.6 Detailed presentation of test results

The instruction manual describes the necessary maintenance tasks.

Table 9 and Table 10 show the results of the long-term stability tests performed for the initial performance test using the CalDust 1100 test standard.

Table 9: Sensitivity drift SN 0111 & SN 0112, PM_{10}

Datum	SN 0111			Datum	SN 0112		
	Messwert	Abweichung zum Vorgängerwert	Abweichung zum Startwert		Messwert	Abweichung zum Vorgängerwert	Abweichung zum Startwert
		%	%			%	%
09.05.2012	40,0	-	-	09.05.2012	40,0	-	-
04.09.2012	39,5	-1,2	-1,2	04.09.2012	37,8*	-5,4	-5,4
22.11.2012	38,5	-2,5	-3,6	22.11.2012	37,8*	0,0	-5,4
05.02.2013	38,1*	-1,1	-4,7	05.02.2013	38,8	2,4	-3,1
26.02.2013	38,8	1,6	-3,1	26.02.2013	36,7**	-5,2	-8,1
02.05.2013	41,6*	7,3	4,0	02.05.2013	39,5	7,6	-1,2
13.06.2013	39,5	-4,9	-1,2	13.06.2013	40,8	3,2	2,0
11.07.2013	40,2	1,7	0,5	11.07.2013	37,8*	-7,2	-5,4

* Abgleich auf Kanal 130
** Abweichung größer 3 Kanäle, Abgleich auf Kanal 130

Table 10: Sensitivity drift SN 0111 & SN 0112, $PM_{2,5}$

Datum	SN 0111			Datum	SN 0112		
	Messwert	Abweichung zum Vorgängerwert	Abweichung zum Startwert		Messwert	Abweichung zum Vorgängerwert	Abweichung zum Startwert
		%	%			%	%
09.05.2012	25,0	-	-	09.05.2012	25,0	-	-
04.09.2012	24,7	-1,2	-1,2	04.09.2012	23,7*	-5,4	-5,4
22.11.2012	24,1	-2,5	-3,6	22.11.2012	23,7*	0,0	-5,4
05.02.2013	23,8*	-1,1	-4,7	05.02.2013	24,2	2,4	-3,1
26.02.2013	24,2	1,6	-3,1	26.02.2013	23**	-5,0	-8,0
02.05.2013	26,1*	7,7	4,3	02.05.2013	24,7	7,4	-1,2
13.06.2013	24,7	-5,3	-1,2	13.06.2013	25,6	3,4	2,2
11.07.2013	25,1	1,7	0,5	11.07.2013	23,7*	-7,5	-5,4

* Abgleich auf Kanal 130
** Abweichung größer 3 Kanäle, Abgleich auf Kanal 130

HORIBA

Ambient Air Analyzers

APDA-372 / APDA-372 E

FINE-DUST MONITORING SYSTEM

Instruction Manual

Version: HE0050419, valid as of firmware version 100449

APDA-372 / APDA-372 E Fine-Dust Monitoring System Instruction Manual

Preface

These instructions describe the operation for the Fine-Dust Monitoring Systems, APDA-372 and APDA-372 E. Be certain to read this manual before using the product in order to ensure that the device is operated properly and safely. You should also save the manual in a reliable manner so that it is readily available whenever required. The product specifications and the appearance as well as the contents of this manual may be altered without advance notification.

Warranty and responsibility

The product delivered to you is covered by a warranty from HORIBA for the period of one (1) year. In the event of malfunctions or damage during this time period for which HORIBA is responsible, the necessary repairs or the replacement of parts will be carried out by HORIBA at no charge. The warranty does not cover the following:

- Any malfunction due to improper operation;
- Any malfunction due to repairs or modifications by any party not authorized by HORIBA;
- Any malfunction due to use in an unsuitable environment;
- Any malfunction due to disregard of the instructions contained in this manual;
- Any malfunction due to use in a manner that is not described in this manual;
- Any malfunction due to natural catastrophes, accidents or mishaps that are not HORIBA's responsibility;
- A deterioration in appearance due to corrosion, rust, and so on;
- Consumables and the replacement of consumables;
- Products of other companies.

HORIBA is not liable for damage resulting from malfunctions of the product, any deletion of data or other uses of this product.

Trademarks

Other brands, company names, brand names or registered trademarks are the property of the respective company.

Copyright

CE conformity declaration

The APDA-372 / APDA-372 E complies with the regulations of the European directives:

Directive:

EMC directive	89/336/EC
Low voltage directive	73/23/EC

Standards:

EMC directive	EN61326-1: 2006 Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements
Low voltage directive	EN61010-1: 2010 Safety regulations for electrical equipment for measurement, control and laboratory use Part 1: General requirements

Contents

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IMPORTANT – Please take note!

- Please check the device for externally discernible transport damage immediately after unpacking. If damage can be ascertained, the device must not be put into service under any circumstances for safety reasons. If this is the case, please contact the manufacturer.

- Only put the APDA-372 / APDA-372 E into service after thoroughly studying the operating instructions!

- The manufacturer is not liable for damage that is caused by improper commissioning, use, cleaning, operating errors or the measurement of aerosols for which the gas state and gas composition are not included in the device's specifications.

- The device must only be operated at atmospheric ambient pressure and at temperatures of +5 °C to +40 °C at the operating site.
  The manufacturer does not assume any functional guarantee for operation under other ambient conditions, e.g. in corrosive or explosive environments, in strong electrical or electromagnetic fields, in areas with ionizing radiation or in areas exposed to shock and vibration.

- **To switch off the APDA-372 control unit, the "shut down" button must be pressed, after which the APDA-372 then switches itself off automatically. The mains switch must only be switched off after the operating system has shut down, otherwise a loss of data is possible!**

- **The APDA-372 is set to a fixed mains voltage by the manufacturer in accordance with the order. Please check to be sure the mains voltage specified on the type plate matches the mains voltage at the intended work site.**

- Only use original spare parts! Please contact the manufacturer if these are needed.

- The measurement procedure employed by the APDA-372 system is not gravimetric, but instead uses an equivalence method. Consequently, an exact match with gravimetric analysis cannot be guaranteed in every case.

- The measuring system must be calibrated regularly using the gravimetric reference method for PM10 and PM2.5 in accordance with DIN EN 12341: 2014 at the installation site.

Caution: Aerosols can be injurious to health depending on the type. They should therefore not be inhaled. With hazardous materials, corresponding protective clothing (respirator mask) should be used. Please observe the respective guidelines and accident prevention regulations.

- General information on optical particle counters, such as the resolving power, counting efficiency and detection limit, can be found in the VDI Guideline 3489, Sheet 3.

- **The APDA-372 is shipped in the state in which it was subjected to the TÜV equivalence test. This also applies for the device version APDA-372 E. If corrections are to be made to this state, please take section 3.5 into account.**

1. Installation and initial commissioning

1.1. Verify the mains voltage

The device is set to a fixed mains voltage by the manufacturer in accordance with the order. Please check to be sure the mains voltage specified on the type plate matches the mains voltage at the intended work site. The manufacturer is not liable for damage resulting from operation with an incorrect mains voltage!

1.2. Verify the completeness of the delivery

When the APDA-372 is transported by a carrier, the APDA-372 system is dismantled into its components. The system must be reassembled once again before initial commissioning. The following parts must be present:

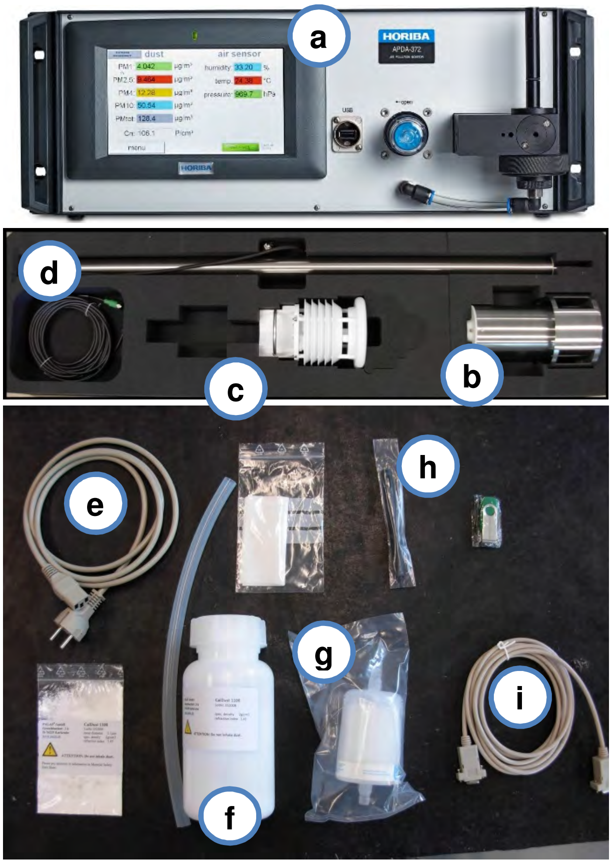


Figure 1: Components of an APDA-372 system

The following components and documentation should be present for all versions
(The letters in parentheses refer to the items in Figure 1).

- APDA-372 control unit **(a)**
- Aerosol inlet tube
- Power cord **(e)**
- Plastic hose, approx. 30 cm, for calibration and verification
- Bottle of MonoDust 1500 for calibration and verification **(f)**
- Refill packet of MonoDust 1500
- Cleaning kit consisting of optical cloths
- Zero filter (g)
- Printed instruction manual for APDA-372 Fine-Dust Monitoring System
- Printed description of APDA-372 firmware
- Printed instruction manual for PDAnalyze
- Instruction manual for weather station WS300-UMB or WS600-UMB
- Printed calibration certificate
- CD or USB flash drive with PDAnalyze analysis software
- Serial cable (null modem) **(i)**
- Pointer for touchscreen **(h)**

The following additional components are also included in the scope of delivery:

All versions:

- Weather station WS300-UMB **(c)** – or WS600-UMB instead as an option
- Sampling tube with IADS **(d)**
- Connector, sampling head to sampling tube
- Sigma-2 sampling head **(b)**
- Mounting for the sampling tube on the housing

APDA-372 E only:

- External aerosol sensor unit with connecting lines

Figure 2: External aerosol sensor unit APDA-372 E

1.3. Device overview

1.3.1. Front view of the APDA-372 control unit

Figure 3: Front of the APDA-372 control unit

The APDA-372 device is operated via a touchscreen (for more on this, see the separate APDA-372 firmware instruction manual which includes detailed information on the user interface).

The data can be read out via the USB port and then processed further with the separate PDAnalyze software (included in the scope of delivery) on an external PC. In addition, it is also possible to transmit the data via an RS-232 or Ethernet connection using one of the communication protocol options.

1.3.2. Rear view of the APDA-372 control unit

Figure 4: Back of the APDA-372 control unit

The control unit is switched on and off using the mains switch. The device has two fuses, T 2 A / 250 V, which are located on the back.

The LED switches on with the mains switch. The operating hours counter runs as long as the device is on. The light source has a service life (MTTF) of >20,000 operating hours. The LED in the APDA-372 is operated at 20% of capacity with a controlled, lower temperature, which considerably prolongs the service life.

1.3.3. Connections on the back of the control unit

Figure 5: Connections on the back of the APDA-372 control unit

The following connections are located on the right-hand side of the back.

- **Network** port, for connecting the APDA-372 system to a network, for example, for online service support and transmitting software updates.
- **USB port**, for example, for connecting a printer, keyboard, mouse or USB flash drive to the APDA-372 control unit.
- Modbus via **RS-232** connection for remote queries of the measured values and external control of the measuring instrument (WebAccess).
- **Connection for the weather station, WS300-UMB or WS600-UMB,** for recording the:
  - ➔ Temperature
  - ➔ Humidity
  - ➔ Pressure
  - ➔ Wind speed (WS600-UMB only)
  - ➔ Wind direction (WS600-UMB only)
  - ➔ Amount of precipitation (WS600-UMB only)
  - ➔ Type of precipitation (WS600-UMB only)
- **Input for external sensors** for recording the temperature and the relative humidity
- **Input for external sensor** for recording the barometric pressure
- **Connection for the humidity compensation module, IADS** (Intelligent Aerosol Drying System)

1.3.4. APDA-372 E – External aerosol sensor unit

With the APDA-372 E, the entire aerosol sensor unit is separate from the control unit and is installed in a separate housing, which easily enables flexible installation in a measuring station. The connection between the control unit and the sensor unit is accomplished via a total of 3 connections:

- Connection cable for data transfer (LAN cable)
- Connection cable for the power supply / temperature measurement of the LED
- Hose connection for the sampling flow

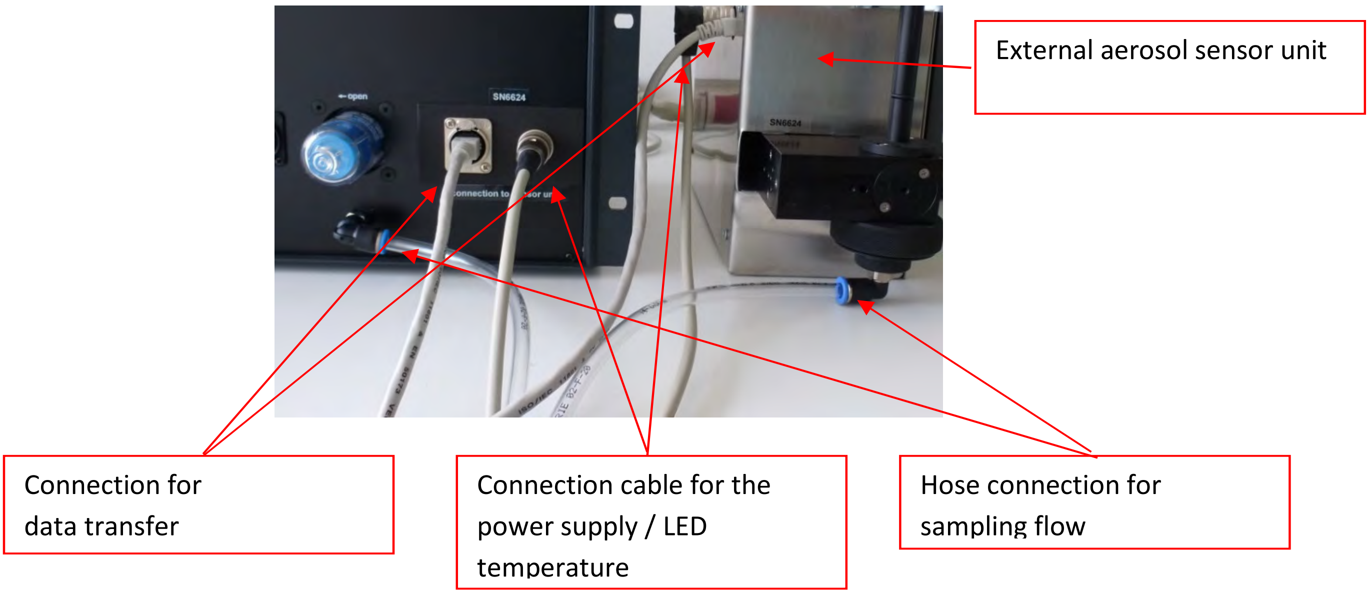


Figure 6: Connection of the external aerosol sensor unit

The standard length of the connection lines is 3 m (other lengths possible on request).

The other aspects of installation / connection of the measuring system are the same as for the APDA-372.

The APDA-372 E measuring system can be converted back to the APDA-372 measuring system, meaning the external sensor can also be reinstalled in the control unit.

1.4. First measurement

Switch the device on (I/0 switch on the back of the APDA-372 control unit).
The measurement process begins automatically when the device is switched on. The measured data are also automatically stored in the internal memory. The initial screen appears after the device has started (see figure 6).

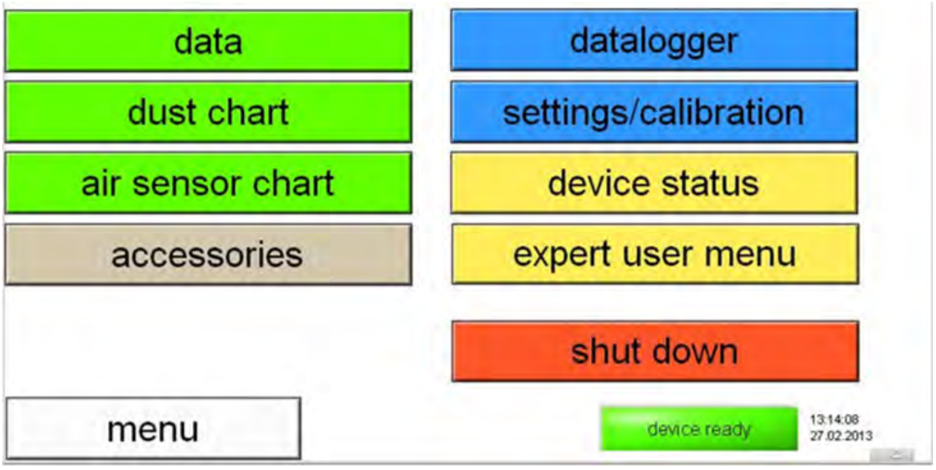


Figure 7: Initial screen

It is now possible to navigate between the individual display options using the touchscreen.

Figure 7 shows an overview of the following as an example:

Dust values
- PM1
- PM2,5
- PM4
- PM10
- PM total (total mass concentration)
- Cn: Particle concentration in P/cm3

Air sensors: (Weather station data)
- Relative humidity
- Temperature
- Barometric air pressure

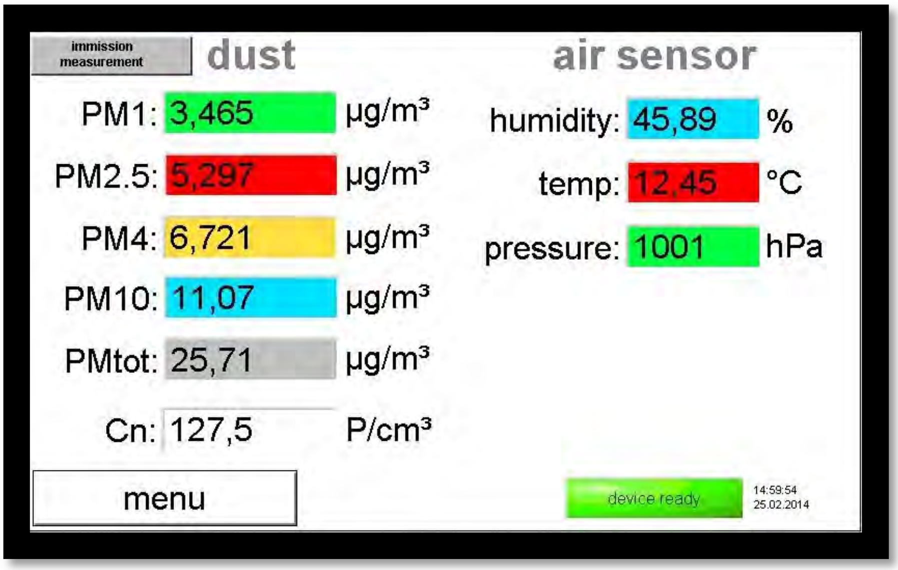


Figure 8: Data overview, e.g. PM values

More detailed information can be found in the separate instruction manual for the APDA-372 firmware. Please note: The value "NaN" (no number) appears briefly after the device is switched on and before the first measurement or during calibration or maintenance.

2. Integrating the measuring system in the measuring station

2.1. General

The measuring systems APDA-372 and APDA-372 E are designed for setup in a temperature controlled environment (climate-controlled measuring station or the like). The measuring system can be installed in an equipment rack or on a table top.

This section describes the special measures for installing and connecting the APDA-372 control unit at the installation site. Any possible measures required for a roof penetration for the sampling tube or for installing the weather station are dependent on the installation situation and are not described in this instruction manual. They must be determined according to the individual case.

When mounting the sampling tube / sampling head at the installation site, the relevant regulatory or legal requirements (e.g. according to Directive 2008/50/EC Annex III) concerning inlet height, flow exposure, distances to sources, etc., must be taken into account.

2.2. Positioning and connection of the APDA-372 control unit

Position the control unit in such a way that the opening of the sampling inlet tube is directly below the sampling tube (see Figure 9). To do so, you must previously have raised the sampling tube. Then, carefully (!) move the sampling tube over the sampling inlet tube as shown in Figure 10. The sampling tube should be as vertical as possible; it may be necessary to change the position of the control unit accordingly.

Then connect the cables from the weather station and the IADS (sampling tube) with the connections provided and labeled for this purpose (The exact location may deviate from that shown in Figure 9 depending on the model). Also connect the mains cable (and, as needed, a network cable as well), but do not switch the APDA-372 yet!

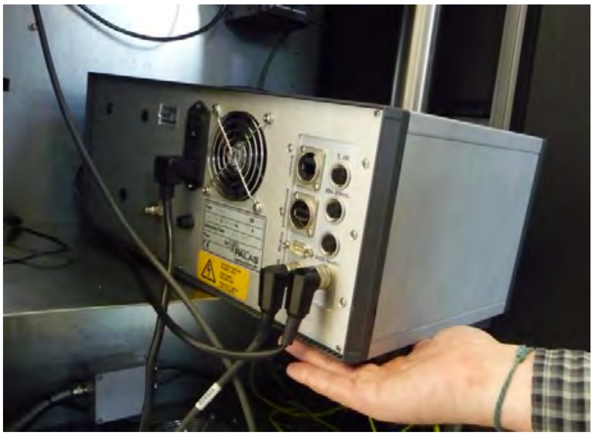


Figure 9: Connecting the weather station and IADS with the connections on the back

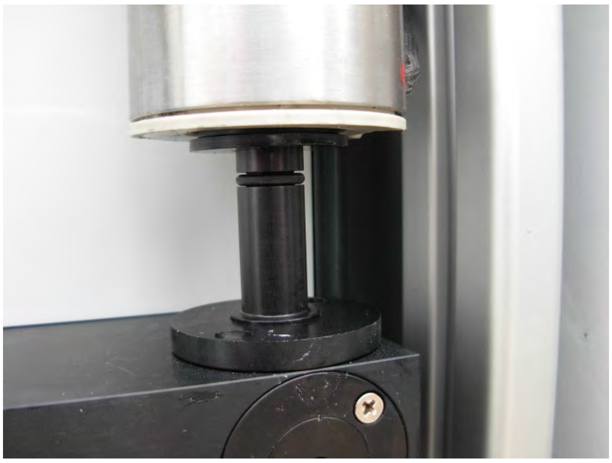


Figure 10: Connecting the sampling tube with the sampling inlet tube and the control unit

Continue with this step until the sampling tube directly touches the sensor unit, meaning there should no longer be any gap. Figure 11 shows the correct position on the right.

Figure 11: Incorrect position of sampling tube shown on left, correct position on right

Then carefully fasten the clamps of the mount located somewhat higher:

Figure 12: Internal mounting of the sampling tube

APDA-372 E only:

Use the connection lines to connect the APDA-372 control unit to the external aerosol sensor as described in section 1.3.4.

2.3. Installing the Sigma-2 sampling head

Slide the Sigma-2 sampling head onto the connecting piece to the sampling tube (it should have full contact with the sampling tube) and then secure the sampling head with the 2 mm Allen head screw (see Figure 13).

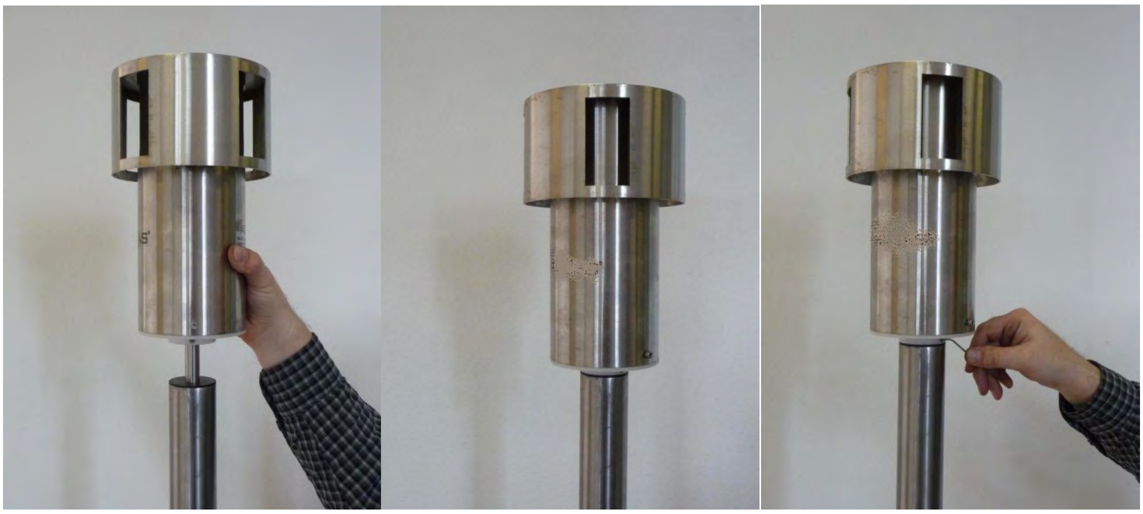


Figure 13: Installing the Sigma-2 sampling head

2.4. Switching on the measuring system

Switch on the mains switch on the back of the APDA-372 control unit. After launching the Windows operating system and the APDA-372 Start-up Manager, you will see the screen with the various different PM fractions, the particle number concentration and the ambient conditions (temperature, relative humidity, air pressure). For the initial PM fraction values, you will need to wait about 4 minutes due to the averaging.

3. Notes on the system

3.1. As-delivered condition of the measuring system

The as-delivered condition of the APDA-372 is the same as the condition of the measuring system during the qualification test with the following default settings:

No.	Parameter	Default setting
1	Evaluation algorithm	PM_ENVIRO_0011
2	Operating mode on start-up	Auto
3	Integration time (time basis for PM moving average)	900 s
4	IADS mode on start-up	1 (remove volatile / moisture compensation)
5	Slope factor for PM fractions	1
6	Offset factor for PM fractions	0
7	Temperature compensation factor	0.17 (APDA-372) or 0.19 (APDA-372 E)
8	Password for "Expert User Menu"	-1
9	Coincidence correction	Not active
10	Velocity correction	Not active

3.2. The promo.ini file

The promo.ini file contains important settings for die APDA-372 user interface. A detailed presentation of the entries in the promo.ini file follows below. Please bear in mind that almost all changes will have a strong influence on the firmware, meaning that changes should be kept to an absolute minimum and should only be made when the effects can be clearly isolated.

Explanation:
Please note: Entries which do not apply for the APDA-372 are struck through

[system]	
type=Fidas 200	Instrument model, note that Fidas® 200 S / Fidas® 200 E are also displayed as Fidas® 200
ser#=XXXX	Serial number of instrument [DO NOT CHANGE!]
password=yxcvbXXXX	Password for internal use [DO NOT CHANGE!]
user_device#=	Customized user identifier (3 characters)
[plugin]	
~~Promo 3000_enabled=no~~	
Fidas 100_enabled=yes	Plugins (top level user interface), that are enabled resp. disabled
Fidas 200/210_enabled=yes	[DO NOT CHANGE!]
Fidas 300/310_enabled=yes	
~~Fidas mobile_enabled=no~~	
~~Nanoco 100_enabled=no~~	
~~Nephel 100_enabled=no~~	
stop_enabled=yes	
start_enabled=yes	
[my-palas.com]	Automatically connect after every start-up to the Palas® website for data upload and remote
my-palas.com_autostart=no	control - Requirement: Instrument is registered on Palas® website

[Fidas]	
velocity_calibrated=9.3 m/s	Setting "Velocity_Average", determined at installation site according to chapter 5.5
PM10_slope=1.000	Entry of slope and offset factors for PM fractions possible
PM10_intercept=0	(e.g. from TÜV-report 936/21226418)
PM4_slope=1.000	
PM4_intercept=0	
PM2.5_slope=1.000	
PM2.5_intercept=0	
PM1_slope=1.000	
PM1_intercept=0	
PMtotal_slope=1.000	
PMtotal_intercept=0	
PM_alternative=yes	Display of alternative PM-values under "accessories" is active
~~PM_volatile=no~~	
textfile=yes	Data logging as text file is active
textfile_interval=60s	Interval for data logging as text file
PM_autoadjust=no	[DO NOT CHANGE!]
~~gravimetric_correction_factor=1.00~~	
IADS_modus=1	Operating mode of IADS
dust_type=2	[DO NOT CHANGE!]
sensor_selection=2	[DO NOT CHANGE!]
automated_cleaning=no	Automatic cleaning not active
alarm_threshold=99999 µg/m³	Limit value for PM fraction, that triggers the digital alarm (digital out)
alarm_value=PM10	Setting of PM fraction, that triggers the alarm
alarm_email_address=""	E-mail adress, to which a notification is sent in case of error message
password_service=-1	Password for "Expert User Mode"
calibration_IADS_restrict=yes	Enabling of calibration only, if nominal temperature is reached
calibration_temperature=50	Nominal temperature IADS for calibration (35°C or 50°C)
~~[Promo3000]~~	
~~interval=300~~	
~~sensor1=15.000000~~	
~~sensor2=33.000000~~	
[hardware]	
weatherstation_connected=yes	Weather station is connected
weatherstation_comport=4	COM-port of connected weather station
weatherstation_scale_T=1	Entry of slope and offset factors possible for adjustment of weather station
weatherstation_scale_p=1	from comparison with transfer standard
weatherstation_scale_h=1	
weatherstation_offset_T=0	
weatherstation_offset_p=0	
weatherstation_offset_h=0	
weatherstation_equation= x_corr=scale*x+offset	Applied equation for calibration of weather station
~~GPS_connected=no~~	GPS is currently not supported
~~GPS_comport=8~~	GPS is currently not supported
discmini_connected=no	DISCmini is not connected
discmini_comport=81	COM-port of DISCmini
discmini_interval=300s	Time basis for reported data from DISCmini
~~[UF-CPC]~~	
~~liquid_pump_impulsinterval=45 s~~	
~~liquid_pump_impulsamplitude=0.5 V~~	
[settings]	
sensor_selection=2	[DO NOT CHANGE!]
PM_interval=900s	Time basis for moving average of PM fractions (according to TUV test 900s)
IP_UDP_broadcast=127.0.0.1	UDP adress for data transmission
PLC_interface=1	Selected communication protocol upon start-up (see below legend)
temperature_compensation=yes	LED temperature control [DO NOT CHANGE!]
temperature_slope=0.17	Setting 0.17 for APDA-372 and 0.19 for APDA-372 E [DO NOT CHANGE!]
velocity_correction=yes	Dynamic border zone correction [DO NOT CHANGE!]
velocity_calibration_enabled=no	[DO NOT CHANGE!]
flow_calibration_enabled=yes	Calibration of flow rate is possible (button under "sensor calibration")
~~server_IP_accesslist=+*~~	
RSBaudRate=9600	Baud rate for data transmission
BayerHessen_DA_commmand=60>60,61>61,62>62,63>63,64>64,65>	Mapping of addresses for Bayern-Hessen protocol

Selected communication protocol upon start-up

0	Modbus
1	Bayern/Hessen
2	UDP ASCII
3	UDP single particle data stream
4	Modbus with UDP
5	Serial ASCII

3.3. Activating the coincidence correction

In the as-delivered condition of the APDA-372, the default setting is that the coincidence correction is **not** activated. This is the same setting that is used in the type approval testing.
If the APDA-372 is used at installation sites at which significantly high concentrations can occur, and if the APDA-372 measures a coincidence value of greater than 10%, it may be necessary to activate the coincidence correction in order to significantly broaden the original concentration range of 0 to 10,000 µg/m^3. The following steps explain how the coincidence correction can be activated.

After starting the APDA-372, you will find yourself in the main menu (Figure 14):

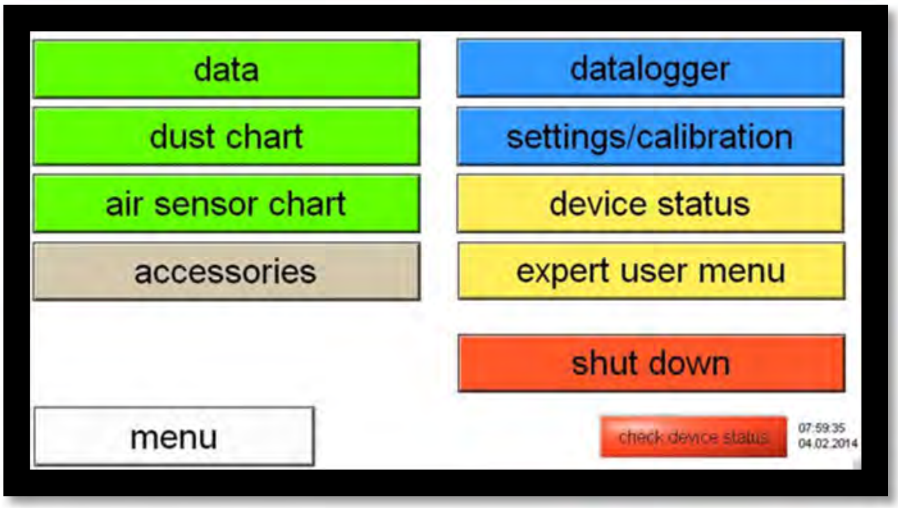


Figure 14: Main menu

Go to the Expert User menu by clicking on the “expert user menu” button, then enter “1” followed by “-” and click on “accept” (Figure 15):

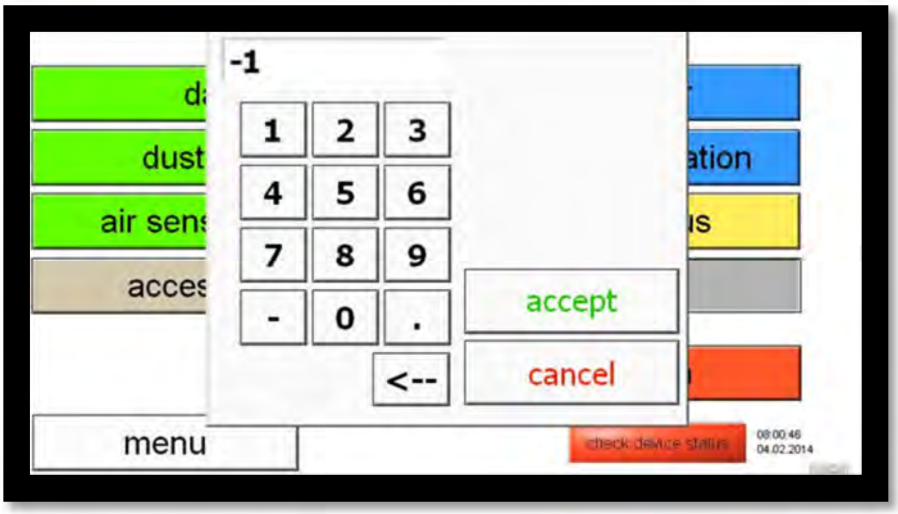


Figure 15: Password entry for accessing the Expert User menu

You are now in the Expert User menu (Figure 16). You can return to the APDA-372 main menu from here by clicking on the green APDA-372 bar at the top left. Please click on "system" to continue:

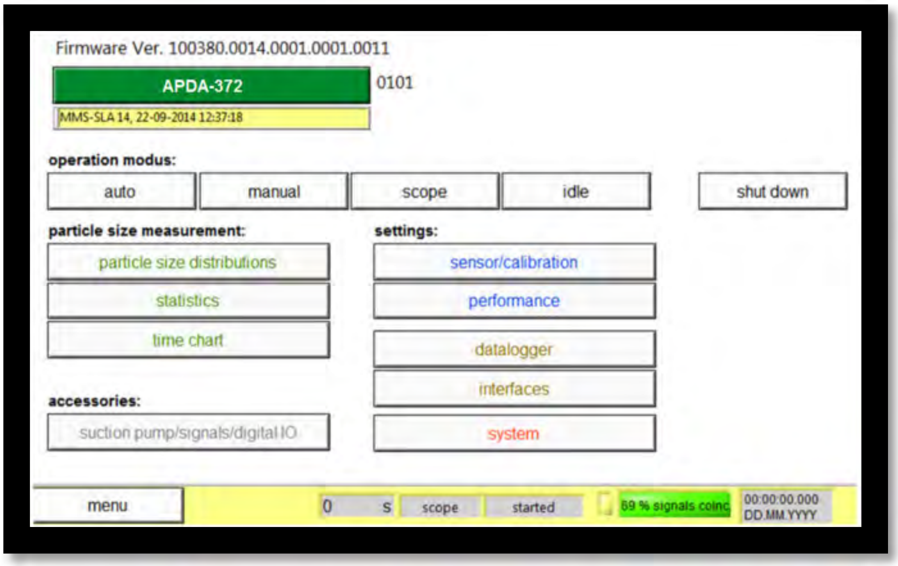


Figure 16: Expert user menu

You are now in the "System" screen (Figure 17). Continue by clicking the "advanced system settings" button:

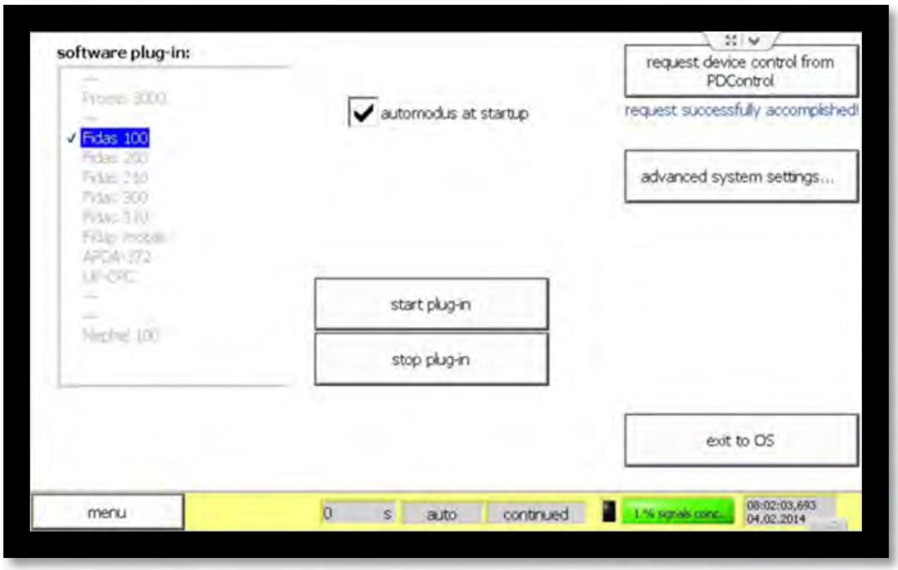


Figure 17: System menu

You are now in the "advanced system settings" screen (Figure 18). Now connect a USB keyboard and make sure that it is recognized by the system (typically indicated by an audible ringtone). Then press "c" on this keyboard. This opens a hidden calibration screen with various different tabs.

Caution:

Please do not change anything other than what is described below. Otherwise you run the risk that your device will no longer function properly!

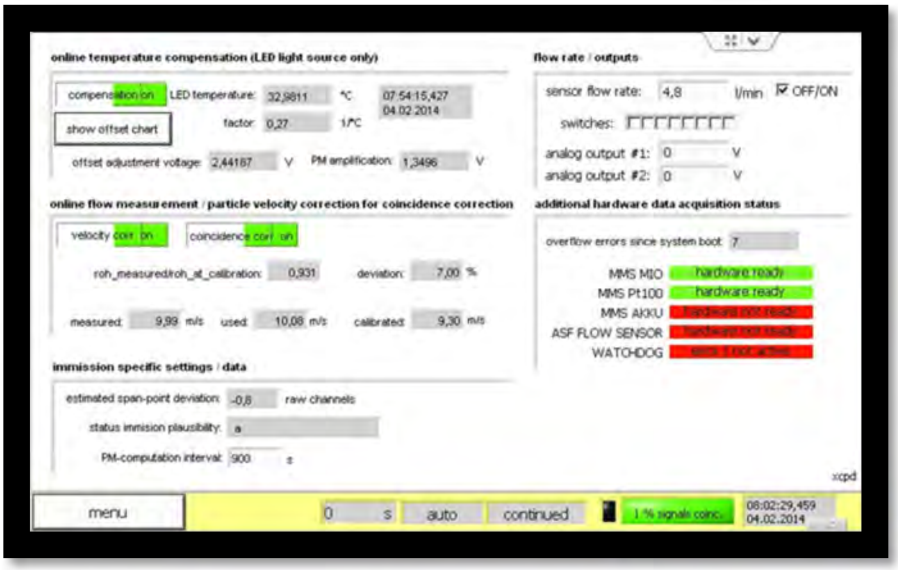


Figure 18: Advanced system settings

You are now in the hidden calibration screen. Go to the "statistics" tab and activate "coincidence correction T-aperture" (C factor + T shape). Then click "save for selected settings only" followed by "close" (Figure 19).

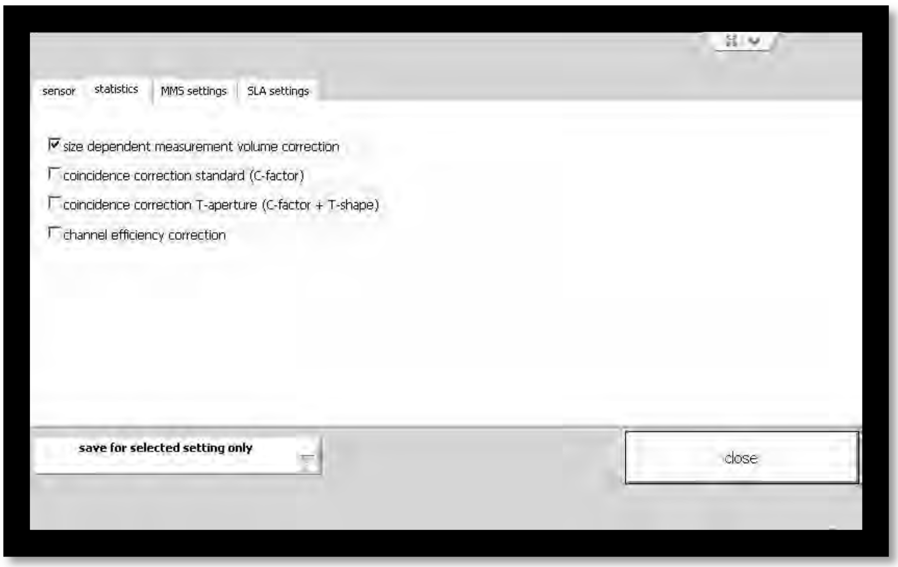


Figure 19: Statistics tab

3.4. Changing the moving-average time basis for APDA-372 measurements

The PM values are measured on the basis of a moving average with a time basis of 900 s. This is the same time basis that was also used for the TÜV equivalence and type approval testing. If you change the time basis, then please be aware that the configuration will then deviate from the certified status and no information is available on the effects of such a change, meaning that neither the correlation nor the gravimetric analysis will remain valid.

Caution:

A change of this value is undertaken at the user's own risk.

Nevertheless, under certain circumstances, changing the time basis can be advantageous. The following steps explain how to change the time basis:

- After starting the APDA-372, you will find yourself in the main menu (see Figure 14):
- Go to the Expert User menu by clicking on the "expert user menu" button, then enter "1" followed by "-" and click on "accept" (see Figure 15).
- You are now in the Expert User menu (Figure 16). You can return to the APDA-372 main menu from here by clicking on the green APDA-372 bar at the top left. Please click on "system" to continue:
- You are now in the "system" screen (see Figure 17). Continue by clicking "exit to OS" to obtain access to the Windows operating system.
- On the Windows Desktop you will see an icon and a folder. You can use the "Shortcut to startupmanager" icon to reboot the APDA-372 user interface. Please click the "startup" folder (see Figure 20)

Figure 20: Windows desktop

- You are now in the “startup” folder; please click the FIDAS folder (see Figure 21).

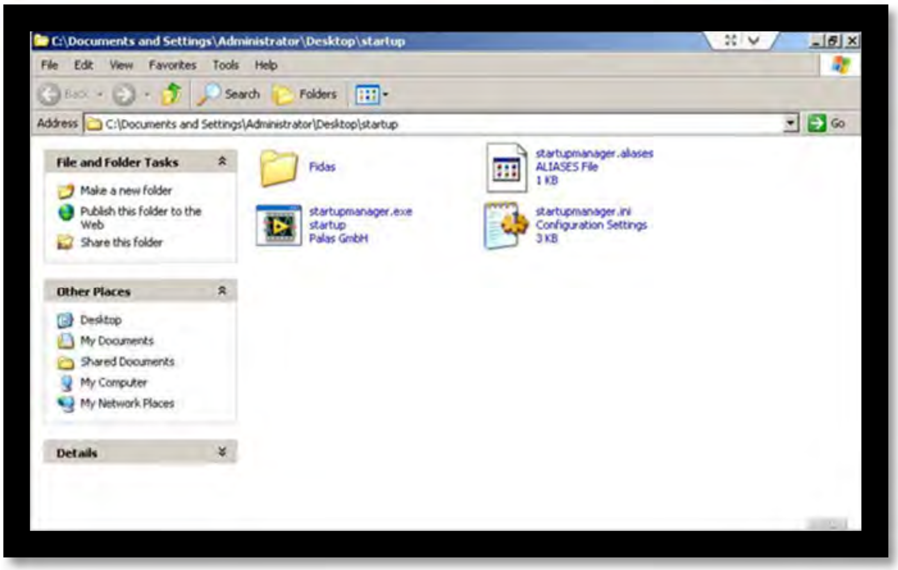


Figure 21: Startup folder

Various different files can be seen in this folder (scroll downwards to see the second half; see Figure 22).

File	Purpose
“_palassupport.exe”	Teamviewer module for remote support and remote control
“counter-win32.100###.exe”	APDA-372 user interface firmware; the highest number is the most current version
“DATA_auto_5048_...”	APDA-372 files
“promo.ini”	APDA-372 *.ini file with permanent settings

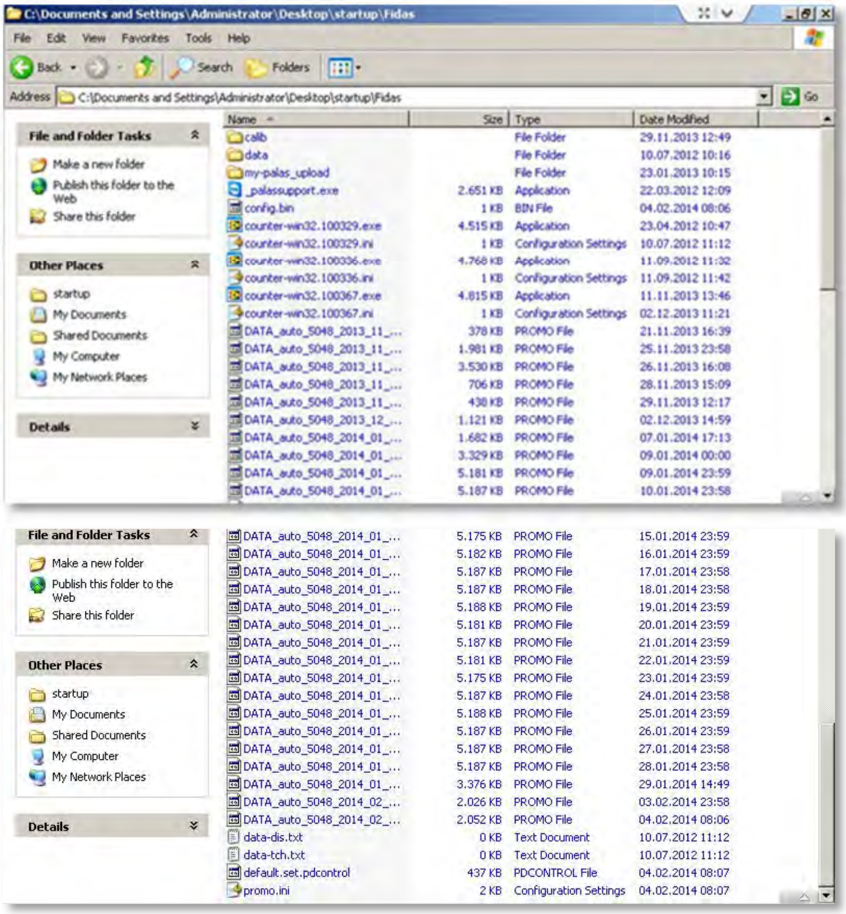


Figure 22: Fidas folder

Please open the "promo.ini" file. For the APDA-372, it should appear as follows (see Figure 23):

[system]
type=Fidas 200
ser#=XXXX
password=yxcvbXXXX
user_device#=

[plugin]
Promo 3000_enabled=no
Fidas 100_enabled=yes
Fidas 200/210_enabled=yes
Fidas 300/310_enabled=yes
Fidas mobile_enabled=no
Nanoco 100_enabled=no
Nephel 100_enabled=no
stop_enabled=yes
start_enabled=yes

[my-palas.com]
my-palas.com_autostart=no

```
[Fidas]
velocity_calibrated=9.3 m/s
PM10_slope=1.000
PM10_intercept=0
PM4_slope=1.000
PM4_intercept=0
PM2.5_slope=1.000
PM2.5_intercept=0
PM1_slope=1.000
PM1_intercept=0
PMtotal_slope=1.000
PMtotal_intercept=0
PM_alternative=yes
PM_volatile=no
textfile=yes
textfile_interval=60s
PM_autoadjust=no
gravimetric_correction_factor=1.00
IADS_modus=1
dust_type=2
sensor_selection=2
automated_cleaning=no
alarm_threshold=99999 µg/m³
alarm_value=PM10
alarm_email_address=""
password_service=-1
calibration_IADS_restrict=yes
calibration_temperature=50

[Promo3000]
interval=300
sensor1=15.000000
sensor2=33.000000

[hardware]
weatherstation_connected=yes
weatherstation_comport=4
weatherstation_scale_T=1
weatherstation_scale_p=1
weatherstation_scale_h=1
weatherstation_offset_T=0
weatherstation_offset_p=0
weatherstation_offset_h=0
weatherstation_equation=  x_corr=scale*x+offset
GPS_connected=no
GPS_comport=8
discmini_connected=no
discmini_comport=81
discmini_interval=300s

[UF-CPC]
liquid_pump_impulsinterval=45 s
liquid_pump_impulsamplitude=0.5 V

[settings]
sensor_selection=2
PM_interval=900s                          Time basis for moving average of PM fractions
IP_UDP_broadcast=127.0.0.1                Recommended and TUV-approved setting: 900 s
PLC_interface=1
temperature_compensation=yes
temperature_slope=0.17
velocity_correction=yes
velocity_calibration_enabled=no
flow_calibration_enabled=yes
server_IP-accesslist=+*
RSBaudRate=9600
BayerHessen_DA_commmand=60>60,61>61,62>62,63>63,64>64,65>65
```

Figure 23: The promo.ini file

The second half can be viewed by scrolling downwards. Please check the time basis and, if necessary, set the time basis for the moving average value to 900 seconds (i.e. 15 minutes). Save and close the "promo.ini" file and restart the APDA-372 user interface.

3.5. Corrections used for the algorithm, e.g. TÜV correction for PM2.5 and PM10

Based on the TÜV Rheinland report concerning the type approval testing of the APDA-372 measurement system for the components PM10 and PM2.5, Report Number: 936/21226418/C, it has been determined that the measurement uncertainty for PM10 and PM2.5 obtained from the comparison of the APDA-372 with the gravimetric reference method is improved when the measured values of the APDA-372 are corrected using the determined slopes and axis intercepts. The following correction parameters were determined in the context of the equivalence test:

PM2.5:	Slope: 1.076	Axis intercept: -0.339
PM10:	Slope: 1.058	Axis intercept: -1.505

The inverse values shown below are used to implement the correction. This means
Correction = 1/slope *y – axis intercept/slope

PM2.5:	cSlope: 0.929	cAxis intercept: -0.315
PM10:	cSlope: 0.945	cAxis intercept: -1.422

If this correction for measurements with the APDA-372 is to be used, it must be entered in the promo.ini file. The same procedure applies for other corrections, such as of a location correlation that has been determined with respect to a gravimetric measurement system.

<u>Example</u>: To be able to use the aforementioned TÜV Rheinland correction, the promo.ini must contain the following data:

Promo.ini:
[Fidas]
PMtotal_slope=1
PMtotal_intercept=0
PM10_slope=0.945
PM10_intercept=1.422
PM4_slope=1
PM4_intercept=0
PM2.5_slope=0.929
PM2.5_intercept=0.315
PM1_slope=1
PM1_intercept=0

3.6. System monitoring functions

The APDA-372 measuring system is delivered with the system monitoring activated. If the firmware is not running or has crashed, the system is restarted automatically after 255 seconds. However, this also means that access to the Windows operating system is limited to 255 seconds if the access is initiated via the following path: “expert user menu” -> “system” -> “exit to OS”.

To obtain access to the Windows operating system without the time limitation, please select “Ver.exe” while starting the APDA-372 Start-up Manager.

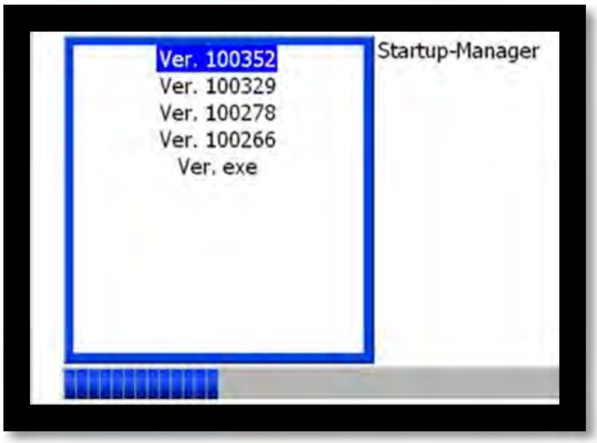


Figure 24: Startup-Manager

3.7. System modifications and installation of additional software under Windows

All devices are delivered with a file-based write filter (FBWF). The purpose of this protection is to prevent a deterioration of the Windows operating system and to protect against any possible installation of malware. This filter ensures preservation of the original state of the operating system.

Any modifications to the operating system or any newly installed file is not saved permanently, but instead, the original state is restored the next time the system is launched. This includes, for example, the setting of the Windows system clock and the date.

The only exception is for data that are saved on the desktop. The APDA-372 data and system files are also saved on the desktop and can be modified at any time, and new files can be added.

To be able to save permanent system modifications, please activate the batch file in the following folder on the desktop: "/startup/Fidas". After rebooting the Windows operating system, the modifications will be saved permanently (e.g. system clock and date). We recommend running the batch file after all desired modifications in order to reactivate the write protection. This requires a reboot of the system; the protection is only active again after this.

Please note:

It is possible to run the system without the FWBF being active, however, we recommend activating the FBWF.

4. Maintenance

We recommend a periodic inspection of the correct operation of the APDA-372 according to the following table and section 5. Apart from this, the device only needs to be serviced if one of the error bits is triggered (see **Figure 25**).

Test	Test interval	Section in the manual
Calibration/verification	1 month or 3 months	5 – 5.8
Clean the optical sensor	1 year or if the photomultiplier voltage during calibration of the optical sensor is > 15% above the calibration value after the last cleaning or the as-delivered condition	5.10
Clean / replace the exhaust filter of the internal pump (part no. 1000106819)	1 year or if the power required for the exhaust pump is >50%	5.11
Check/cleaning of the Sigma-2 head	3 months	5.12
Replacement of the O-ring seals (part no. 1000106822)	1 year or if leakage is ascertained	5.13
Replacement of the pump assembly (part no. 1300010121)	If there is a failure or the pump power required is > 80%	5.14

Table 1 Overview of maintenance tasks

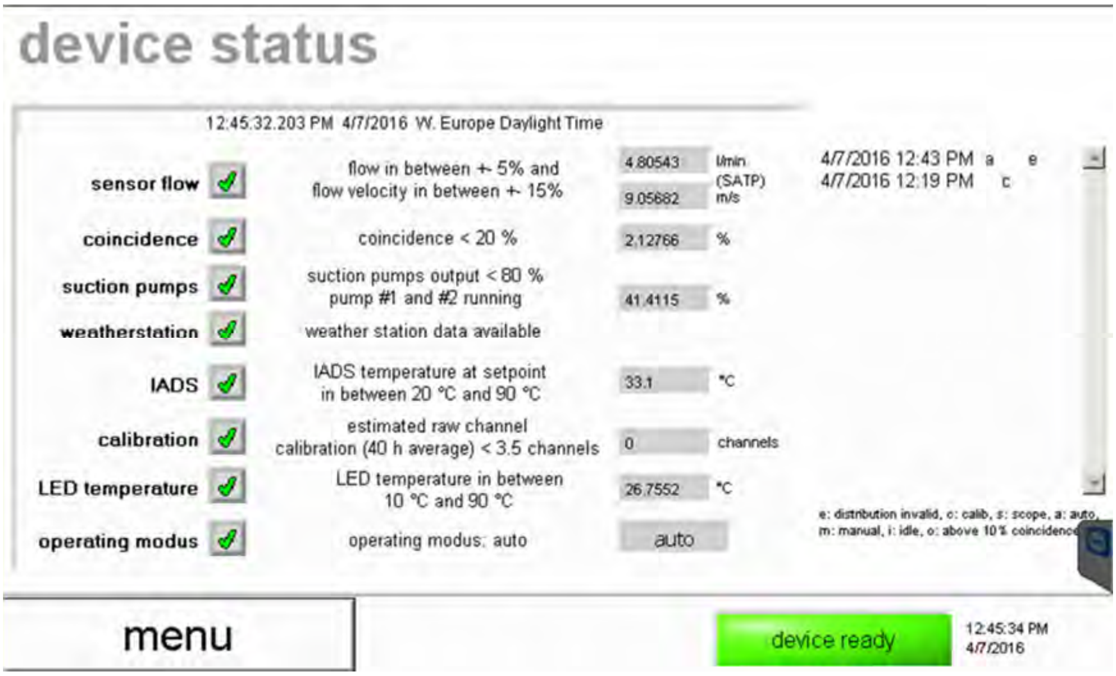


Figure 25: Status overview

Various items of sensor information are shown here which are required for correct operation of the APDA-372. This information is also saved along with every data record in the form of a status/error byte.

This specifically includes:

Sensor flow

The APDA-372 regulates the volumetric flow rate at 4.8 l/min by means of a control circuit with mass flow meters and inclusion of the values measured for temperature and air pressure. This volumetric flow rate is then standardized for "standard atmospheric temperature and pressure" (SATP), that is, with reference to 25 °C and 1013 hPa.

An error is displayed if the volumetric flow rate deviates from the setpoint value by more than 5%.

The second value indicates the velocity (flow velocity) of the particles through the optical detection volume. An error is displayed if the velocity of the particles deviates from the setpoint value by more than 15%. The setpoint value corresponds to the velocity entered in the promo.ini file which is determined at the installation site in accordance with section 5.5. An error message indicates a possible leak after the sensor.

IMPORTANT:

The result of the velocity measurement has **no** influence on the calculation of the PM values, but is instead only used as an indicator for the leak tightness.

Coincidence

Detection of more than one particle in the optical detection volume. An error is output if this occurs with a frequency of greater than 20%.

Suction pumps

The volumetric flow in the APDA-372 is generated by two pumps that are connected in parallel. If one pump fails, the other can assume its role; the power consumption is then accordingly higher, which leads to an error. If both pumps should age uniformly, an error is also triggered when 80% is exceeded. It is important to note that the device still continues to measure correctly, however, the user must see to it that the pumps are replaced soon.

Weather station

This indicates that a weather station is correctly connected and is transmitting values.

IADS

This indicates that the IADS is correctly connected and the temperature corresponds to the prescribed regulation point.

Calibration

This monitors the calibration online. If the average over 40 hours deviates by more than 3.5 raw data channels , an error is set.

Note: In individual cases, this value might be out of tolerance for brief periods while the device is nonetheless still operating properly. Need for action (i.e. a field calibration using calibration dust) only arises if this is a longer-term trend (>40 hours).

LED temperature

The LED light source is subject to temperature control. If a problem arises in this control circuit, this error bit is set.

Operating mode

The operating mode should be set to “auto” because otherwise it is possible that the data will not be saved correctly or the device will not restart again on its own after a power outage.

5. Calibration/verification of the APDA-372

The device should always be calibrated before a measurement campaign. The calibration should be checked at regular intervals while a measurement campaign is running (see Table 2).

The device must be in operation for at least one hour before the calibration so that it is in a thermally stable condition. The ambient temperature for this must be between 10 °C and 40 °C.

Please note:

If the device is calibrated using MonoDust, the calibration is only valid if it is conducted at a temperature in the range of from +10 °C to +40 °C!

The device must be switched to the calibration mode for the calibration. To do so, select “settings/calibration” in the main menu of the APDA-372 firmware. In the next screen select “activate calib mode”. Return to the main menu.

The complete calibration consists of five individual steps:

1.) Leak test
2.) Flow rate test / calibration
3.) Check of the particle sensor offset
4.) Check of the particle sensor zero point
5.) Check of the average particle velocity
6.) Check / calibration of the particle sensor sensitivity
7.) Check of the MonoDust particle velocity
8.) Save the data

The steps are described individually below:

5.1. Leak test

5.1.1 In the main menu, select the “expert user menu” (password “-1”). In the next screen, select “suction pumps/signals/digital IO”.

5.1.2 In the “suction pumps/signals/digital IO” screen, you will see the current gas volume flow (“sensor flow rate”). Use the “suction pump” sliding switch to switch the pump off. “Sensor flow rate” now shows the zero value of the flow rate sensor. Write down this value (“Offset”).

5.1.3 Disassemble the sampling head. Loosen the mount of the IADS tube and raise it about 20 cm to gain access to the aerosol inlet of the APDA-372 sensor. Secure the IADS in this position. Close off the aerosol inlet with a cap / plug / clamped off piece of hose or your thumb. As an ALTERNATIVE, if you do not want to disassemble the IADS, you can disconnect the short piece of hose between the filter holder (under the sensor) and the inlet on the Fidas front panel (under the blue filter) by pulling it out of the connection on the filter holder. Block the inlet of the hose.

5.1.4 Switch the pump back on. The pump now evacuates the sampling system. The output power of the pump control will rise to 100% and the working noise will be significantly louder – this is normal. Wait until the flow rate that is displayed has reached its minimum and write down the value (as "APDA-372 control unit gross leakage"). If the value is not stable, write down the lowest value read. Switch off the pump once again.

5.1.5 Calculate the net leakage:

"APDA-372 control unit net leakage" =
"APDA-372 control unit gross leakage" – "Offset".

The result should be < 0.08 l/min. If this value is exceeded, check the filter holder under the sensor as well as the transparent protective cover of the blue filter on the front panel of the control unit for damage to the ring seal and for a firm seat. If you are authorized to perform internal repairs on an APDA-372 and the APDA-372 is no longer under warranty, you can open the device to look for possible causes for the internal leakage, such as loose/damaged/hardened sections of hose, and repair them inasmuch as possible. Repeat the leak test until the result is acceptable – otherwise, contact your APDA-372 supplier.

5.1.6 Reconnect the IADS, but leave the Sigma-2 head aside (or reconnect the piece of hose between the filter holder and the aerosol inlet on the front). Close off the IADS inlet with a cap / plug / clamped off piece of hose.

5.1.7 Repeat the procedure described in 5.1.4, except that the value your write down this time is now the "APDA-372 system gross leakage".

5.1.8. Calculate the net leakage:

"APDA-372 system net leakage" =
"APDA-372 system gross leakage" – "Offset".

The result should be < 0.5 l/min. If this value is exceeded, check the IADS for damaged ring seals and correct seating of the aerosol inlet of the APDA-372 sensor. Also check whether the IADS inlet is really closed off tightly. Repeat the leak test until the result is acceptable – otherwise, contact your APDA-372 supplier.

5.1.9 Put the Sigma-2 head back in place and switch the pump on once again.

5.2. Flow rate test / calibration

Checking and possibly calibrating the flow rate must only be carried out after a successful leak test.

5.2.1 Connect a suitable flow rate measuring instrument with a low level of pressure loss to the IADS input (remove the Sigma-2 head).

Important:

Because the flow rate references SATP (standard ambient temperature and pressure), please be certain that your flow rate is referenced to the same temperature (25 °C) and the same pressure (1013 hPa). If this is not the case, this must first be corrected manually before the measured flow rate is entered in the firmware!

5.2.2 In the main menu, select the "expert user menu" (password "-1"). In the next screen, select "suction pumps/signals/digital IO".

5.2.3 In the "suction pumps/signals/digital IO" screen, you will see the current gas volume flow ("sensor flow rate"). Under normal operating conditions, this value is approximately 4.8 l/min. Compare the value with the display of your flow rate measuring instrument. The gas volume flow according to the display of your flow rate measuring instrument must be 4.8 ±0.15 l/min. If the value read is in this range, you can disconnect the flow rate measuring instrument and reinstall the Sigma-2 head. Otherwise, continue with step 5.2.4.

5.2.4 Access to the setting of the flow rate control can be obtained as follows: Go back to the “expert user menu” -> select “sensor/calibration” -> in the next screen select “sensor calibration” -> in the next screen, select “calibrate flow sensor offset” -> enter the value that your flow rate measuring instrument displays (observe the decimal separator!) and select “accept”.

5.2.5 After the calibration, check the flow rate once again according to 5.2.3.

Please note:

If the “calibrate flow sensor offset” is not visible, the following changes must be made in the promo.ini file in the [settings] area:

flow_calibration_enabled=yes

5.3. Check of the particle sensor offset

The check of the particle sensor offset is only a monitoring measurement – contact your APDA-372 supplier if the measured values lie outside of the specified range.

5.3.1 In the main menu, select the “expert user menu” (password “-1”). In the next screen, select “sensor/calibration” -> in the next screen select “sensor calibration” -> in the next screen, select “adjust offset” -> the procedure begins automatically.

Observe the offset value displayed at the top right, which changes continuously while the offset adjustment voltage is varied. The minimum value displayed as the curve passes through its lowest point should be less than 0.2 mV. Once the measurement has been completed, the value for the offset compensation voltage is calculated and the display in the field below the graph is updated. The value should be between 2 and 3 V.

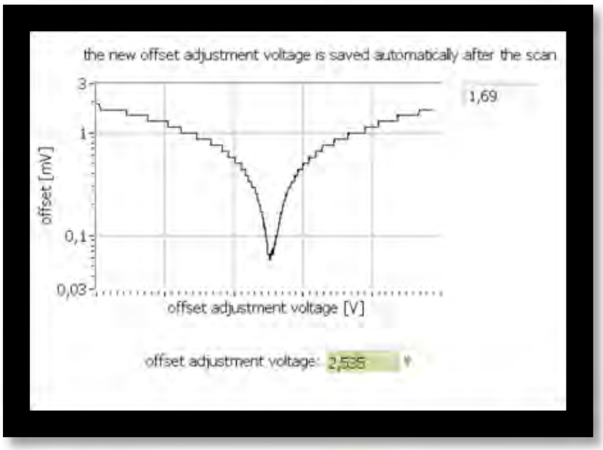


Figure 26: Screen display during the automatic offset adjustment

5.4. Check of the particle sensor zero point

Checking and possibly calibrating the particle sensor zero point must only be carried out after a successful leak test (5.1) and sensor offset (5.3).

5.4.1 In the main menu, select “data”. The value initially displayed on the screen (“Cn”) is the currently detected particle number concentration (moving average over 10 s).

5.4.2 Remove the Sigma-2 head and attach an HEPA filter to the IADS inlet. This filter removes all of the particles that are normally detected from the intake air. Observe the Cn value. It should go to zero within one minute and remain there as long as the HEPA filter is attached. If this is the case, the HEPA filter can be removed again.

If the value is not zero, check to see if the filter is perhaps not seated tightly or there is electronic interference (interference sources). If the problem continues, please contact your APDA-372 supplier.

If you wish to check the zero point of the PM values in [µg/m³], then the HEPA filter must remain connected over the entire period of the integration time that is set (default setting: 900 s).

5.5. Check of the average particle velocity

The check of the average particle velocity is typically only performed when the device is installed. It must be carried out only after a successful leak test, sensor offset and sensor zero point. IMPORTANT: The result has **no** influence on the calculation of the PM values, but is instead only used for the internal leak tightness test (see section 4)!

5.5.1 In the main menu, select the “expert user menu” (password “-1”). In the next screen, select “sensor/calibration” -> in the next screen select “sensor calibration” -> in the next screen, various values are displayed to the right of the “raw data distribution” graph. The fifth entry shows the “velocity (average)”. Write down this value and return to the overview screen of the “expert user” menu.

5.5.2 In the “expert user” screen, select “system”. In the next screen, select “exit to OS” to exit the Fidas® firmware and gain access to the operating system.

5.5.3 Navigate to the “promo.ini” file. Open the file and scroll to the entry “velocity_calibrated”. Replace the value there with the value noted previously in 5.5.1, “velocity (average)”. Save and close the “promo.ini” file.

5.5.4 Restart the APDA-372 firmware.

5.6. Check / calibration of the particle sensor sensitivity

The check / calibration of the particle sensor sensitivity must be carried out only after a successful leak test, sensor offset and sensor zero point.

5.6.1 In the main menu, select “settings/calibration”. Once you select “sensor calibration” in the following screen, the system prepares the check / calibration of the particle sensor sensitivity by heating the IADS up to 50 °C (in older systems, possibly 35 °C). This ensures that the volumetric flow rate and the gas dynamics are always the same during the calibration, and the test dust used is subject to a certain conditioning.

The IADS temperature must remain within ±1 °C of the setpoint value for 120 s before the calibration can be continued. Usually, this will mean a wait of 10 minutes.

5.6.2 Remove the Sigma-2 head while the IADS heats up. Attach a hose to the IADS inlet. Its length should ideally be sufficient to allow you to be present in front of the device during the check of the amplification. For a Fidas® that is installed in a measurement container, you may need a hose that is several meters in length. Take care to ensure that the hose is not kinked anywhere.

5.6.3 Once the IADS temperature has stabilized in the vicinity of the setpoint value, you can select "continue calibration" and the calibration screen will be displayed.

5.6.4 Take a closed bottle of MonoDust 1500 and shake it lightly or tap on the bottom of the bottle to release dust particles. Open the bottle and hold the end of the hose connected to the IADS near the bottle, but do not put the end of the hose into the bottle. Squeeze the bottle together slightly a few times to exchange a little air between the inside of the bottle and the environment. The APDA-372 will draw in particle-laden air and the "raw data distribution" graph will display a signal peak. The firmware will recognize the location of the peak and display the numerical value as "measured peak at …". Write down this value.

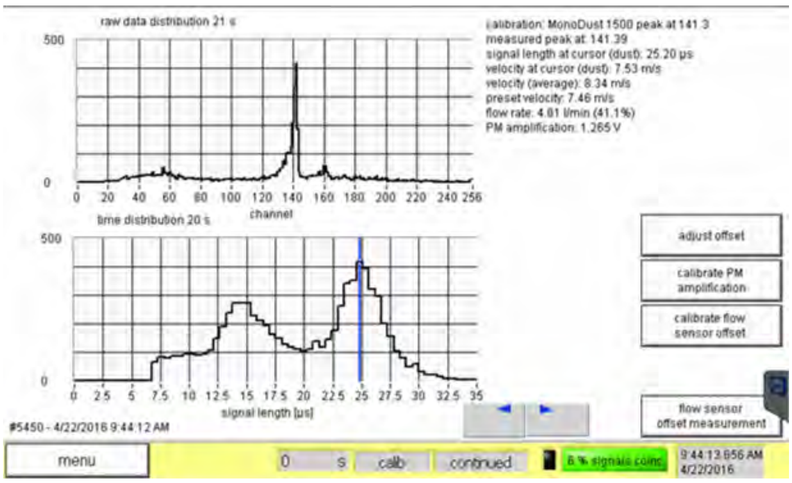


Figure 27: Screen display during the calibration

(Graphic above: Raw data distribution of channel 0 to 256 with maximum at 141.39)

5.6.5 The target channel of the MonoDust 1500 test dust is known exactly through comparative measurements with the PSL standard, is indicated in the enclosed test certificate and on the bottle, and is also indicated on the top line in the calibration screen through firmware version 100448 (see Figure 27). As of firmware version 100449, the top line of the calibration screen no longer contains the specified target channel, but instead only the text "see bottle".

If the MonoDust signal peak is detected in the **target channel ±0.5** (in Figure 27 141.3±0.5), no further measures are required.

If the deviation lies between 0.5 and 1.5 channels, adjust the voltage of the photomultiplier:

Select "calibrate PM amplification" and change the value that is displayed. Increase the voltage if the signal peak was detected below the target value and decrease it in the reverse case. For a rough guideline: 1 channel of deviation – adjust the PM voltage by 0.01 volts. Repeat the measurement with MonoDust 1500 after adjusting the PM voltage. Repeat the measurement with MonoDust 1500 and the adjustment of the PM voltage until the signal peak is detected in the target channel ± 0.5. If the MonoDust 1500 signal peak lies more than 1.5 channels below the value of the last calibration (provided this took place no longer than 1 month previously), the first thing to do is clean the sensor (see section 5.10). Cleaning is also required if the PM voltage is more than 15% above the calibration value after the last cleaning or the as-delivered condition. Switch off the device before cleaning the sensor – when switched on, the sensor reacts very sensitively to too much light. After cleaning, check the leak tightness once again (section 5.1.) and then continue at 5.6.1.

In the event of substantial deviation (> 10 channels) between the measured position of the MonoDust 1500 signal peak and the target value, contact your APDA-372 supplier.

An evaluation of the effect of a shift of the peak in the raw data channel with respect to the mass concentration was carried out in the context of the type approval testing by TÜV Rheinland using CalDust 1100 (setpoint, 130) (see excerpt from Report 936/21226418/C) – The evaluation procedure remains unchanged by the use of MonoDust 1500 instead of CalDust 1100:

Table 3: Matrix on the influence of a peak shift on the mass concentration

	PM2,5		PM10	
channel shift	slope	offset	slope	offset
-3	1,086	0,03889	1,0877	0,0331
-2	1,056	0,025	1,057	0,012
-1	1,029	0,0122	1,028	0,048
0	1	0	1	0
1	0,973	-0,00785	0,976	-0,0047
2	0,945	-0,0197	0,947	0,038
3	0,918	-0,031	0,9224	0,083

For instance, if there is a shift by -3 channels, the actual PM values bear relation to the hypothetically determined PM values in the following way:

$PM_{2.5}$_actual=1.086*$PM_{2.5}$_hypothetical+0.03889
PM_{10}_actual=1.0877*PM_{10}_hypothetical+0.0331.

A shift by -3 channels results in the particle size being determined too small. As a consequence, the $PM_{2.5}$ value is measured too low by the factor 1.086.

For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for PM_{10} were defined. The concentration value to be expected depending on the peak shift was then calculated according to the following matrix

Figure 28: Excerpt from TÜV Rheinland Report 936/21226418/C

5.7. Check of the velocity with MonoDust particles

In addition to the signal amplitude for each individual particle, the sensor also measures the signal length for each individual particle. This signal length is directly proportional to the velocity of the particle in the sensor because the height of the optical measurement volume is known. If the velocity of the particles in the sensor is not correct, the flow rate in the sensor is also not correct, or the flow configuration in the sensor is disturbed.

IMPORTANT:

For the regular inspection of the particle sensor sensitivity using MonoDust 1500, only a check of the channel position for the MonoDust signal peak according to section 5.6 is of relevance for evaluating the correct functioning of the measuring system. **A check of the average particle velocity using MonoDust 1500 is not relevant for the determination of the measured value** and therefore does not need to be monitored. The particle velocity only serves as an indicator for possible disturbances in the flow (e.g. leakage) and is monitored continuously by default as a parameter under the status item “sensor flow” (see section 4).

The check of the velocity with MonoDust particles must be carried out only after a successful leak test, sensor offset and sensor zero point.

The testing requires a conditioned IADS (50 °C or 35 °C), meaning that the test is ideally conducted in combination with the testing of the particle sensor sensitivity.

5.7.1 Follow the instructions in sections 5.6.1 through 5.6.4 and Figure 27 of this manual. Please consult the signal length distribution graph (Figure 27 lower graph) while the APDA-372 aerosol is analyzed using MonoDust particles. The two modes for the velocity distribution should be clearly distinguishable, and the peak value of the second mode (graph, right maximum) should be stable and unambiguously readable.

5.7.2 Use the buttons shown on the screen with the blue left and right arrows to move the vertical blue line in the signal length distribution graph to the position of the peak value of the second mode. The signal length marked in this manner will be converted to a velocity ("velocity at cursor") which is displayed to the right of the "raw data distribution" graph along with additional information. Write down this value.
Important: This procedure is merely intended to simplify the reading of the signal length in the second mode of the velocity distribution – the position of the blue line has no influence on the evaluation of the measurement data (except for "velocity at cursor").
Compare the velocity value with the value that is listed in the APDA-372 calibration certificate (measurement performed at either 35 or 50 °C, depending on what is indicated on the certificate). The deviation should be less than ±0.5 m/s.

5.8. Saving the data

It is recommended that the firmware be closed after the calibration (via the "expert user" menu) and an external back-up copy of the files "promo.ini" and "default.set.pdcontrol" be created (e.g. on a USB flash drive). Then restart the APDA-372 (using the corresponding command from the Windows® "Start" menu, NOT using the On/Off switch!).

Test	Test interval	Tested parameter	Limit values	Comment
Leak test	3 months	Flow rate	< 0.08 l/min (control unit) < 0.5 l/min (overall system) (excluding the pump offset)	by sealing off the intake
Flow rate test	3 months	Flow rate	4.8 l/min ± 0.15 l/min relative to 25 °C and 1013 hPa (Standard Ambient Temperature and Pressure - SATP)	With a suitable transfer standard (volume flow measuring instrument)
Particle sensor offset	3 months	Offset (minimum)	< 0.2 mV	Fully automatic
		Offset adjustment voltage	> 2 V; < 3V	Fully automatic
Particle sensor zero point	1 year	C_N or PM values	C_N : 0 PM: ≤ 1 µg/m³	With HEPA filter on the inlet
Particle sensor sensitivity	1 month	Measured peak	Setpoint ± 0.5 According to the test certificate included in delivery / MonoDust 1500 marking	With MonoDust 1500 test dust
Velocity of the MonoDust particles	3 months	Velocity (MonoDust)	± 0.5 m/s from the factory value According to the APDA-372 test certificate	With MonoDust 1500 test dust by marking the right maximum

Table 2: Summary: Operational procedure for calibration

5.9. Removal of the gravimetric filter / filter replacement

To remove the gravimetric filter, the gravimetric filter holder on the bottom of the aerosol sensor must be removed.

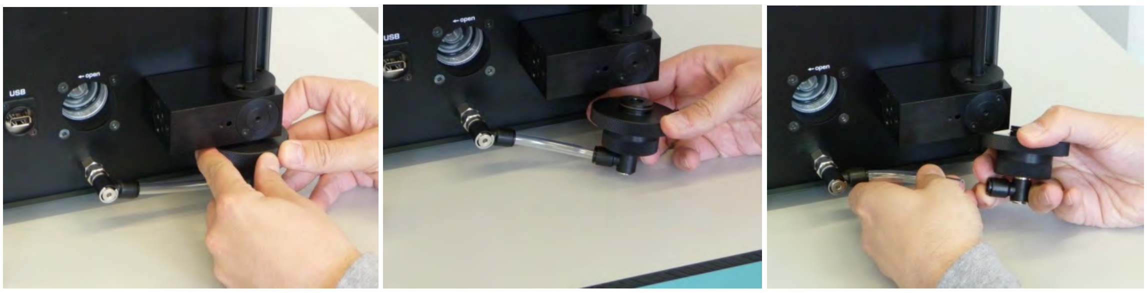


Figure 29: (A-C) Removing the filter holder

The filter holder (Figure 29A) can easily be pulled off downwards (Figure 29B). Afterward, the plug-on connection of the exhaust hose can be removed. To do so, press the plug-on connection towards the back and at the same time, pull off the hose with the other hand (Figure 29C). The filter holder can now be opened by rotating it to the left.

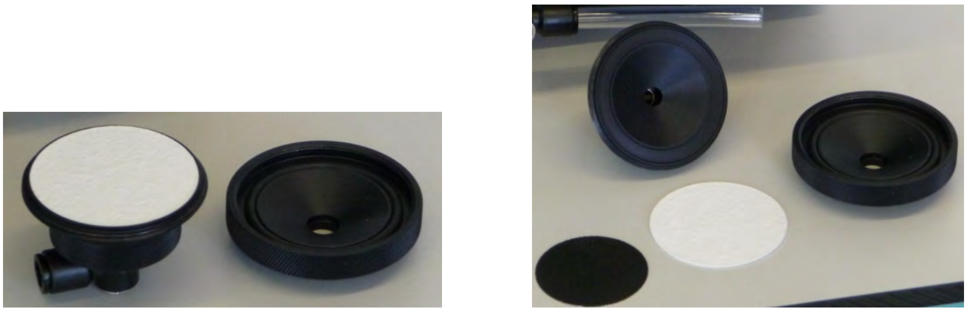


Figure 30: (A and B) filter holder assembly

The filter holder consists of an upper and lower part which are secured to each other by a screw connection (see Figure 30 A&B). The lower part also contains a supporting grid on which the gravimetric filter rests.

5.10. Cleaning the APDA-372

Cleaning of the optical sensor is required if the photomultiplier voltage during calibration of the optical sensor lies more than 15% above the calibration value after the last cleaning or the as-delivered condition.

5.10.1. Cleaning the APDA-372 with IADS

When using an IADS humidity compensation module, it must first be removed from the aerosol inlet of the sensor so that the APDA-372 control unit with the integrated aerosol sensor can be moved aside.

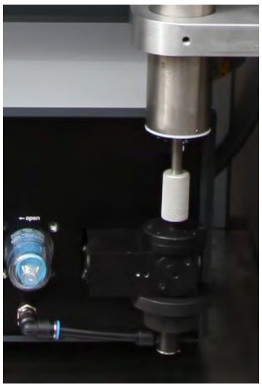


Figure 31: Connection of the sensor inlet with IADS humidity compensation module

The adapter for connecting the IADS humidity compensation module on the aerosol inlet must be pushed downwards. Afterwards, the IADS humidity compensation module can be pushed all the way upwards so that the inlet of the aerosol sensor is freely accessible.

5.10.2. For all APDA-372 systems

To clean the internal optical lenses of the sensor requires that the filter holder be removed from the sensor outlet and the plug-on connection between the filter holder and the inlet of the exhaust pump also be removed.

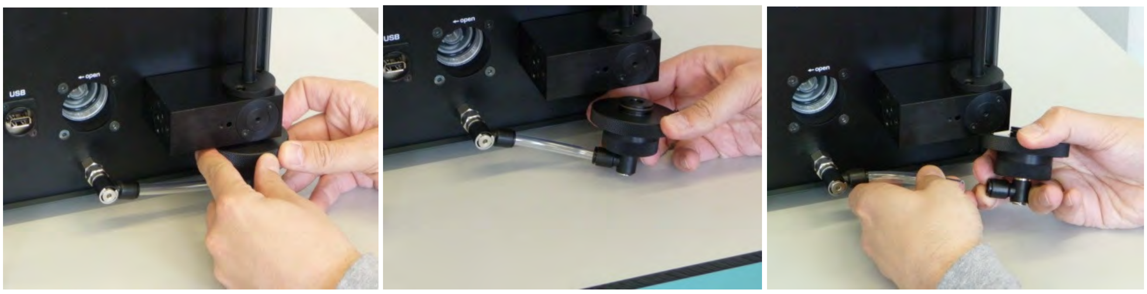


Figure 32: (A-C) Removing the filter

The filter holder (Figure 32A) can easily be pulled off downwards (Figure 32B). Afterward, the plug-on connection of the exhaust hose can be removed. To do so, press the plug-on connection towards the back and at the same time, pull off the hose with the other hand (Figure 32C). Afterwards, the two M3 Phillips head screws must be unscrewed with a suitable screwdriver.

Figure 33: Unscrewing the M3 Phillips head screws

Figure 34: Removing the aerosol guide tube

Caution:

When removing the aerosol guide tube, care must be taken to ensure that the inner optical lenses of the aerosol sensor are not scratched or damaged by the aerosol tube!

Now the two optical lenses in the inside of the aerosol inlet can be cleaned. This must be done with an optical cloth only (included in the scope of delivery).

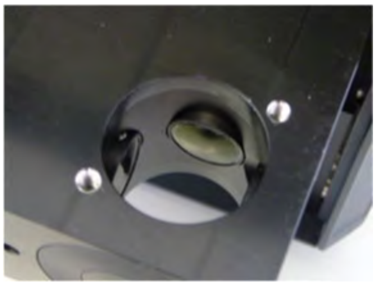


Figure 36: Optical lenses in the inside of the aerosol sensor

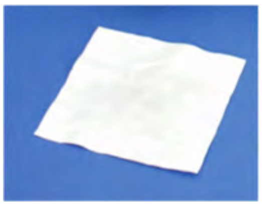


Figure 35: Optical cloth

Caution:

Do not touch the lenses with your fingers!

Clean only with optical cloths!

The aerosol guide tube can be cleaned with compressed air.

5.11. Cleaning the exhaust filter of the internal pump

The filter must be cleaned or replaced if the power required by the exhaust pump is greater than 50%. The protective cover of the exhaust filter (Figure 37) of the internal pump can be released and pulled off easily by rotating it to the left. The filter itself can also be removed by rotating it to the left (Figure 39).

Figure 37: Removing the protective cover

Figure 38: Filter without protective cover

The filter can either be blown out with compressed air or be replaced if too heavily contaminated.

Figure 39: Removing the filter

Figure 40: Filter and protective cover after removal

Proceed in the reverse order for installation.

5.12. Cleaning the Sigma-2 head

For monitoring purposes, the Sigma-2 head should be inspected for coarse dirt and cleaned as needed every three months (in connection with the calibration).

5.13.Replacing the O-ring seal

If a leak test or a visual inspection reveals that an O-ring seal must be replaced, we recommend only using the O-ring seals that HORIBA supplies. HORIBA offers a “set of O-ring seals for the APDA-372” as a spare part item. This set consists of the following O-ring seals:

Figure 41: Set of O-ring seals for the APDA-372

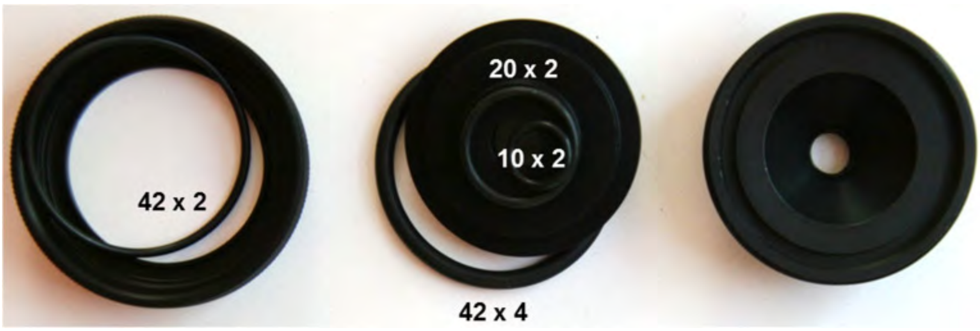


Figure 42: Absolute filter holder

Figure 43: Aerosol inlet, sensor inlet

5.14. Servicing of the pump assembly

The volumetric flow in the APDA-372 is generated by two pumps (= pump assembly) that are connected in parallel. The pumps used require no maintenance during operation. The pump performance is monitored continuously (also see section 4). Replacement of the pump assembly is only necessary when the pump power required increases to > 80% (status warning). Generally, the pump assembly service life is at least two years.

6. Particle detection with the APDA-372 system

The APDA-372 is an optical aerosol spectrometer which uses the principle of light scattering according to Lorenz Mie to determine the size of individual particles.

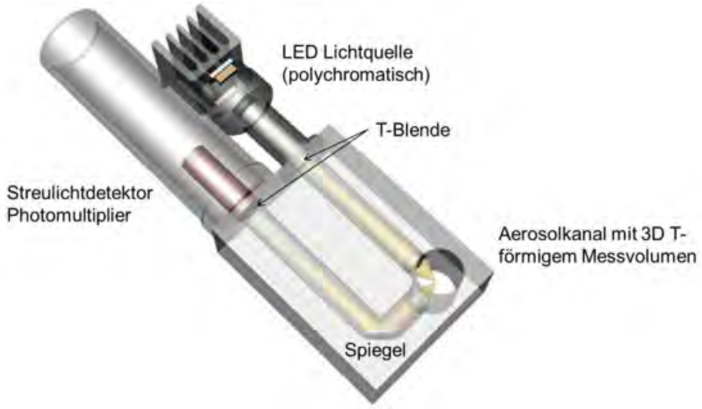


Figure 44: Sensor setup of the APDA-372 measurement system

The particles move through an optically restricted measurement volume that is illuminated homogeneously with polychromatic light.

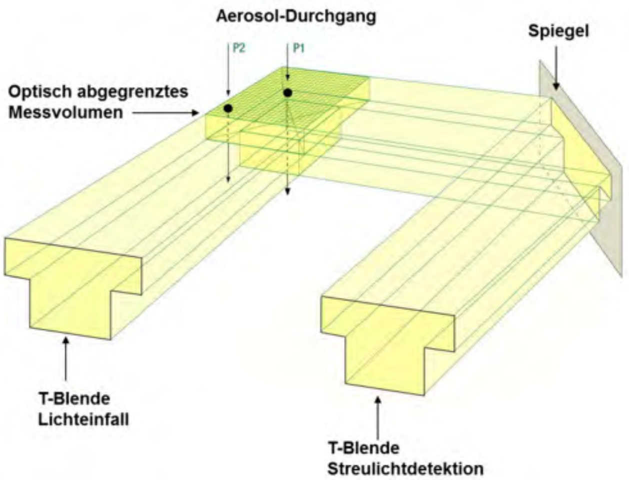


Figure 45: Depiction of the T-aperture

Using a polychromatic light source (LED) in combination with 90° scattered light detection, a very precisely defined calibration curve is obtained with no unambiguities in the Mie range. This allows the use of a very high size resolution.

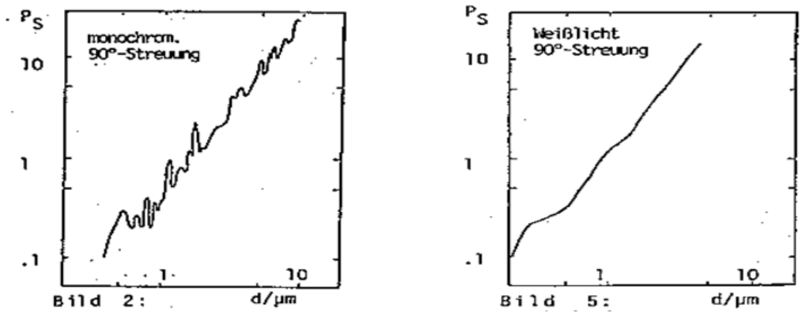


Figure 46: Calibration curve for 90° scattered light detection

With a monochromatic light source (left) and with a polychromatic light source (right)

For each individual particle, a scattered light pulse is generated that is recorded at an angle of from 85° to 95°. The particle number emission is measured based on the number of scattered light pulses. The amplitude (height) of the scattered light pulse is a measure of the particle diameter. Moreover, the signal length is also measured.

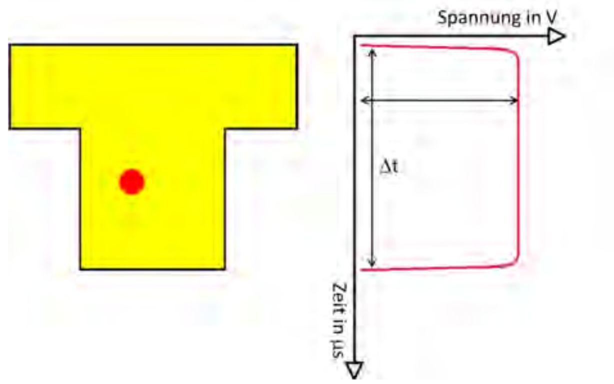


Figure 47: Measurement of the scattered light signal on the individual particle.

The amplitude and the signal length are measured.

Use of the special T-aperture optics with simultaneous measurement of the signal length allows elimination of border zone errors. When particles at the edge of the measuring range are only partially illuminated, this is referred to as a border zone error. This partial illumination results in particles being classified as smaller than they actually are (see Figure 48, red curve). Using the T-aperture allows a distinction to be made between the particles that can only fly through the arm of the T (shorter signal length) and those which can also pass through the middle section of the T (longer signal length). The latter are sure to be fully illuminated in the upper part. This means there are no border zone errors with the APDA-372 (Figure 48, blue curve).

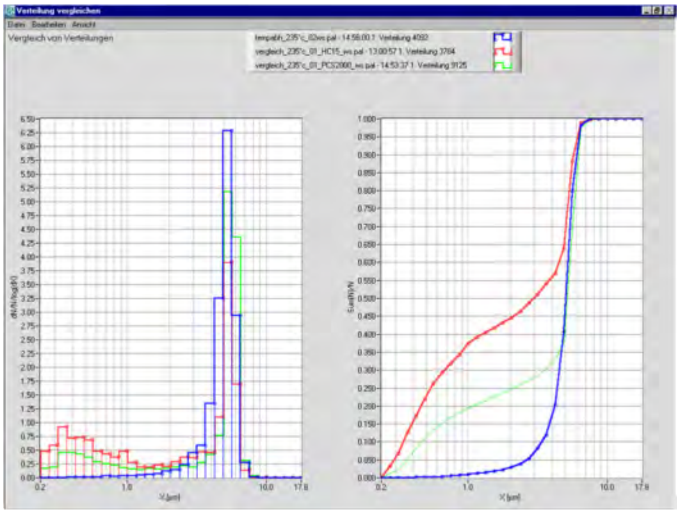


Figure 48: Comparison of an optical scattered light spectrometer with

a simple rectangular aperture (HC15, red) with an optical scattered light spectrometer with a T-aperture (welas®, blue) when monodisperse 5 µm particles are introduced

Measurement of the signal length also makes detection of coincidence possible (more than one particle in the optical detection volume), because the signal length is greater in this case. Using a correction factor determined and verified by Dr. Umhauer and Prof. Dr. Sachweh, this then allows the coincidence to be corrected online.

Using improved optics, a higher light density achieved through a new white-light LED as a light source and improved signal analysis electronics (logarithmic A/D converter), it was possible to reduce the lower detection limit to 180 nm. This allows smaller particles, especially those which are found in high concentrations in the vicinity of streets, to be taken into account a good deal better (Figure 49).

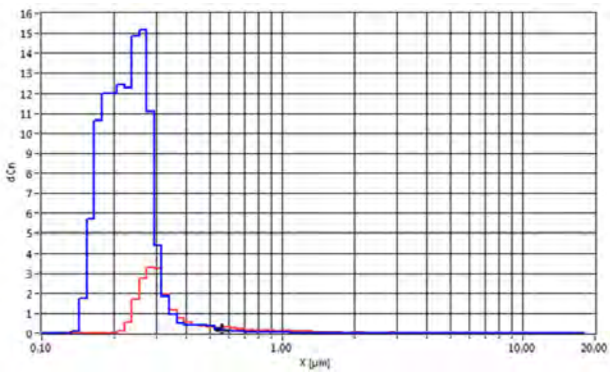


Figure 49: Measurement in the vicinity of streets with the APDA-372

(Size range from 0.18 µm, blue curve) compared with a different optical measurement system (size range from 0.25 µm, red curve)

6.1. Special properties of the APDA-372 system

The APDA-372 system is characterized by the following properties:

Using the techniques presented

- unambiguous calibration curve (polychromatic light and 90° scattered light detection)
- no border zone error (patented T-aperture technology)
- coincidence detection and coincidence correction (digital individual particle analysis)

the following decisive advantages are achieved

- very good size resolution (high number of raw data channels)
- very good size classification accuracy
- exact concentration determination

In summary, it can be stated that:
The mass concentration can only be determined reliably with a very good size resolution and very good size classification accuracy as well as with precise concentration determination.

6.2. Overview of the individual measuring steps

Particles of different sizes

Representative „suction“ of particles in ambient air with Sigma-2

Drying of particles with IADS (Intelligent Aerosol Drying System)

Measurement of scattered light intensity with white light and 90° scattered light at the single particle

Filtration of border zone and coincidence signals

Determination of optical particle size by allocation of the scattered light signal to the particle diameter via an unambiguous calibration curve based on Latex

Classification of measured particles into size classes in form of a histogram

Detection of fog by analyzing the distribution form,
eliminating the mass of fog droplets

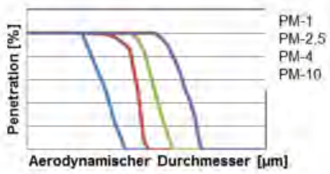
Conversion of particle size distribution based on the Latex diameter to a distribution based on a representative refractive index for the environment

Conversion of particle size distribution based on the

optical diameter to a

distribution based on the aerodynamic diameter

Analysis of the distribution form, determination of density parameters depending on the distribution form



Transfer of the separation behavior of the individual

PM sampling inlets to the size distribution depending on the density parameters

$$PM = \frac{\sum N(d)\cdot\frac{1}{6}\cdot\pi\cdot d^3\cdot\rho(d)}{V}$$

Calculation of the particle mass by using a size depended transformation function depending on the form of the distribution

PM value

The APDA-372 uses the measured particle size information to calculate the following dust values:

- PM-1[µg/m³]: Dust fractions smaller than $d_{50,Aero}$ = 1 µm in accordance with the US EPA
- PM-2.5 [µg/m³]: Dust fractions smaller than $d_{50,Aero}$ = 2.5 µm in accordance with the US EPA
- PM-4 [µg/m³]: Dust fractions smaller than $d_{50,Aero}$ = 4 µm
- PM-10 [µg/m³]: Dust fractions smaller than $d_{50,Aero}$ = 10 µm in accordance with the US EPA
- PM-thoracic [µg/m³]: Dust fractions that can enter the bronchi
- PM-alveolar [µg/m³]: Dust fractions than can enter the alveoli
- PM-respirable [µg/m³]: Total respirable dust fraction
- PM-total [µg/m³]: Total measured dust

The dust fractions mentioned above are calculated using the penetration curves for standardized sampling heads to EN-481 (PM-respirable, PM-thoracic and PM-alveolar) as well as of the US EPA (PM-1, PM-2.5, PM10).

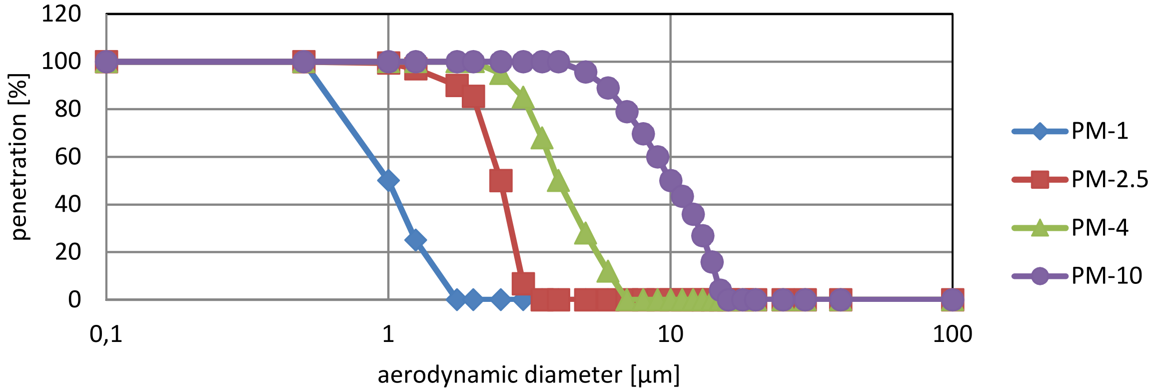


Figure 50: Penetration curves used

for PM-1, PM-2.5, PM-4, PM-10 (US EPA)

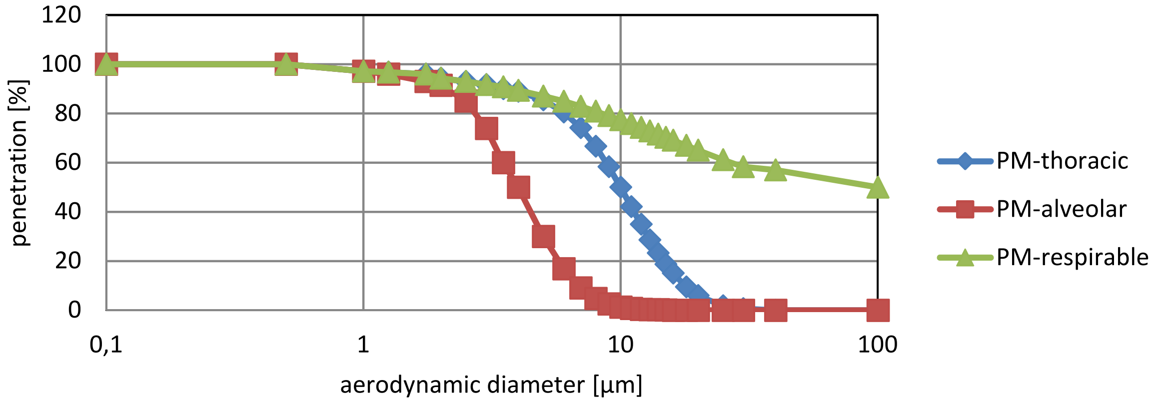


Figure 51: Penetration curves used

for dust measurements at workplaces in the health-care sector (EN-481)

Aerodynamic diameter [µm]	PM-1 [%]	PM-2.5 [%]	PM-4 [%]	PM-10 [%]	PM-thoracic [%]	PM-alveolar [%]	PM-respirable [%]
0.1	100	100	100	100	100	100	100
0.5	100	100	100	100	100	100	100
1	50	99.5	100	100	97.1	97.1	97.1
1.25	25	97	100	100	96.8	96	96.8
1.75	0	90	100	100	96	93	96
2	0	85.5	100	100	94.3	91.4	94.3
2.5	0	50	95	100	93	85	93

3	0	6.7	85	100	91.7	73.9	91.7
3.5	0	0	68	100	90	60	90.8
4	0	0	50	100	89	50	89.3
5	0	0	28	95.7	85.4	30	87
6	0	0	12	89	80.5	16.8	84.9
7	0	0	0	79	74.2	9	82.9
8	0	0	0	69.7	66.6	4.8	80.9
9	0	0	0	60	58.3	2.5	79.1
10	0	0	0	50	50	1.3	77.4
11	0	0	0	43.5	42.1	0.7	75.8
12	0	0	0	36	34.9	0.4	74.3
13	0	0	0	26.9	28.6	0.2	72.9
14	0	0	0	15.9	23.2	0.2	71.6
15	0	0	0	4.1	18.7	0.1	70.3
16	0	0	0	0	15	0	69.1
18	0	0	0	0	9.5	0	67
20	0	0	0	0	5.9	0	65.1
25	0	0	0	0	1.8	0	61.2
30	0	0	0	0	0.6	0	58.3
40	0	0	0	0	0	0	57
100	0	0	0	0	0	0	50

Table 3: Penetrations used for determining the dust mass concentration

The dust fractions mentioned above are based on the aerodynamic diameter. The aerodynamic diameter can be calculated as follows:

$$x_{aerodynamic} = x \cdot \sqrt{\frac{\rho_{particle}}{1\frac{g}{cm^3} \cdot \chi}}.$$

Generally, the density of the particles $\rho_{particle}$ lies between 0.7 and 3 g/cm^3, and the shape factor χ between 1 and 1.5. For the calculation of the PM values, the APDA-372 assumes a density of 1.5 g/cm^3 and a shape factor of 1. These values are suitable for most aerosols. However, the APDA-372 is equipped with a gravimetric filter system which can be used for the measurement of the correction factor C. This system also takes into account the influence of the refractive index on the measured PM values. Using the factor C, the PM values are corrected as follows:

$$PM_{corrected} = C \cdot PM.$$

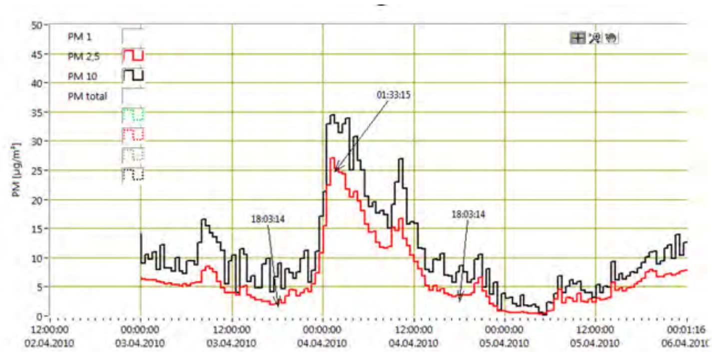
6.3. Additional advantages

In addition to the PM fractions, which are output continuously and simultaneously, the data on the measured particle number concentration and particle size distribution are available with a high level of time and size resolution (up to 32 size classes per decade). This additional information can be used to carry out a “source apportionment” or to assess the health relevance (larger particles penetrate more deeply into the human respiratory tract).

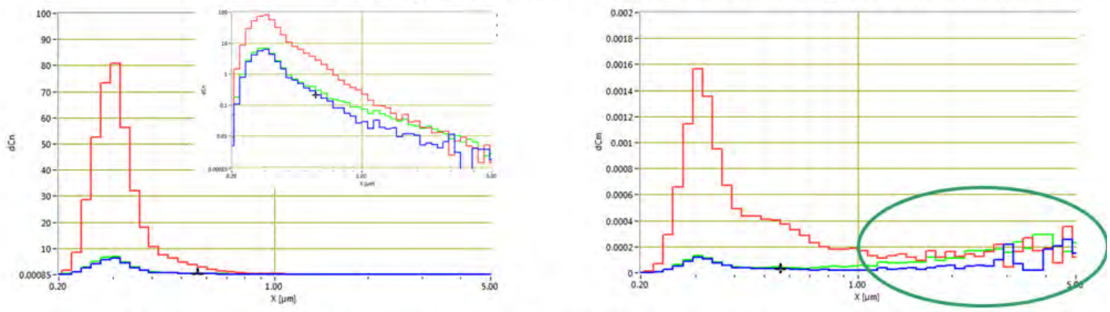
Figure 52 shows an example from Vienna around Easter time. The time history of the PM fractions evidenced a sudden and substantial increase, which then slowly subsided.

An investigation of this phenomenon in consideration of the particle size distribution revealed that this was caused by a massive increase in the number concentration of very small particles such as are typical of a combustion process. In fact, in many cities of Germany and Austria, a significant increase in particulate pollution is measurable in the night from Saturday to Easter Sunday. This is caused by Easter fires – a custom from ancient times which serves to drive away the winter. The combustion aerosols which are thereby created contain a high percentage of small particles. In order to be able to model the dispersion behavior of fine dust, both the particle size distribution and a high time resolution are important (whereby a time resolution of one second is technically feasible with the APDA-372 system), since the physical properties of the particles are decisive for a prediction of the dispersion. For example, the diameter can be used to derive the sinking velocity, and the number concentration to derive the coagulation behavior.

Easter fire
A tradition from olden times, which is used to frighten away and to burn winter



Chronological sequence of PM concentrations in the night to Easter Sunday in Vienna



Number size distribution (left) and mass size distribution (right) of the combustion aerosol of Easter fire.
Blue – 3.4.2010 6:03 pm, red – 4.4.2010 1:33 pm, green – 4.4.2010 06:03 pm

Figure 52: Additional information based on particle size distributions during an increase of the PM concentrations

6.4. Definition of terms

- Classification accuracy

How exact is the measurement of the testing aerosol? Does the determined particle size distribution meet the actual particle size distribution of the testing aerosol?

- Resolution capacity

How exact is the resolution of the device? Does the optical particle counter even determine the difference between very close particle sizes?

- Ambiguity

Does the optical particle counter determine unambiguously the particle sizes within the range of wave length of the laser light?
There even 180° white light forward scattering delivers ambiguous results.

- Border zone error

Does the device consider the tolerances in the border zones caused by the Gaussian distribution of laser light?

- Counting efficiency

How many particles of the testing aerosol are really measured at a known concentration?

- Coincidence error

How do you assure that the light impulse is caused by only one particle?

6.5. Effects of the device parameters

- Border zone errors

The particle size spectrum is measured with a fine fraction that is too high. The broader the particle size spectrum, the greater the border zone errors.

- Coincidence errors

The particle size spectrum is measured too coarsely while the particle concentration is measured too finely. Per definition, a 10% coincidence is allowed during a measurement.

- Counting efficiency

A lower counting efficiency causes a shift of the particle size distribution in the direction of coarser particles because the fine fraction is underrated. With a high counting efficiency, the coarse fraction is correspondingly underrated. The quantity is determined incorrectly. If measurements are made using several particle counters, the difference in counting efficiency between the counters used must be known. Only then can the results be compared!

- Classification accuracy

In correlation measurements, e.g. with impactors, the correlation factor becomes better the better this device parameter is.

Devices with good classification accuracy over the entire measurement range deliver reliable distributions.

- Resolution capacity

In correlation measurements, e.g. with impactors, the correlation factor becomes better the better this device parameter is. Devices with a high resolving power can also measure tightly grouped bimodal and trimodal distributions.

7. Ensuring correct measuring conditions

The measurement result, i.e. the particle size distribution of the individual measurements that is determined, can deviate significantly from the actually present values in the aerosol flow under unfavorable measuring conditions.

Therefore, pay attention to:

- Representative sampling
- Minimal particle losses due to the aerosol transport
- No coincidence errors

As a matter of principle, the APDA-372 system can only measure and display what it has registered in its optical measurement volume. This means that the sampling flow of the aerosol must be guided there in as unadulterated a manner as possible.

Towards this end, the following points should be observed:

- Short hoses for the aerosol
- Metal tubes should be used whenever feasible and under no circumstances should there be longer plastic hoses (strong particle deposition due to electrostatic charging)
- Vertical aerosol guidance because large particles (greater than 5 µm) settle out or the aerosol looses its original mixture.

In principle and for all counting scattered light measurement methods, only one individual particle may be present in the optically delimited measuring volume of the aerosol sensor at any one time, since the scattered light of the individual particle is evaluated to determine the particle size.

If more than one particle is present in the measurement volume, these particles are registered as one particle, which means the particle is measured as too large and the number measured is too small.

If the APDA-372 is used at installation sites at which significantly high concentrations can occur, and if the Fidas® measures a coincidence value of greater than 10%, it may be necessary to activate the coincidence correction in order to significantly broaden the original concentration range of 0 to 10,000 µg/m^3 (also see section 3.3).

8. Technical data of the APDA-372 system:

Measurement volume size, WxDxH	262 µm x 262 µm x 164 µm	
Maximum concentration for 10% coincidence errors	Sensor integrated in the control unit Max. concentration of up to 4,000 P/cm³	
Maximum concentration with coincidence detection and coincidence correction	20,000 P/cm³	
Maximum concentration (mass)	10,000 µg/m³	
Communication between the control unit and the evaluation computer	RS-232 (Bayern-Hessen, ASCII or Modbus) Ethernet (UDP ASCII, TeamViewer, etc.)	
Sample volumetric flow rate	4.8 l/min SATP	
Cleaning	The housings can be cleaned with non-aggressive detergent (e.g. dishwashing liquid) or spirits. Cleaning optical parts: see maintenance	
Mains connection: see rating plate! Supply voltage Mains fusing	230 V, +/-10% 2 pcs. T 2 A / 250 V	115 V, +/-10% 2 pcs. T 4 A / 130 V
Power consumption Network frequency	200 W 47-63 Hz	
Ambient conditions	Temperature range, 5 °C to 40 °C Acoustic emission of the device << 85 dBA	
Dimensions (HxWxD)	Control unit incl. built-in sensor: 185 mm x 450 mm x 320 mm	
Weight	Control unit incl. built-in sensor: 9.3 kg	

Technical data are subject to change.

APDA-372 / APDA-372 E
Fine-Dust Monitoring System
Appendix

9. Appendices:

9.1. Humidity compensation module, IADS

When the ambient humidity is high, water condenses on the particles and thereby falsifies the particle size. This effect is avoided by the use of the IADS humidity compensation module.

The temperature of the IADS is controlled in dependence on the ambient temperature and humidity (measured by the weather station). The minimum temperature is 23 °C. The humidity compensation is accomplished by means of a dynamic adaptation of the IADS temperature utilizing up to a maximum of 90 watts of heating power.

The IADS humidity compensation module is connected to the aerosol sensor of the APDA-372 system using an adapter. When cleaning the APDA-372 aerosol sensor, the adapter must be pushed down so that the IADS humidity compensation module can be pushed completely upwards and the aerosol inlet of the APDA-372 sensor is freely accessible.

The APDA-372 firmware controls the humidity compensation module (see the APDA-372 firmware instruction manual for more on this).

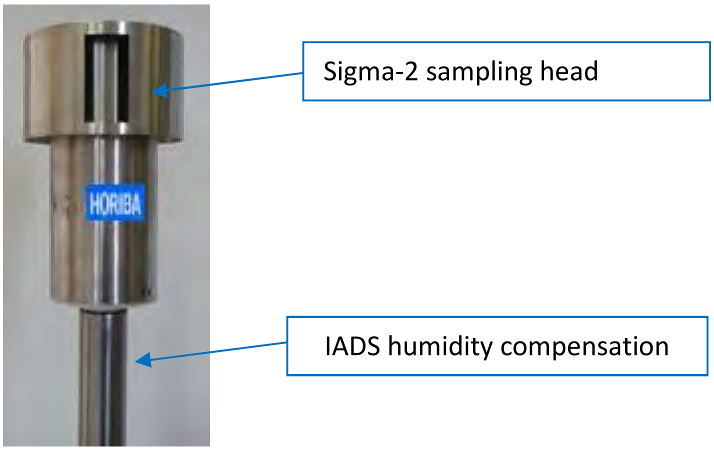


Figure 53: Sigma-2 sampling head

Figure 54: APDA-372 control unit, aerosol sensor with IADS

Important technical dimensions of the IADS:
Length: 1150 mm plus 80 mm narrow tube on which the Sigma-2 head is installed
Outer diameter 48.3 mm

Extended IADS
For installation of the APDA-372 in an existing container, HORIBA offers the option of using an extended IADS.

Figure 55: IADS extension with external tube

Length: 1.20 m to 2.10 m

9.2. Sigma-2 sampling head

Sigma-2 sampling head to VDI 2119-4 for measurements that are predominantly independent of the wind is simply pushed onto the inlet of the IADS and secured by means of the locking screw using an Allen key.

Figure 56: Sigma-2 sampling head

For monitoring purposes, the Sigma-2 head should be inspected for coarse dirt every three months (in connection with the calibration).

9.3. Compact weather station, WS300/WS600-UMB

Figure 57: Compact weather station, WS600-UMB

The WS300/WS600-UMB weather station is read out by the APDA-372 firmware (see the APDA-372 firmware instruction manual for more on this).

Special features:

- All in one
- Ventilated radiation protection
- Maintenance-free measurement
- Open communication protocol

Description of country variants: EU, USA, Canada

WS600-UMB Compact weather station for measuring air temperature, relative humidity, precipitation intensity, precipitation type, precipitation amount, air pressure, wind direction and wind speed. The relative humidity is recorded by means of a capacitive sensor and the air temperature by a precision NTC sensor element. The precipitation measurement is accomplished by means of a 24 GHz Doppler radar. The droplet velocity of each individual drop (rain/snow) is measured. The precipitation amount and intensity are determined based on the correlation of the droplet size and velocity. The type of precipitation (rain/snow) is determined based on the different falling velocities. A great advantage as compared to common tipping spoon and tipping scale methods is that the measurements are maintenance-free. The wind measurement is based on ultrasonic sensor technology. The measurement data are available in the form of a standard report (Lufft UMB protocol) for further processing.

WS300-UMB Compact weather station for measuring air temperature, relative humidity and air pressure. The relative humidity is recorded by means of a capacitive sensor and the air temperature by a precision NTC sensor element. The measurement data are available in the form of a standard report (Lufft UMB protocol) for further processing.

9.3.1. Technical data of the WS600-UMB

Dimensions	Ø approx. 150 mm, height approx. 345 mm
Weight	approx. 2.2 kg
Interface	RS-485, 2-wire, semi-duplex
Power supply	24 VDC ±10% <4 VA (without heating)
Permissible operating temperature	-50...60°C
Permissible rel. humidity	0...100% R.H.
Heater	40 VA at 24 VDC
Cable length	10 m

Temperature sensor

Principle	NTC
Measurement range	-50 .. 60 °C
Units	°C
Accuracy	±0.2 °C (-20...50 °C), otherwise ±0.5 °C (>-30°C)

Rel. humidity sensor:

Principle	Capacitive
Measurement range	0 .. 100% R.H.
Units	% R.H.
Accuracy	±2% R.H.

Air pressure sensor:

Principle	MEMS capacitive
Measurement range	300 .. 1200 hPa
Units	hPa
Accuracy	±1.5 hPa

Wind direction sensor:

Principle	Ultrasonic sound
Measurement range	0 .. 359.9 °
Units	°
Accuracy	±3 °

Wind speed sensor:

Principle	Ultrasonic sound
Measurement range	0 .. 60 m/s
Units	m/s
Accuracy	±0.3 m/s or 3% (0...35m/s)

Precipitation amount sensor:

Resolution	0.01 mm
Reproducibility	typ. > 90%
Droplet size measurement range	0.3...5 mm
Type of precipitation	Rain/snow

9.3.2. Technical data of the WS300-UMB

Dimensions	Ø approx. 150 mm, height approx. 223 mm
Weight	approx. 1 kg
Interface	RS-485, 2-wire, semi-duplex
Power supply	4…32VDC
Permissible operating temperature	-50...60°C
Permissible rel. humidity	0...100% R.H.
Cable length	10 m

Temperature sensor

Principle	NTC
Measurement range	-50 .. 60 °C
Units	°C
Accuracy	±0.2 °C (-20...50 °C), otherwise ±0.5 °C (>-30°C)

Rel. humidity sensor:

Principle	Capacitive
Measurement range	0 .. 100% R.H.
Units	% R.H.
Accuracy	±2% R.H.

Air pressure sensor:

Principle	MEMS capacitive
Measurement range	300 .. 1200 hPa
Units	hPa
Accuracy	±1.5 hPa

HORIBA

Ambient Air Analyzers

APDA-372 / APDA-372 E

FINE-DUST MONITOR SYSTEM

Instruction Manual
Firmware

Version: HE0050419, valid as of firmware version 100449

APDA-372 / APDA-372 E Firmware Instruction Manual

Preface

These instructions describe the operation of the firmware for the Fine-Dust Monitor Systems, APDA-372 and APDA-372 E. Be certain to read this manual before using the product in order to ensure that the device is operated properly and safely. You should also save the manual in a reliable manner so that it is readily available whenever required. The product specifications and the appearance as well as the contents of this manual may be altered without advance notification.

Warranty and responsibility

The product delivered to you is covered by a warranty from HORIBA for the period of one (1) year. In the event of malfunctions or damage during this time period for which HORIBA is responsible, the necessary repairs or the replacement of parts will be carried out by HORIBA at no charge. The warranty does not cover the following:

- Any malfunction due to improper operation;
- Any malfunction due to repairs or modifications by any party not authorized by HORIBA;
- Any malfunction due to use in an unsuitable environment;
- Any malfunction due to infringement of the instructions contained in this manual;
- Any malfunction due to use in a manner that is not described in this manual;
- Any malfunction due to natural catastrophes, accidents or mishaps that are not HORIBA's responsibility;
- A deterioration in appearance due to corrosion, rust, and so on;
- Consumables and the replacement of consumables;
- Products of other companies.

HORIBA is not liable for damage resulting from malfunctions of the product, any deletion of data or other uses of this product.

Trademarks

Other brands, company names, brand names or registered trademarks are the property of the respective company.

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Contents

1. Important information concerning switching the APDA-372 / APDA-372 E on and off

Because the APDA-372 firmware runs on a dynamic operating system based on Windows XP Embedded for industrial applications, APDA-372 models should never be switched off by means of the mains power switch.

Instead, the "shut down" button on the APDA-372 must be pressed. The mains switch must only be used once the operating system has shut down automatically!

Caution:
If the measuring system is not shut down by means of the firmware using the "shut down" function and instead the on/off switch is merely actuated, data can be lost!

The APDA-372 is a powerful optical aerosol spectrometer with a 1.7 GHz Intel® Atom™ processor. This allows the information concerning the measured particle size to be assessed in real time. The APDA-372 starts automatically after the start switch is actuated.

After switching on, the Windows operating system boots and then the Start-Up Manager is launched automatically. The firmware (software for the user interface) with the highest number is loaded automatically, however, at this point it is also possible to load an older version of the firmware.

Note: If "Ver.exe" is chosen, the user then has immediate access to the Windows user interface.

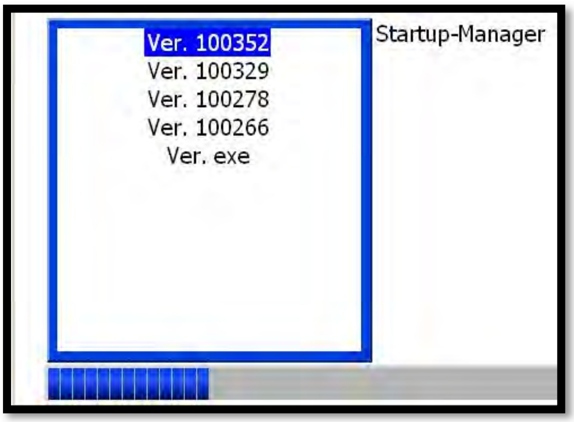


Figure 1: Initial screen of the APDA-372 Start-Up Manager

During start-up, the aerosol pump begins to operate and the volumetric flow rate is set to 4.8 l/min. Then the APDA-372 begins the measurement automatically and saves the data in the internal memory. The main menu appears once the start-up procedure has been completed (Figure 2).

2. APDA-372 / APDA-372 E user interface

2.1. Main menu

The main menu appears automatically when the device is started or when ***menu*** is pressed in the status bar.

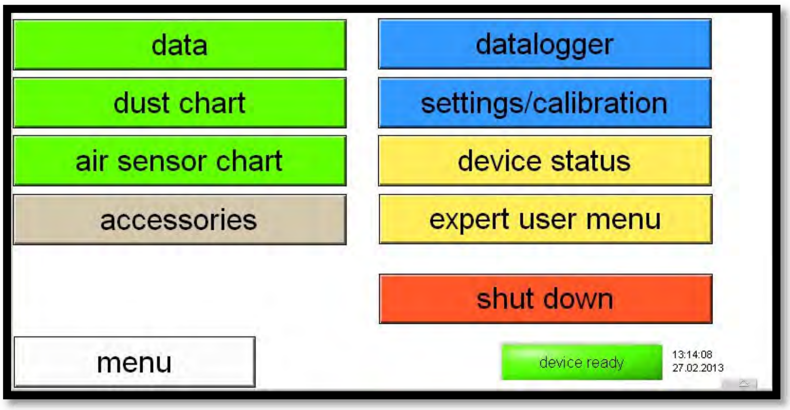


Figure 2: Main menu of the APDA-372 user interface

The main menu is structured as follows:

The buttons with a green background deal with the measured data:

data	Shows a data overview with the current measured values for PM_1, $PM_{2,5}$, PM_4, PM_{10}, PMtot (TSP) and the Cn number concentration. In addition, the weather station values for relative humidity, ambient temperature and air pressure are shown.
dust chart	Shows the chronological history of the APDA-372 measured values
air sensor chart	Shows the chronological history of the weather station measured values

The button with a gray background offers additional information and options:

accessories	Shows the accessories menu, i.e. IADS, GPS, weather station, Nano sizer add-on, filter system, particle size distributions, alarm setting.

The buttons with a blue background deal with data storage and data quality:

datalogger	Allows the input of comments that are saved along with the data record as well as the transfer of data from the internal memory to, for example, a USB flash drive. In addition, it is also possible to create a text file here in which data are saved continuously in a text format and for which an additional separate comment can be entered.
settings/calibration	For checking the calibration of the APDA-372 sensor and recalibration if necessary. Continuous online monitoring of the calibration is also shown here.

The buttons with a yellow background deal with hardware functions of the measuring instrument:

device status	Shows an overview of critical system parameters, such as volumetric flow rate, coincidence, pump performance, weather station, IADS, calibration, LED temperature and operating mode.
expert user menu	Allows entry into the expert mode. Note: Access here is password protected so that only trained personnel can obtain access to the associated functions.

The button with the red background terminates the measurement:

shut down	This shuts down both the APDA-372 as well as the Windows operating system and is to be used to shut down the APDA-372.

Caution:
Switching off the APDA-372 without first using the "shut down" button can lead to corruption of the data structure!

The "menu" button is located at the lower left edge and allows navigation to this main menu at any time.
The system status display ("device ready" or "check device status") and the system time and day's date are displayed at the lower right edge. The time and the date can be changed in the Windows operating system.

2.2. "data" – Data overview

This data overview displays all measured PM fractions and the Cn number concentration as well as the weather station values for relative humidity, ambient temperature and air pressure.

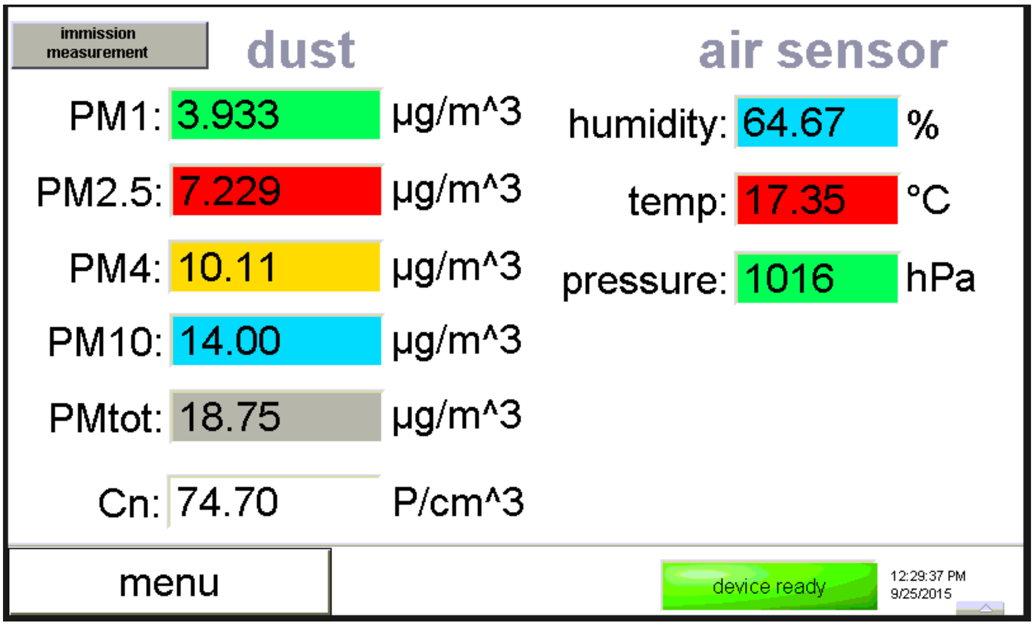


Figure 3: "data" – Data overview

The number concentration is displayed in real time, while the PM fractions show the moving average value over 900 s (entry in the promo.ini file), updated every 30 seconds. The weather station data are updated once per minute.
All data are saved with a chronological resolution of 1 minute, provide that no other setting has been made in the datalogger using the expert mode.

The display at the top left, "immission measurement," indicates that the immission function for converting the measured data for particle size and particle number emission to the PM fractions is in use (further information on the measurement technology can be found in the manual for the APDA-372 / APDA-372 E FINE DUST MONITOR SYSTEM). This algorithm was verified in the context of a qualification test (TÜV report 936/21226418/C).

2.3. Dust chart – Chronological history of the fine-dust measurement values

The dust chart displays the chronological history of all measured PM values (in color, right ordinate) and the number concentration (white line, left ordinate).

This display can be restarted using “clear charts” (this has no effect on the saved data).

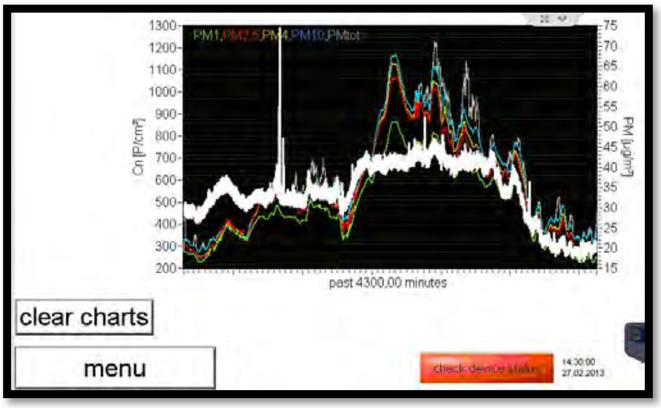


Figure 4: Chronological history of the fine-dust measurement values

2.4. Air sensor chart – Chronological history of the weather station measured values

This chart shows the color-coded weather station values for the measured humidity (h [%]), the temperature T [°C] and the pressure [hPa]. This chart is updated once per minute and shows the chronological history for one week.

Blue	relative humidity	left ordinate
Red	ambient temperature	right ordinate
Green	air pressure	right ordinate

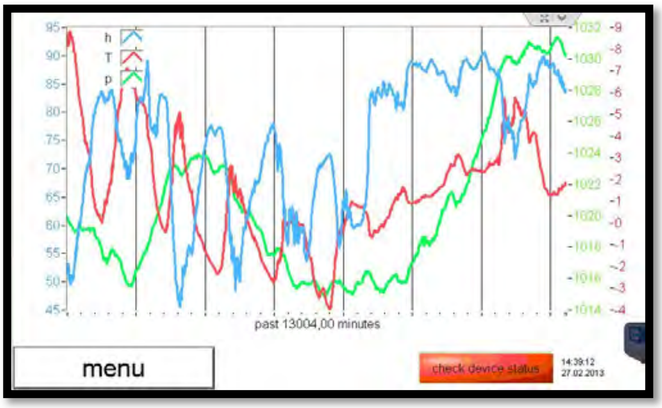


Figure 5: Chronological history of the weather station measured values

Note: If the weather station in use provides additional values (e.g. Lufft WS600-UMB) such as amount of precipitation, wind direction and wind speed, these are also saved. These are then displayed under “accessories -> weather station”.

2.5. accessories – Accessories and additional information

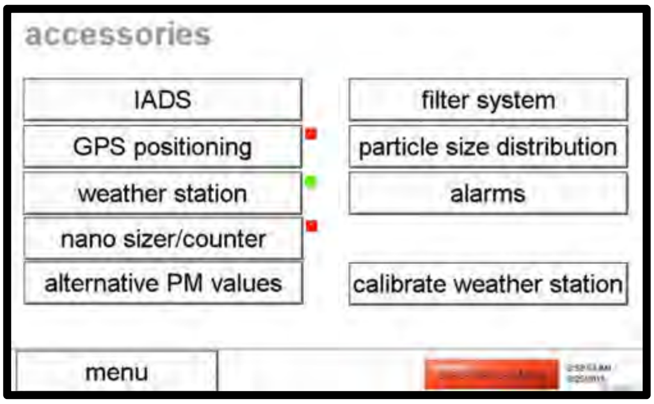


Figure 6: Accessories and additional information

This menu shows accessories and provides additional information including specifically:

IADS	Stands for "intelligent aerosol drying system" and refers to the regulated heater integrated in the sampling. The basic settings for the IADS can be changed here.
GPS positioning	Note: This option is no longer supported!
weather station	Shows all of the values measured by the weather station. The wind speed, wind direction and amount of precipitation are displayed graphically if they are measured by the weather station, e.g. Lufft Weather Station WS 600-UMB.
nano sizer/ counter	A DiSCmini made by Matter/Testo can be connected to the Fidas via USB.
alternative PM values	Displays the PM values and the algorithm used (e.g. PM2.5_ambient #11). These are the same as those displayed under "data". Then come the PM values (e.g. PM2.5_classic) that are based on the density individually defined under the "expert user menu". The last values to come are the PM values (e.g. PMthoracic) that are calculated according to EN 481 and are most frequently used for indoor air quality measurements.
filter system	Assists the user during a manual filter replacement. The time and date of the filter insertion and removal as well as the weight of the filter before and after the measurement can be entered.
particle size distribution	Shows two charts with the current measured particle size distributions according to the number concentration (top) and the mass concentration (bottom). The discrete distribution is shown in red and the cumulative distribution is in blue.
Alarms	Here it is possible to activate the feature which instructs the APDA-372 to send an email to the email address entered if one of the status parameters (see "device status") exceeds the limits. A limit value for a PM fraction can be defined in the lower part (the limit value is specified in the promo.ini file) at which a digital alarm is triggered (at the digital output).
Calibrate weather station	Starting with Firmware version 100389, the weather station sensors for temperature, ambient pressure and rel. humidity can be adjusted.

2.5.1. IADS – Settings for the intelligent aerosol drying system

The IADS serves to remove the moisture from the aerosol so that the particles can be measured at their actual size and, for example, fog droplets are not interpreted as particles.

This regulated heater integrated in the sampling has three basic settings:

off:	The IADS is switched off. The internal tube of the IADS, however, is heated to +1 K relative to the ambient temperature in order to avoid condensation inside the IADS and the optical sensor.
remove volatile / moisture compensation:	The IADS removes volatile particles (water droplets) and compensates for the condensation of the water and the associated particle growth. The temperature of the IADS is controlled in dependence on the ambient temperature and humidity (measured by the weather station). The minimum temperature is 23 °C. The humidity compensation is accomplished by means of a dynamic adaptation of the IADS temperature utilizing up to a maximum of 90 watts of heating power.
remove volatile and semi-volatile:	The IADS removes volatile and semi-volatile particles (water droplets, hydrocarbon droplets) and compensates for the influence of the humidity on the particle size. The internal heater of the IADS is set to a constant temperature of 75 °C.

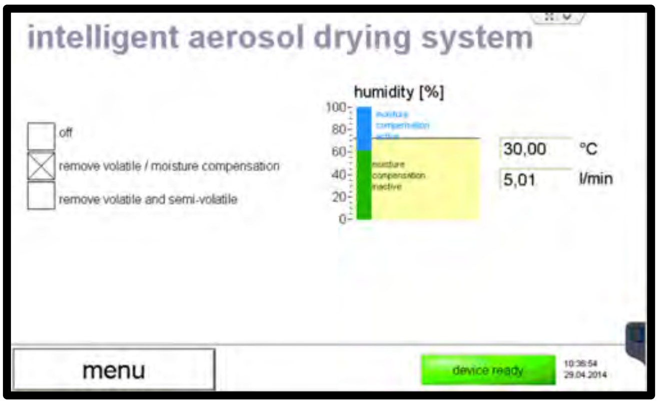


Figure 7: Settings for the intelligent aerosol drying system

2.5.2. GPS positioning – Coordinates of the GPS mouse

Note:
This option is no longer supported!

When a GPS mouse is connected, the data are transferred and displayed automatically.

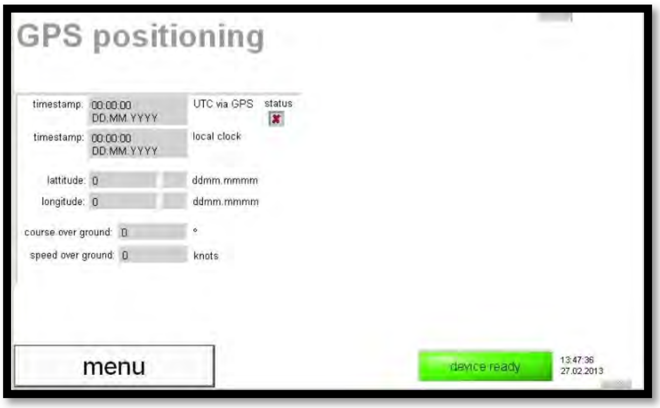


Figure 8: Settings for the intelligent aerosol drying system

Note:
This menue item can be completely suppressed by request. For this the following setting in the promo.ini must be done: „GPS_connected=no“

2.5.3. Weather station – Measurement data of the weather station

This shows all of the values measured by the weather station (they are also components of the data record). The wind speed, wind direction and amount of precipitation are displayed graphically if the weather station that is connected supports this (e.g. Lufft WS600-UMB).

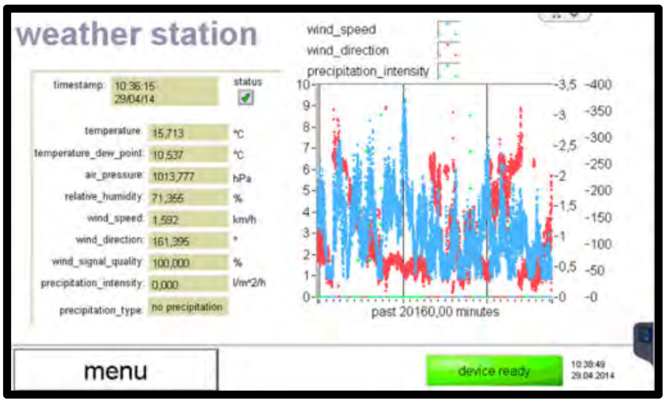


Figure 9: Measurement data of the weather station

2.5.4. Nano sizer/counter – Add-on for smaller particle sizes

A DiSCmini made by Matter/Testo can be connected to the Fidas via USB; then these data are automatically saved in the APDA-372 and displayed here graphically.

Figure 10: Add-on for smaller particle sizes

Note: It is possible that the COM port that is assigned automatically by the USB adapter may need to be reassigned in the Windows operating system.

Note:
This menue item can be completely suppressed by request. For this the following setting in the promo.ini must be done: „discmini_connected=no“

2.5.5. Alternative PM values

Displays the PM values and the algorithm used (e.g. PM2.5_ambient #11), meaning that algorithm number 11 that is TÜV certified is used here. The PM values are the same as those displayed under “data”.

Then come the PM values (e.g. PM2.5_classic) that are based on the density, individually defined in the “expert user menu”.

The last values to come are the PM values (e.g. PMthoracic) that are calculated according to EN 481 and are most frequently used for indoor air quality measurements.

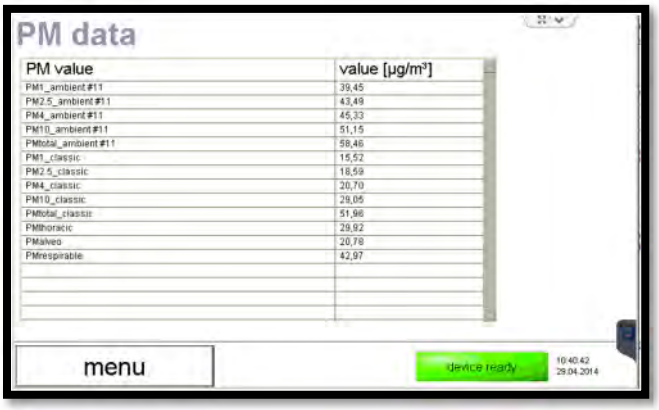


Figure 11: Display of alternate particle size fractions

2.5.6. Filter system – Manual filter measurement

When the filter holder of the APDA-372 is used to perform a gravimetric filter measurement, then the timestamp can be marked here as to when the filter was installed and removed. Moreover, the net (weight in) and gross weight (weight out) of the filter can be indicated.

After all necessary values have been entered, the ***save to datalogger*** field appears and the filter data can be saved in a file.

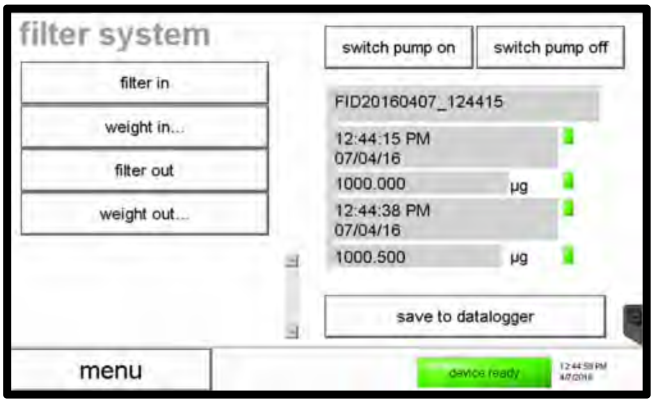


Figure 12: Manual filter measurement

This specifically includes:

switch pump on / switch pump off	Switch on/off of sampling pump
filter in	The actual time is selected automatically as the time at which the filter was installed. In addition, a filter identification number (FID) is generated and shown at the top.
weight in...	A dialog box opens for the entry of the net weight of the total filter. The net weight must reference the timestamp for "filter in".
filter out	The actual time is selected automatically as the time at which the filter was removed.
weight out...	A dialog box opens for the entry of the gross weight of the total filter. The gross weight must reference the timestamp for "filter out".
save to datalogger	The data generated for a total filter are saved to the datalogger and are available during the analysis of the data using PDAnalyze.

2.5.7. Particle size distribution

Here, two charts are shown with the current measured particle size distributions according to the number concentration (top) and the mass concentration (bottom). The discrete distribution is shown in red and the cumulative distribution is in blue.

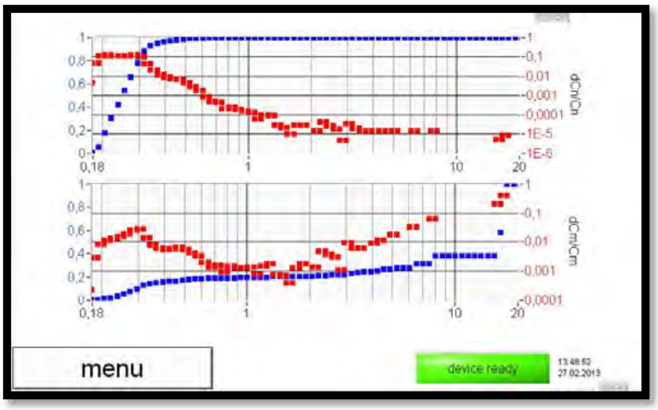


Figure 13: Particle size distributions

2.5.8. Alarm – Email notification

Here it is possible to activate the feature which instructs the APDA-372 to send an email to the email address entered if one of the status parameters (see "device status") exceeds the limits.

A limit value for a PM fraction can be defined in the lower part (the limit value is specified in the promo.ini file) at which a digital alarm is triggered (at the digital output).

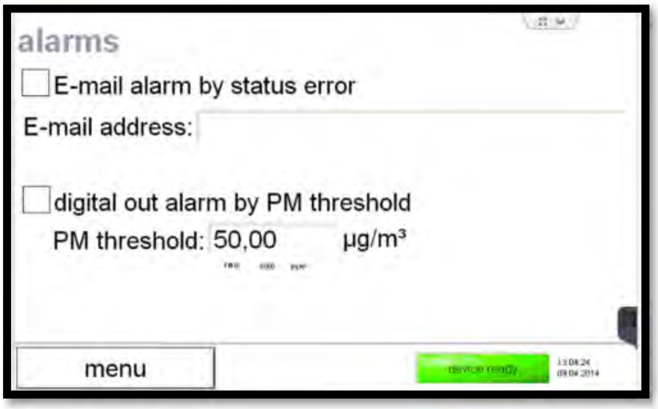


Figure 14: Email notification

The following entry must be contained in the promo.ini file:
In the [Fidas] section:
alarm_threshold=50 (or a different value)
alarm_value=PM10 (or e.g. PM2.5)

2.5.9. "calibrate weather station" – Adjusting the weather station

As of firmware version 100389, the sensors for temperature, air pressure and relative humidity of the weather station that is connected (WS300-UMB or WS600-UMB) can be adjusted by comparing the measured values with the measured values of a transfer standard and determining the corresponding linear equation.

1-Point-Adjustment (typically under field conditions):

→ Determination of slope factor (Scale), offset remains at 0

2 oder Multiple-Point-Adjustment (e.g. in calibration lab):

→ Determination of slope factor (Scale) and offset by regression analysis

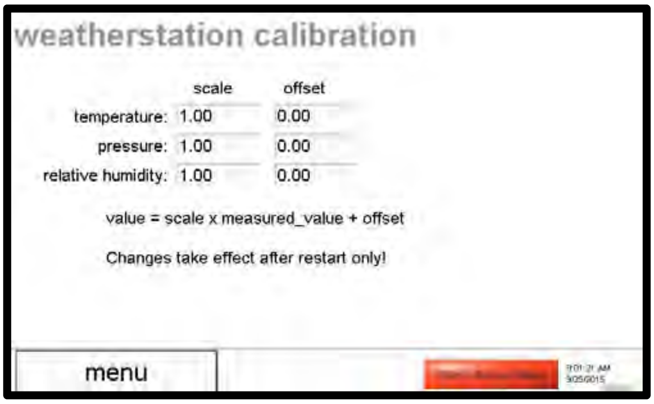


Figure 15: „calibrate weather station" – Adjustment of weather station

Note: Modifications only take effect after a reboot of the system.

2.6. Datalogger – Measurement data memory

The APDA-372 saves the measurement data continuously internally in a file. It creates a new file for every day. The files can be copied to a USB flash drive (copy data files to D:\). When a USB flash drive is connected to the APDA-372, it automatically copies the files to the USB flash drive at midnight.

Copies the files of the internal memory to the USB flash drive (drive D:\ is the USB port on the front).

A comment can be entered manually at any time that is then automatically saved along with every data save operation. This continues indefinitely until the comment is deleted or a different comment is entered.

Figure 16: Measurement data memory

In addition, an option can be enabled that causes the data to be saved continuously (with a time resolution of typically 1 minute) to a text file using a text format. The name of this file is "dustmonitor_serial_number_year_month.txt (example: dustmonitor_0117_2014_04.txt). When in continuous operation, this file is generated new every month and saved on the harddisk of the panel PC in the folder "Fidas\textfiles" (Precondition: At least 1 GB of available diskspace).

The text-files can be copied to a USB flash drive (copy textfiles to D:\).

The columns of this text file are labeled as follows:

Columns A-L

Date	Time	Comment	PM1	PM2.5	PM4	PM10	PMtotal	Number Concentration	Humidity	Temperature	Pressure

Columns M-U

Flag for status parameters								
Flow	Coincidence	Pumps	Weather station	IADS	Calibration	LED	Operating mode	Device status

Columns V-AE

PM1	PM2.5	PM4	PM10	PMtotal	PM1_classic	PM2.5_classic	PM4_classic	PM10_classic	PMtotal_classic

Columns AF-AH

PMthoraic	PMalveo	PMrespirable

Columns AI-AO

Numerical values for status parameters						
Flowrate	Velocity	Coincidence	Pump_output	IADS_temperature	Raw channel deviation	LED temperature

Columns AP-AR

Temperature*	Humidity*	Pressure*

* only relevant, if optional sensor for temperature, pressure and rel. Humidity is connected.

device status means the operating mode of the APDA-372. This is a numerical value that is assigned as follows:

Scope	**0**
Auto	**1**
Manual	2
Idle	**3**
Calib	**4**
Offset	**5**
PDControl	6

Note: only the operating modes in bold letters are relevant for the APDA-372.

Note: if the text file is moved or deleted, the APDA-372 will automatically create a new text file for the current month. If a text file exists for the current month, the data are simply appended.

2.7. Settings/calibration – Calibration/verification of the APDA-372

Calibration of the APDA-372 is monitored online by means of a patented measurement signal analysis and displayed in a graph called “immission estimated channel deviation – trend 40h”.

If the calibration drifts slowly, this can be observed due to a sloping curve of the individual points within two red horizontal lines. The points result from a measurement made every half hour. When there is a mean deviation of more than 3.5 raw data channels over 40 hours, an error is set (see also 2.8) and the APDA-372 needs to be verified with MonoDust 1500.

<u>Note</u>: Individual points may lie outside of the limit values; this can happen and is no cause for concern. The calibration is also still in order in these cases.

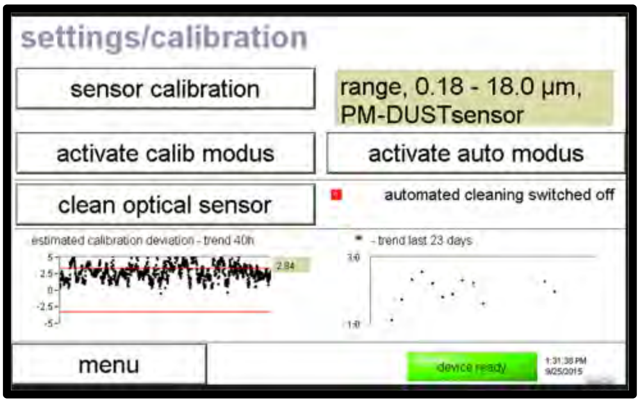


Figure 17: Calibration/verification of the APDA-372

To calibrate the APDA-372, press “optical sensor calibration”. A screen then appears in which the calibration can be carried out using calibration dust (further information on this can be found in the APDA-372 manual).

When **activate calib mode** is used, all subsequent data are marked as if they had been measured during the calibration procedure and are consequently not included in an evaluation except if this is expressly selected in PDAnalyze. This mode can also be used to ensure that the intermediate data measured during maintenance activities are not used any further.

<u>Caution</u>:

Because <u>activate calib mode</u> activates the calibration mode manually, it must also be deactivated manually, also using <u>activate auto mode</u>, meaning that the APDA-372 must be reset to the Auto mode. If this is not done, the status remains set to <u>device not ready</u> because the operating mode in <u>device status</u> is not set to <u>auto</u>.

The **clean optical sensor** option starts a routine which heats the IADS up to 75 °C and at the same time alternates the pumps from 0 l/min to the maximum volumetric flow rate. The objective here is to essentially "shake loose" any material deposits in the sampling tube. Automatic activation of this routine can be set in the promo.ini file.

Note: If there is no problem with frequent entry of material or insects, automatic activation is not recommended because this is an additional load on the pumps and reduces their service life.

2.8. Device status – Status overview

Various items of sensor information are shown here which are required for correct operation of the APDA-372. This information is also saved along with every data record in the form of an error byte.

Figure 18: Status overview

This specifically includes:

sensor flow	The APDA-372 regulates the volumetric flow rate at 4.8 l/min by means of a control circuit with mass flow meters and inclusion of the values measured for temperature and air pressure. This volumetric flow rate is then standardized for “standard atmospheric temperature and pressure” (SATP), that is, with reference to 25 °C and 1013 hPa. An error is displayed if the volumetric flow rate deviates from the setpoint value by more than 5%. **<u>Note</u>: Older models regulated the flow at 5.0 l/min and displayed it accordingly.** The second value indicates the velocity (flow velocity) of the particles through the optical detection volume. An error is displayed if the velocity of the particles deviates from the setpoint value by more than 15%. The setpoint value corresponds to the velocity entered in the promo.ini file which is determined at the installation site in accordance with section 5.5. An error message indicates a possible leak after the sensor. IMPORTANT: The result of the velocity measurement has **no** influence on the calculation of the PM values, but is instead only used as an indicator for the leak tightness.
coincidence	Detection of more than one particle in the optical detection volume. An error is output if this occurs with a frequency of greater than 20%.

suction pumps	The volumetric flow in the APDA-372 is generated by two pumps that are connected in parallel. If one pump fails, the other can assume its role; the power consumption is then accordingly higher, which leads to an error. If both pumps should age uniformly, an error is also triggered when 80% is exceeded. It is important to note that the device still continues to measure and the data are valid, however, the user must see to it that the pumps are replaced soon.
weather station	This indicates that a weather station is correctly connected and is transmitting values.
IADS	This indicates that the IADS is correctly connected and the temperature corresponds to the prescribed regulation point.
calibration	This monitors the calibration online. If this deviates by more than 3.5 raw data channels, an error is set. **Note: In individual cases, this value might be out of tolerance for brief periods while the device is nonetheless still operating properly. Need for action (i.e. a field calibration using calibration dust) only arises if this is a longer-term trend (>40 hours).**
LED temperature	The LED light source is subject to temperature control. If a problem arises in this control circuit, this error bit is set.
operating mode	The operating mode should be set to “auto” because otherwise it is possible that the data will not be saved correctly or the device will not restart again on its own after a power outage.

The **status log** displays activities of the APDA-372 with the date and time:

a	auto mode	The standard operating mode of the APDA-372.
c	calibration mode	While the APDA-372 is undergoing calibration, the data are marked with the letter “c” and are not included in the evaluation.
i	idle	The APDA-372 has been set to the “idle” operating mode and is not measuring any data.
m	manual mode	The APDA-372 has been set to the “manual” operating mode.
s	scope mode	The electronic oscilloscope with which individual signals can be analyzed has been activated, but no measurement is currently underway.
e	distribution invalid	The measured particle size distribution is invalid.
o	above 10% coincidence	The concentration was so high that more than 10% of the measured values were measured in coincidence, meaning that in these cases there was more than one particle in the detection volume.

2.9. Expert user menu – Expert mode

For further functions and information, the user may enter the expert mode. Doing so requires the entry of a code, which is "1" followed by "-" followed by "accept" (Figure 19: Expert user menu).

Note: It is possible to set the password yourself. To do so, the following entry must be made in the promo.ini file in the section [Fidas]: password_service=-1 (-1 is the default password; select your own here then).

Further information on the expert mode can be found in the expert mode manual.

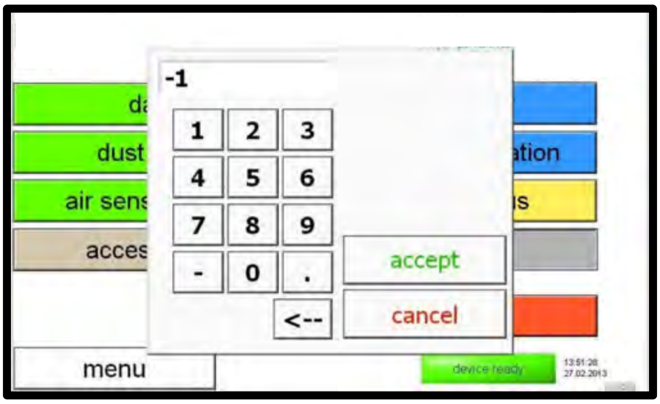


Figure 19: Expert user menu

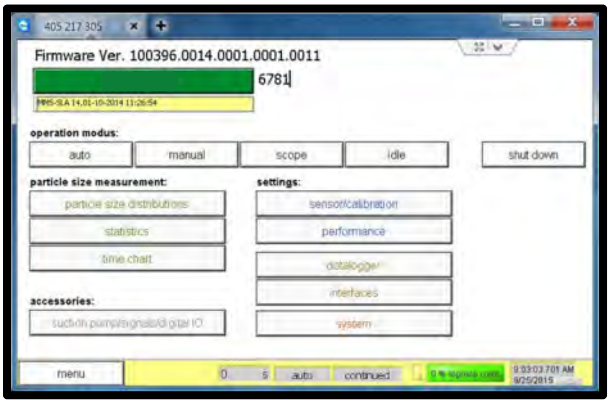


Figure 20: Expert user menu – Main menu

Note: The string for the firmware version is composed of the following:

Position 1:	100396	Firmware version of the panel PC (touchscreen)
Position 2:	0014	Firmware version of the SCA circuit board
Position 3:	0001	Firmware version of the MIO circuit board
Position 4:	0001	Firmware version of the Pt100 circuit board
Position 5:	0011	Method

2.10. Shut down – Switching off the APDA-372

Always use the "shut down" button to switch off the APDA-372.

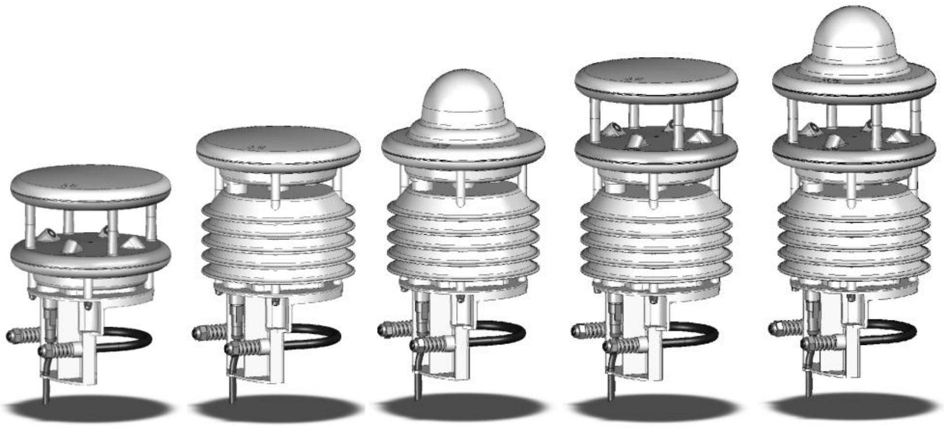
Because the APDA-372 firmware runs on a dynamic operating system based on Windows XP Embedded for industrial applications, APDA-372 models should never be switched off by means of the mains power switch because otherwise the data system can become corrupt.

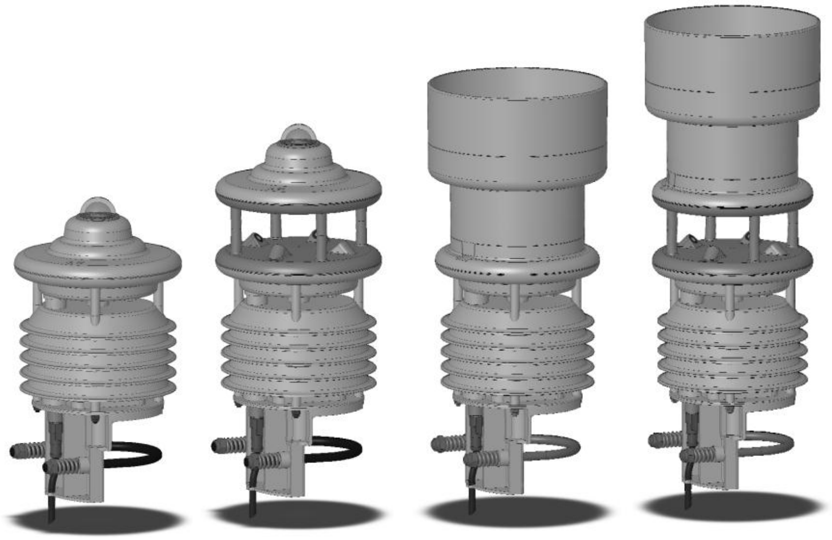
Once the “shut down” has been activated, you will see the following pop-up:

After the touchscreen is off (green power indicator at the top edge of the touchscreen), the mains switch on the back of the device should be switched off because otherwise the internal fan continues to run.

Compact Weather Station

WS200-UMB
WS300-UMB
WS301-UMB WS302-UMB WS303-UMB WS304-UMB
WS400-UMB WS401-UMB
WS500-UMB
WS501-UMB WS502-UMB WS503-UMB WS504-UMB
WS600-UMB WS601-UMB





www.lufft.com

Contents

1 Please Read Before Use

This manual is valid for devices of the Lufft WS family with device version 31 or higher(7/2012).Some functions or features specified in this manual may not be available or may not be valid with older device versions. The device version is indicated as the last number of the serial number, e.g.: the device with SN: 063.1010.0701.**021**has the device version 21.

If you are using an older device of the WS family, please refer to the manual for device versions prior to 30 (www.lufft.com/en/support/downloads).

1.1 Symbols Used

Important information concerning potential hazards to the user

Important information concerning the correct operation of the equipment

1.2 Safety Instructions

- Installation and commissioning must be carried out by suitably qualified specialist personnel only.
- Never take measurements on or touch live electrical parts.
- Pay attention to the technical data and storage and operating conditions.

1.3 Designated Use

- The equipment must only be operated within the range of the specified technical data.
- The equipment must only be used under the conditions and for the purposes for which it was designed.
- The safety and operation of the equipment can no longer be guaranteed if it is modified or adapted.

1.4 Incorrect Use

If the equipment is installed incorrectly

- It may not function.
- It may be permanently damaged.
- Danger of injury may exist if the equipment is allowed to fall.

If the equipment is not connected correctly

- It may not function.
- It may be permanently damaged.
- The possibility of an electrical shock may exist.

1.5 Guarantee

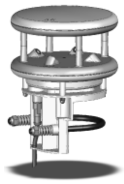
The guarantee period is 12 months from the date of delivery. The guarantee is forfeited if the designated use is violated.

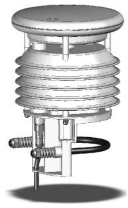
1.6 Brand Names

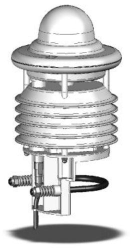
All brand names referred to are subject without limitation to the valid trademark and ownership rights of the respective owner.

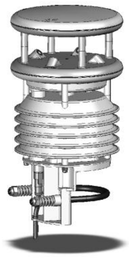
2 Scope of Delivery

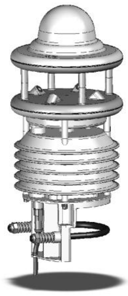
- Equipment


WS200-UMB


WS300-UMB

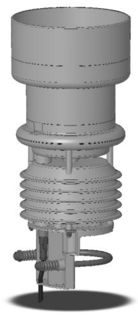

WS400-UMB

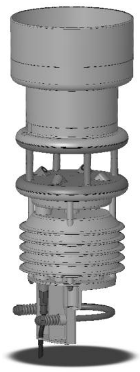

WS500-UMB


WS600-UMB


WS301-UMB


WS501-UMB


WS401-UMB


WS601-UMB

- Connection cable 10m

- Operating manual

3 Order Numbers

WS200-UMB **8371.U01**

- Wind Direction
- Wind Speed
- Compass

WS300-UMB **8372.U01**

- Air Temperature
- Relative Humidity
- Air Pressure

WS301-UMB **8374.U01**
WS302-UMB **8374.U10**
WS303-UMB **8374.U11**
WS304-UMB **8374.U12**

- Air Temperature
- Relative Humidity
- Air Pressure
- Global Radiation

WS400-UMB **8369.U01** (Europe, USA, Canada)

- Precipitation Radar **8369.U02** (UK)
- Air Temperature
- Relative Humidity
- Air Pressure

WS401-UMB **8377.U01**

- Precipitation Rain Gauge
- Air Temperature
- Relative Humidity
- Air Pressure

WS500-UMB **8373.U01**
- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass

WS501-UMB **8375.U01**
WS502-UMB **8375.U10**
WS503-UMB **8375.U11**
WS504-UMB **8375.U12**
- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass
- Global Radiation

WS600-UMB **8370.U01** (Europe, USA, Canada)
- Precipitation Radar **8370.U02** (UK)
- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass

WS601-UMB **8376.U01**
- Precipitation Rain Gauge
- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass

3.1 Accessories

Power supply unit 24V/100VA	8366.USV1
ISOCON-UMB	8160.UISO
Surge protection	8379.USP
Leaf Wetness Sensor WLW100 (WS401-UMB, WS601-UMB only)	8358.10
External Rain Gauge WTB100	8353.10
External Temperature Sensors	
Temperature Sensor WT1	8160.WT1
Passive Road Surface Temperature Sensor WST1	8160.WST1

3.2 Spare Parts

Connection cable 10m	On enquiry

3.3 Additional Documents and Software

You can download the following documents and software via the Internet at www.lufft.com.

Operating Manual	• This document
UMB-Config-Tool	• Windows® software for testing, firmware updates and configuration of UMB devices
UMB Protocol	• Communications protocol for UMB devices
Firmware	• The current device firmware

4 Equipment Description

The WS family is a range of low cost, compact weather stations for the acquisition of a variety of measurement variables, as used for example for environmental data logging in road traffic management systems. Depending on the model, each device has a different combination of sensors for the various measurement variables.

	WS200-UMB	WS300-UMB	WS301-UMB**	WS400-UMB	WS401-UMB	WS500-UMB	WS501-UMB***	WS600-UMB	WS601-UMB
Air temperature		●	●	●	●	●	●	●	●
Humidity		●	●	●	●	●	●	●	●
Air pressure		●	●	●	●	●	●	●	●
Precipitation				●	●*			●	●*
Wind direction	●					●	●	●	●
Wind speed	●					●	●	●	●
Compass	●					●	●	●	●
Global Radiation			●				●		
Leaf Wetness (ext)					●				●
Temperature (ext)	●	●	●	●	●	●	●	●	●
Rain Gauge (ext)	●	●	●			●	●		
Power Save 2	●	●	●		●	●	●		●

*) WS401-UMB and WS601-UMB use a rain gauge for precipitation measurement

**) is also valid for WS302-UMB, WS303-UMB, WS304-UMB

***) is also valid for WS502-UMB, WS503-UMB, WS504-UMB

Sensors marked (ext) in the table are additional accessories and not included with the device. The table shows which external sensors can be connected to the different models.

Note: The external temperature sensor and the external rain gauge use the same input, so only one of them can be connected simultaneously.

Attention: Please note that, due to the approval of the radar sensor used, there are different country options on equipment which includes precipitation measurement by radar technology.

The equipment is connected by way of an 8 pole screw connector and associated connection cable (length 10m).

The measured values are requested over the RS485 interface in accordance with UMB protocol.

During commissioning, configuration and measurement polling takes place using the UMB-Config-Tool (Windows® PC software).

4.1 Air Temperature and Humidity

Temperature is measured by way of a highly accurate NTC-resistor while humidity is measured using a capacitive humidity sensor. In order to keep the effects of external influences (e.g. solar radiation) as low as possible, these sensors are located in a ventilated housing with radiation protection. In contrast to conventional non-ventilated sensors, this allows significantly more accurate measurement during high radiation conditions.

Additional variables such as dewpoint, absolute humidity and mixing ratio are calculated from air temperature and relative humidity, taking account of air pressure.

4.2 Air Pressure

Absolute air pressure is measured by way of a built-in sensor (MEMS). The relative air pressure referenced to sea level is calculated using the barometric formula with the aid of the local altitude, which is user-configurable on the equipment.

4.3 Precipitation

Tried and tested radar technology from the R2S-UMB sensor is used to measure precipitation. The precipitation sensor works with a 24GHz Doppler radar, which measures the drop speed and calculates precipitation quantity and type by correlating drop size and speed.
WS401-UMB and WS601-UMB are using an unheated rain gauge for precipitation measurement. This version can be recommended for low power application etc.

4.4 Wet Bulb Temperature

The wet bulb temperature is the temperature resulting between a wetted or iced surface at a flowing air.

4.5 Specific Enthalpy

Parameter of state of the humid air, composed of the specific enthalpies (heat capacity) of the components of the mixture and related to the mass fraction of the dry air (at 0°C).

4.6 Air Density

The air density indicates how much mass in a given volume of air is contained and it is calculated from the measured values of air temperature, humidity and air pressure.

4.7 Wind

The wind meter uses 4 ultrasonic sensors which take cyclical measurements in all directions. The resulting wind speed and direction are calculated from the measured run-time sound differential. The sensor delivers a quality output signal indicating how many good readings were taken during the measurement interval.

4.8 Compass

The integrated electronic compass can be used to check the north – south adjustment of the sensor housing for wind direction measurement. It is also used to calculate the compass corrected wind direction.

4.9 Heating

The precipitation sensor and wind meter are heated for operation in winter.

4.10 Global Radiation

The global radiation is measured by a pyranometer mounted in the top cover of the compact weather station.

4.11 Leaf Wetness

WS401-UMB and WS601-UMB can be equipped with an external sensor for leaf wetness evaluation.

4.12 External Temperature Sensor

Optionally all models may be equipped with an external NTC temperature sensor for the acquisition from additional measurement points. The type of NTC is the same as used for the internal air temperature sensor.

External temperature sensor and external rain gauge can **not** be connected at the same time.

4.13 External Rain Gauge

Models without integrated precipitation acquisition can be equipped with an external rain gauge.

External rain gauge and external temperature sensor can **not** be connected at the same time.

4.14 Sensor Technology (example: WS600-UMB)

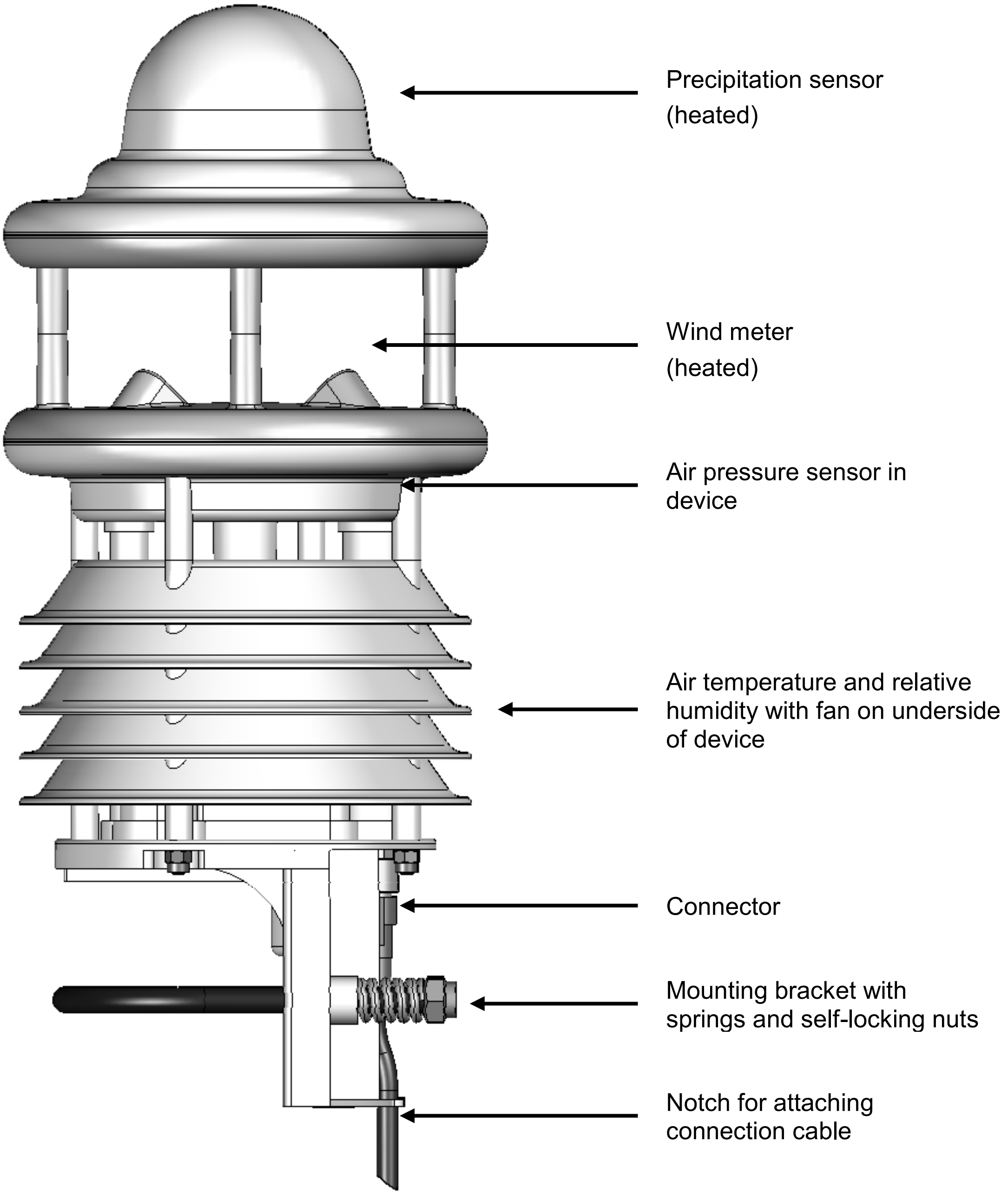


Figure 1: Sensor Technology

5 Generation of Measurements

5.1 Current Measurement (act)

In accordance with the specified sampling rate, the value of the last measurement is transmitted when the current measurement value is requested. Each measurement is stored in a circular buffer for the subsequent calculation of minimum, maximum and average values.

5.2 Minimum and Maximum Values (min and max)

When requesting the minimum and maximum values, the corresponding value is calculated - via the circular buffer at the interval (1 – 10 minutes) specified in the configuration - and transmitted.

Note: In the case of wind direction, the minimum / maximum value indicates the direction at which the minimum / maximum wind speed was measured.

5.3 Average Value (avg)

When requesting the average value, this is calculated - via the circular buffer at the interval (1 – 10 minutes) specified in the configuration - and transmitted. In this way moving averages can also be calculated.

For some values the standard deviation is calculated for the same interval. The calculation of standard deviation will only be activated after the related UMB channel has been requested for the first time.

5.4 Vectorial Average Value (vct)

In the specific case of wind measurement, measurements are calculated vectorially. To this end, the average values of the vectors are generated internally. Hence the value (wind speed) and angle (wind direction) of the vector are calculated.

Note: On delivery, the interval for the calculation of minimum, maximum and average values is set at 10 minutes. If necessary, this can be adjusted to the particular requirements (1 – 10 minutes) with the aid of the UMB-Config-Tool (see page 28).

6 Measurement Output

Measurements are transmitted in accordance with UMB binary protocol (Factory Settings).

You can find an example of a measurement request in different protocols and a complete summary of the list of channels in the Appendix.

6.1 Air and Dewpoint Temperature

Sampling rate 1 minute

Generation of average value 1 – 10 minutes

Units °C; °F

Request channels:

UMB Channel					Measuring Range		
act	**min**	**max**	**avg**	**Measurement Variable (float32)**	**min**	**max**	**unit**
100	120	140	160	Air temperature	-50.0	60.0	°C
105	125	145	165	Air temperature	-58.0	140.0	°F
110	130	150	170	Dewpoint temperature	-50.0	60.0	°C
115	135	155	175	Dewpoint temperature	-58.0	140.0	°F
101				External Temperature Sensor	-40.0	80.0	°C
106				External Temperature Sensor	-40.0	176.0	°F

6.2 Wind Chill Temperature

Sampling rate 1 minute, computed on base of the average temperature and average wind speed

Units °C; °F

Request channels:

UMB Channel					Measuring Range		
act	**min**	**max**	**avg**	**Measurement Variable (float32)**	**min**	**max**	**unit**
111				Wind chill temperature	-60.0	70.0	°C
116				Wind chill temperature	-76.0	158.0	°F

6.3 Humidity

Sampling rate 1 minute

Generation of average value 1 – 10 minutes

Units %RH; g/m³; g/kg

Request channels:

UMB Channel					Measuring Range		
act	**min**	**max**	**avg**	**Measurement Variable (float32)**	**min**	**max**	**unit**
200	220	240	260	Relative humidity	0.0	100.0	%
205	225	245	265	Absolute humidity	0.0	1000.0	g/m³
210	230	250	270	Mixing ratio	0.0	1000.0	g/kg

6.4 Air Pressure

Sampling rate 1 minute

Generation of average value 1 – 10 minutes

Unit hPa

Request channels:

UMB Channel					Measuring Range		
act	**min**	**max**	**avg**	**Measurement Variable (float32)**	**min**	**max**	**unit**
300	320	340	360	Absolute air pressure	300	1200	hPa
305	325	345	365	Relative air pressure	300	1200	hPa

Note: For the correct calculation of relative air pressure, the altitude of the location must be entered in the device configuration (see Figure 11 on page 30). The factory setting for altitude is 0m; in this way both measurement variables deliver the same values.

6.5 Wet Bulb Temperature

Sampling rate 1 minute

Units °C; °F

Request channels:

UMB Channel					Measuring Range		
act				Measurement Variable (float32)	min	max	unit
114				Wet Bulb Temperature	-50.0	60.0	°C
119				Wet Bulb Temperature	-58.0	140.0	°F

6.6 Specific Enthalpy

Sampling rate 1 minute

Unit kJ/kg

Request channels:

UMB Channel					Measuring Range		
act				Measurement Variable (float32)	min	max	unit
215				Specific Enthalpy	-100.0	1000.0	kJ/kg

6.7 Air Density

Sampling rate 1 minute

Unit kg/m³

Request channels:

UMB Channel					Measuring Range		
act				Measurement Variable (float32)	min	max	unit
310				Air Density	0.0	3.0	kg/m³

6.8 Wind Speed

Sampling rate 10 seconds

Generation of average value 1 – 10 minutes

Generation of maximum value 1 – 10 minutes based on the internal second measurements

Units m/s; km/h; mph; kts

Response threshold 0.3 m/s

Request channels:

UMB Channel						Measuring Range		
act	min	max	avg	vct	Measurement Variable (float32)	min	max	unit
400	420	440	460	480	Wind Speed	0	75.0	m/s
405	425	445	465	485	Wind Speed	0	270.0	km/h
410	430	450	470	490	Wind Speed	0	167.8	mph
415	435	455	475	495	Wind Speed	0	145.8	kts
401					Wind Speed Fast	0	75.0	m/s
406					Wind Speed Fast	0	270.0	km/h
411					Wind Speed Fast	0	167.8	mph
416					Wind Speed Fast	0	145.8	kts
403					Wind Speed Standard Deviation	0	75.0	m/s
413					Wind Speed Standard Deviation	0	167.8	mph

Note: The second measurements are averaged over 10 seconds for the output of the current measurement. The 'fast' channels deliver every second a current value, but with reduced accuracy.

6.9 Wind Direction

Sampling rate 10 seconds

Generation of average value 1 – 10 minutes

Generation of maximum value 1 – 10 minutes based on the internal second measurements

Unit °

Response threshold 0.3 m/s

Request channels:

UMB Channel						Measuring Range		
act	min	max	avg	vct	Measurement Variable (float32)	min	max	unit
500	520	540		580	Wind Direction	0	359.9	°
501					Wind Direction Fast	0	359.9	°
502					Wind Direction Corrected	0	359.9	°
503					Wind Direction Standard Deviation	0	359.0	°

Note: The second measurements are averaged over 10 seconds for the output of the current measurement. The 'fast' channels deliver every second a current value, but with reduced accuracy.

The minimum / maximum wind direction indicates the direction at which the minimum / maximum wind speed was measured.

The corrected wind direction is calculated from the wind direction measured by the wind sensor and the heading measured by the compass.

Optionally the compass correction of the wind direction can be activated for all wind direction values. (Settings by UMB Config Tool)

Note: The correction function is designed for correction of the wind direction of a statically mounted sensor. If the alignment of the sensor changes during the measurement (i.e. if the sensor is mounted on a rotating platform or similar) the correction function will not in all cases work properly, especially not for the vector average.

It is of course possible to use the correction function for mobile measurement units, where the alignment is changed between measurement periods.

6.10 Wind Measurement Quality

Sampling rate 10 seconds

Unit %

Request channels:

UMB Channel						Measuring Range		
act	min	max	avg	vct	Measurement Variable (float32)	min	max	unit
805					Wind Value Quality	0	100	%

Note: The value is updated every 10 seconds and transmits the minimum wind measurement quality for the last minute.

This value allows the user to assess how well the measurement system is functioning in the respective ambient conditions. In normal circumstances the value is 90 - 100%. Values up to 50% do not represent a general problem. If the value falls towards zero the measuring system is reaching its limits.

If during critical ambient conditions the system is no longer able to conduct reliable measurements, error value 55h (85d) is transmitted (device unable to execute valid measurement due to ambient conditions).

6.11 Compass

(only device version 030 or higher)

Sampling rate: 5 min

Unit °

Request channels:

UMB Channel						Measuring Range		
act	min	max	avg	vct	Measurement Variable (float)	min	max	unit
510					Compass Heading	0	359	°

Note: Reliable operation of the compass is only possible, if the sensor has been mounted according to the instructions in this manual, i.e. on top of the pole. Should the sensor be mounted on a traverse, the distribution of iron masses will be different from the situation during factory calibration. This may lead to additional deviation of the bearing. This also applies to lightning rods mounted at the pole top!

Dependent on the location of the installation the local declination of the earth magnetic field has to be considered. The declination value is entered using the UMB-Config-Tool (see page 30). The declination for the installation location can be found in the Internet, e.g. at

http://www-app3.gfz-potsdam.de/Declinationcalc/declinationcalc.html

http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp

6.12 Precipitation Quantity - Absolute

Sampling rate	Event-dependent on reaching the response threshold
Response threshold	0.01mm (Radar)
Response threshold	0.2 / 0.5 mm (Rain Gauge)
Units	l/m²; mm; in; mil

Request channels:

UMB Channel	Measurement Variable (float32)	Unit
600	Precipitation Quantity - Absolute	l/m²
620	Precipitation Quantity - Absolute	mm
640	Precipitation Quantity - Absolute	in
660	Precipitation Quantity - Absolute	mil

Note: This measurement indicates the accumulated precipitation quantity since the last device reboot. The measurement is retained for the duration of a short power failure. To reset this value, use the corresponding function in the UMB-Config-Tool (see page 33) or disconnect the device from the power supply for at least one hour.

6.13 Precipitation Quantity - Differential

Sampling rate	Event-dependent on reaching the response threshold
Response threshold	0.01mm (Radar)
Response threshold	0.2 / 0.5 mm (Rain Gauge)
Units	l/m²; mm; in; mil

Request channels:

UMB Chanel	Measurement Variable (float32)	Unit
605	Precipitation Quantity - Differential	l/m²
625	Precipitation Quantity - Differential	mm
645	Precipitation Quantity - Differential	in
665	Precipitation Quantity - Differential	mil

Note: Each request from a differential channel sets the accumulated quantity back to zero. If the response from the device is lost due to a transmission error (e.g. poor GPRS connection), the quantity accumulated to date is also lost. The quantity accumulated to date is also reset each time the equipment is rebooted.

6.14 Precipitation Intensity

Sampling rate	1 minute
Response threshold	0.6 mm/h
Units	l/m²/h; mm/h; in/h; mil/h

Request channels:

UMB Channel	Measurement Variable (float32)	Range	Unit
800	Precipitation Intensity	0 … 200.0	l/m²/h
820	Precipitation Intensity	0 … 200.0	mm/h
840	Precipitation Intensity	0 … 7.874	in/h
860	Precipitation Intensity	0 … 7874	mil/h

Note: The device versions with radar technology (WS400-UMB, WS600-UMB) calculate the precipitation intensity is always on the basis of the precipitation of the previous minute.

The lower resolution of the rain gauge would lead to high fluctuation of the intensity values, so the rain gauge versions (WS401-UMB and WS601-UMB), as well as the external rain gauge, use the accumulated precipitation of the last 60 minutes before the current measurement for intensity calculation.

6.15 Precipitation Type

Sampling rate Event-dependent on reaching the response threshold
Response threshold 0.01mm (Radar)
Response threshold 0.2 / 0.5 mm (Rain Gauge)
Follow-up time 2 minutes
Request channels:

UMB Channel	Measurement Variable (uint8)	Coding
700	Precipitation Type	0 = No precipitation 60 = Liquid precipitation, e.g. rain 70 = Solid precipitation, e.g. snow 40 = unspecified precipitation (WS401-UMB, WS601-UMB, external rain gauge)

Note: A detected precipitation type remains valid for 2 minutes after the end of the precipitation event. In order to record precipitation types which only occur for a short period (e.g. short-term rain), the request time should be at least 1 minute.

Ice, hail and sleet are transmitted as rain (60).

The versions WS401-UMB and WS601-UMB as well as the external rain gauge do not include detection of precipitation type, so in this case only type 40 (unspecified precipitation) is indicated. Due to the function of the rain gauge only liquid or molten precipitation can be recognized.

6.16 Heating Temperature

Sampling Rate 1 Minute
Units °C; °F
Request Channels:

UMB Channel					Measuring Range		
act	min	max	avg	Measurement Variable (float32)	min	max	Unit
112				Heating Temperature Wind Sensor	-50.0	150.0	°C
113				Heating Temperature Precipitation Sensor	-50.0	150.0	°C
117				Heating Temperature Wind Sensor	-58.0	302.0	°F
118				Heating Temperature Precipitation Sensor	-58.0	302.0	°F

6.17 Global Radiation

Sampling Rate 1 minute
Generation of average values 1 – 10 minutes
Unit W/m²
Request Channels:

UMB Channel					Measuring Range		
act	min	max	avg	Measurement Variable (float32)	min	max	unit
900	920	940	960	Global Radiation	0.0	1400.0	W/m²

6.18 Leaf Wetness

Sampling Rate	1 minute
Generation of average values	1 – 10min (using the setting for rel. humidity)
Unit	mV / code

Request Channels:

UMB Channel					Measuring Range		
act	min	max	avg	Measurement Variable (float32)	min	max	unit
710	730	750	770	Leaf Wetness mV	0.0	1500.0	mV
711				Leaf Wetness State	0 = dry 1 = wet		

The leaf wetness state is evaluated comparing with the adjustable leaf wetness threshold. The setting of this threshold shall be done according to the instructions of the sensor manual and, if necessary, readjusted as part of the maintenance procedure.

7 Installation

The sensor bracket is designed to be installed on the top of a mast with a diameter of 60 – 76mm.

The following tools are required for the installation:

- Open-end or ring spanner (SW13)
- Compass for aligning the wind meter to the North

7.1 Fastening

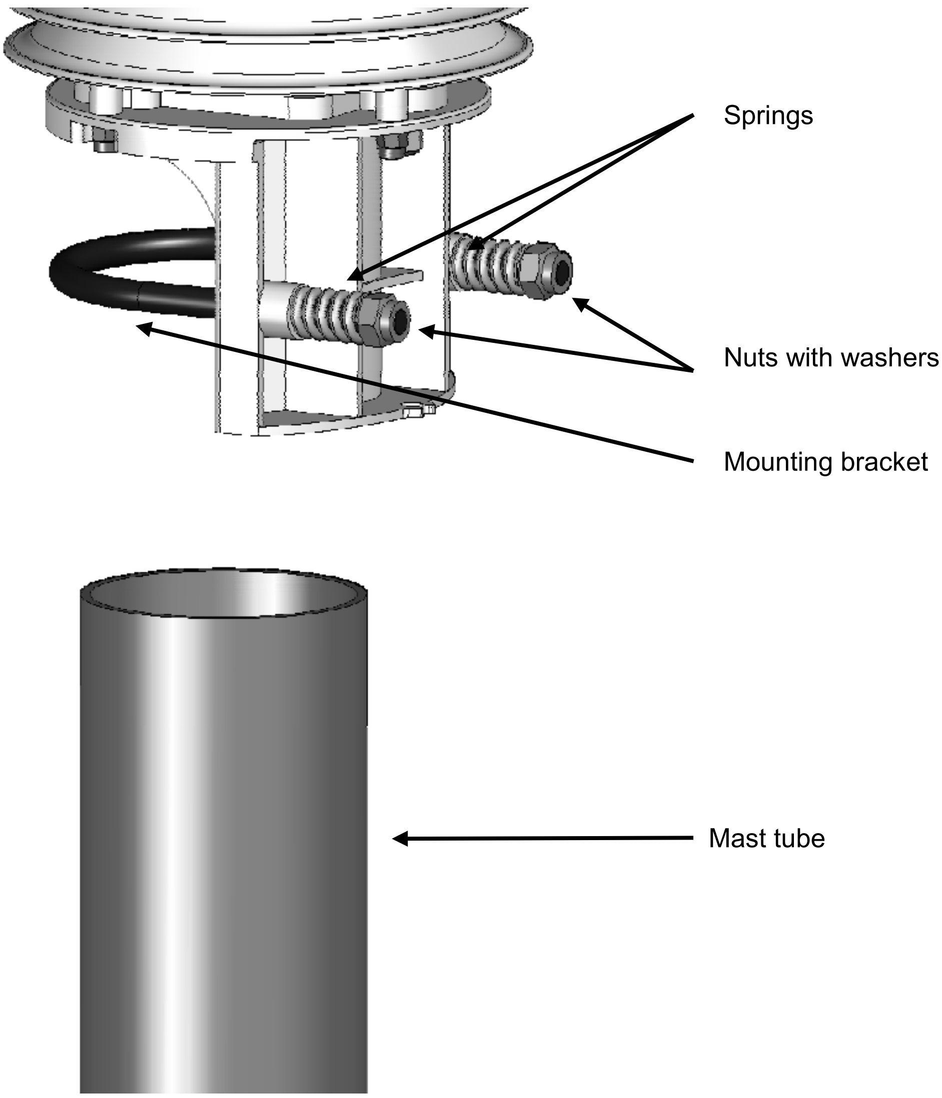


Figure 2: Fastening to the Mast

- Loosen nuts
- Push the sensor onto the top of the mast from above
- Tighten the nuts evenly until contact is made with the springs but the sensor can still be moved easily
- Align the sensor to the North (for wind meters)
- Tighten both nuts with **3 revolutions**

7.2 North Alignment

In order for the wind direction to display correctly, the sensor must be aligned to the North. The sensor has a number of directional arrows for this purpose.

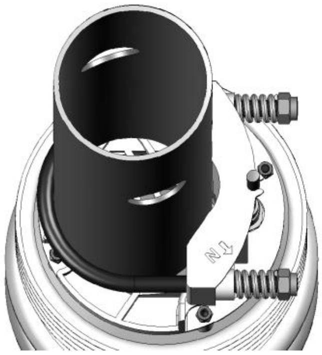
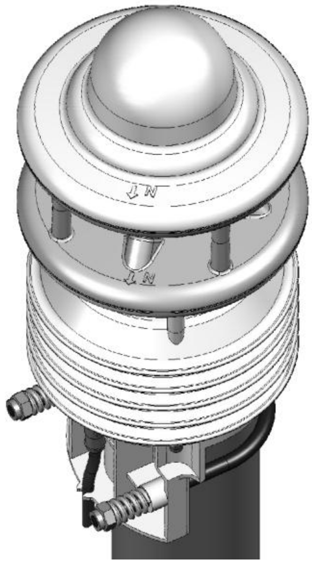



Figure 3: North Markings

Procedure:

- If the sensor is already installed, first loosen both nuts evenly until you can turn the sensor easily
- Using the compass, identify the North and fix a point of reference on the horizon
- Position the sensor in such a way that the South and North sensors are in alignment with the fixed point of reference in the North
- Tighten both nuts with 3 revolutions

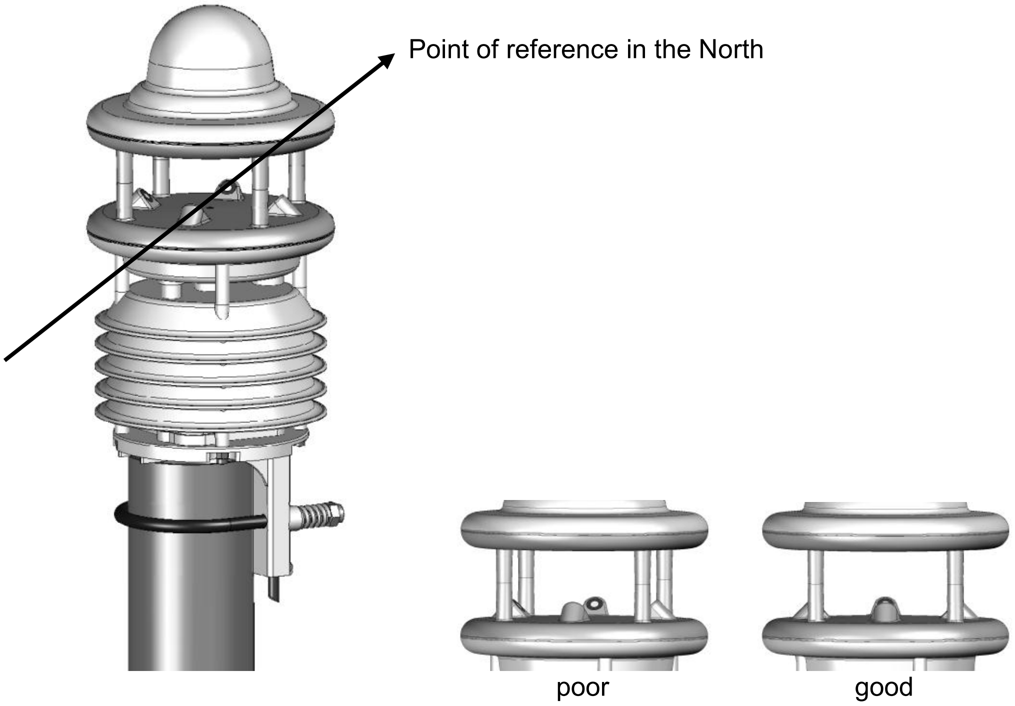


Figure 4: Alignment to North

Note: As the magnetic North Pole indicated by the compass differs from the Geographic North Pole, account must be taken of the declination (variation) at the location when aligning the sensor.

Depending on the location, the variation can be more than 15° (in North America for example). In Central Europe the variation can be largely ignored at present (< 3°). You can find further helpful information on this subject on the Internet.

7.3 Selecting the Installation Location

In order to guarantee long service life and correct equipment operation, please pay attention to the following points when selecting the installation location.

7.3.1 General Instructions

- Stable subsurface for installing the mast
- Free access to the equipment for maintenance works
- Reliable power supply for permanent operation
- Good network coverage when transmitting over a mobile communications network

Note: The computed measurements specifically apply to the equipment location only. No conclusions can be drawn with regard to the wider environment or a complete road section.

ATTENTION:

- Only approved and tested appliances (conductors, risers etc.) should be used to install the device on the mast.
- All relevant regulations for working at this height must be observed.
- The mast must be sized and anchored appropriately.
- The mast must be earthed in accordance with regulations.
- The corresponding safety regulations for working at road side and in the vicinity of the road carriageway must be observed.

If the equipment is installed incorrectly

- It may not function.
- It may be permanently damaged.
- Danger of injury may exist if the equipment is allowed to fall.

7.3.2 Sensors with Wind Measurement / Compass

- Installation at the top of the mast
- Installation height at least 2m above the ground
- Free field around the sensor

Note: Buildings, bridges, embankments and trees may corrupt the wind measurement. Equally, passing traffic may cause gusts which may influence the wind measurement.

Note: for accurate compass readings, an aluminium mast is recommended.

7.3.3 Sensors with Radar Precipitation Measurement

- Installation on the top of the mast
- Installation height at least 4.5m above the ground
- Distance to road carriageway at least 10m
- Distance from moving objects (e.g. trees, bushes and even bridges) at least 10m at the height of the sensor

Note: Falling or moving objects, e.g. falling leaves or leaves blowing in the wind, may cause false measurements and/or precipitation types.

Note: Strong wind can influence the accuracy of the precipitation measurement.

Note: When selecting the installation location please take care to position the device at a suitable distance from other systems incorporating a 24GHz radar sensor, such as traffic counting devices on overhead gantry signs. Otherwise cross effects and system malfunctions may occur. In the final analysis, the distance to other measuring systems also depends on their range of coverage and signal strength.

7.3.4 Sensors with Rain Gauge

- Installation on the top of the mast or on crossbar with distance to the mast
- Mast or crossbar mounting shall be exactly perpendicular, otherwise the precision of the rain gauge may be influenced.

Note: The location should be selected so that pollution of the rain gauge funnel by falling leaves etc. can be avoided as far as possible.

7.3.5 Sensors with Global Radiation Measurement

- Installation on top of the pole
- Shadow free location, if possible 360° free view to the horizon at the height of the pyranometer
- Distance to shadow casting objects (trees, buildings) at least 10 times of the object height relative to the sensor.

7.3.6 Installation Sketch

Example WS600-UMB:

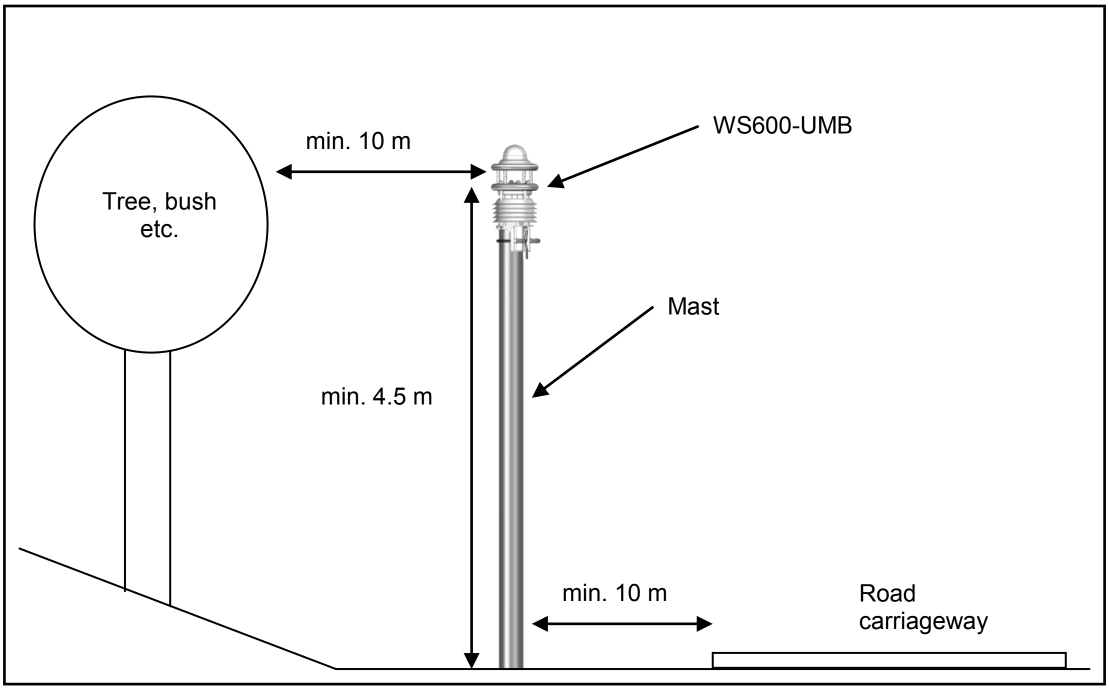


Figure 5: Installation Sketch

8 Connections

There is an 8 pole screw connector on the underside of the equipment. This serves to connect the supply voltage and interfaces by way of the supplied connection cable.

Equipment connector:

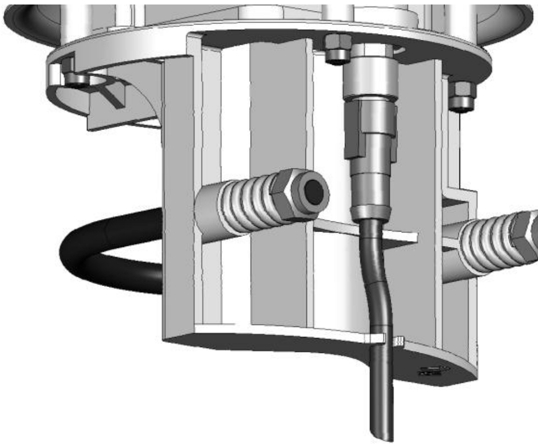
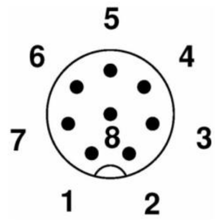


Figure 6: Connections



View on sensor connection

Pin assignment:

1	White	Supply voltage ground
2	Brown	Positive supply voltage
3	Green	RS485_A / SDI-12 GND
4	Yellow	RS485_B / SDI-12 Data Line
5	Grey	External Sensor a
6	Pink	External Sensor b
7	Blue	Heating voltage ground
8	Red	Positive heating voltage

The cable marking is in accordance with DIN 47100.

Note: The yellow protective cap must be removed before plugging in the equipment.

If the equipment is not connected correctly

- It may not function
- It may be permanently damaged
- The possibility of an electrical shock may exist

When connecting the heating voltage the correct polarity must be strictly observed. Wrong polarity of the heating voltage, as well as wrong polarity of the supply voltage will cause damage of the instrument.

8.1 Supply Voltage

The supply voltage for the compact weather station is 12 - 24V DC. The power supply unit used must be approved for operation with equipment of protection class III (SELV).

8.1.1 Limitations in 12V mode

If the heating is operated on 12V DC, account must be taken of the functional restrictions in winter operation.

Note: A heating voltage of 24V DC is recommended to guarantee full heating duty.

8.2 RS485 Interface

The equipment has an electrically isolated, half-duplex, 2 wire RS485 interface for configuration, measurement polling and the firmware update.

See page 41 for technical details.

8.3 Connection to ISOCON-UMB (8160.UISO)

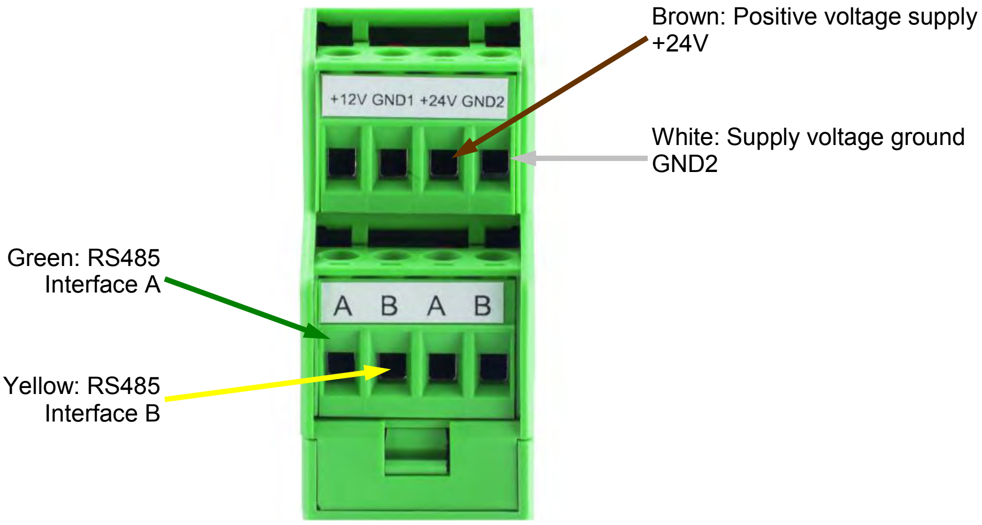


Figure 7: Connection to ISOCON-UMB

Warning: The heating voltage (red = positive heating voltage; blue = heating voltage ground) is **not** connected to the ISOCON-UMB but wired direct to the power supply unit.

During installation please also refer to the operating manual for the ISOCON-UMB.

8.4 Use of Surge Protection (8379.USP)

When using surge protection (Order No.: 8379.USP), please pay attention to the connection example in the surge protection operating instructions.

8.5 Connection of the Leaf Wetness Sensor

The sensor versions WS401-UMB and WS601-UMB (precipitation measurement by rain gauge) can be equipped with an optional external leaf wetness sensor.

The connection terminals for the leaf wetness sensor are located inside the rain gauge module. The sensor connection cable is put through the cable bushing in the wall of the rain gauge module and connected to the terminals (see Chap. 18.1).

Terminal assignment for Leaf Wetness Sensor WLW100:

1	blank (shield)	Ground
2	red	Signal Voltage
3	white	Sensor Supply Voltage 5V

8.6 Connection of External Temperature and Precipitation Sensors

External sensors are to be connected to pins 5 and 6 of the plug connector, i.e. to the gray and pink wires of the cable delivered with the compact weather station.

The temperature sensors as well as the external rain gauge are unipolar, so any connection sequence can be chosen.

The type of external sensor has to be set using the UMB Config Tool.

For details please refer to Chapter18.

9 Commissioning

After the equipment has been installed and connected correctly, the sensor begins autonomously to take measurements. A Windows® PC with serial interface, UMB-Config-Tool software and interface cable (SUB-D 9 pole; jack - socket; 1:1) are required for configuration and test purposes.

Attention must be paid to the following points:

Check for correct equipment operation on site by carrying out a measurement request with the aid of the UMB-Config-Tool (see page 34).

- Configure the local altitude in order to ensure the correct calculation of relative air pressure (see page 30).
- The device must be aligned to the North in order to ensure correct wind measurement (see page 22), or the automatic compass correction must be activated (see page 30).
- In order to get correct compass headings the local declination must be configured (see page 17and 30).
- If several compact weather stations are operated on a UMB network, a unique device ID must be assigned to each device (see page 29).

There is no protective cover to remove on the sensor itself.

10 Configuration and Test

Lufft provides Windows® PC software (UMB-Config-Tool) for configuration purposes. The sensor can also be tested and the firmware updated with the aid of this software.

10.1 Factory Settings

The compact weather station is delivered with the following settings:

Class ID:	7 (cannot be modified)
Device ID:	1 (gives address 7001h = 28673d)
Baud rate:	19200
RS485 protocol:	Binary
Calculation interval:	10 measurements
Local altitude:	0 m

Note: The device ID must be changed if several compact weather stations are operated on a UMB network, as each device requires a unique ID. It makes sense to start from ID 1 and continue in ascending order.

10.2 Configuration with the UMB-Config-Tool

The operation of the UMB-Config-Tool is described in detail in the operating instructions for the Windows® PC software. For this reason only the menus and functions specific to the compact weather station are described here.

10.2.1 Sensor Selection

The compact weather station is shown here with sensor selection WSx-UMB (Class ID 7).

Figure 8: Sensor Selection

Note: You do require the current version of the UMB-Config-Tool to configure the compact weather station.

Note: All other devices which are used in the polling process, e.g. modems, LCOM etc., must be disconnected from the UMB network during configuration.

10.2.2 Configuration

After a configuration has been loaded, all relevant settings and values can be adjusted. Depending on the device type, only the settings pertinent to the respective available sensors are relevant.

10.2.3 General Settings

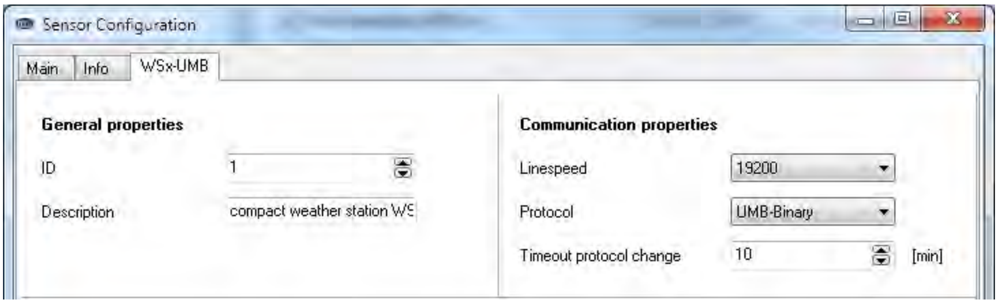


Figure 9: General Settings

ID:	Device ID (factory setting 1; assign device IDs to additional devices in ascending order).
Description:	In order to differentiate the devices you can enter a description here, e.g. the location.
Linespeed:	Transmission speed of the RS485 interface (factory setting 19200; **DO NOT CHANGE for operation with ISOCON-UMB**).
Protocol:	Communications protocol of the sensor (UMB-Binary, UMB-ASCII, SDI-12, Modbus-RTU, Modbus-ASCII, Terminal-Mode).
Timeout:	In the event of a temporary changeover of the communications protocol, the system switches back to the configured protocol after this time (in minutes)

Important note: If the baud rate is changed, after saving the configuration on the sensor, the sensor communicates at the new baud rate. When operating the sensor in a UMB network with ISOCON-UMB, **this baud rate must not be changed**; otherwise the sensor **is no longer addressable** and can no longer be configured.

10.2.4 Temperature, Humidity and Fan Settings

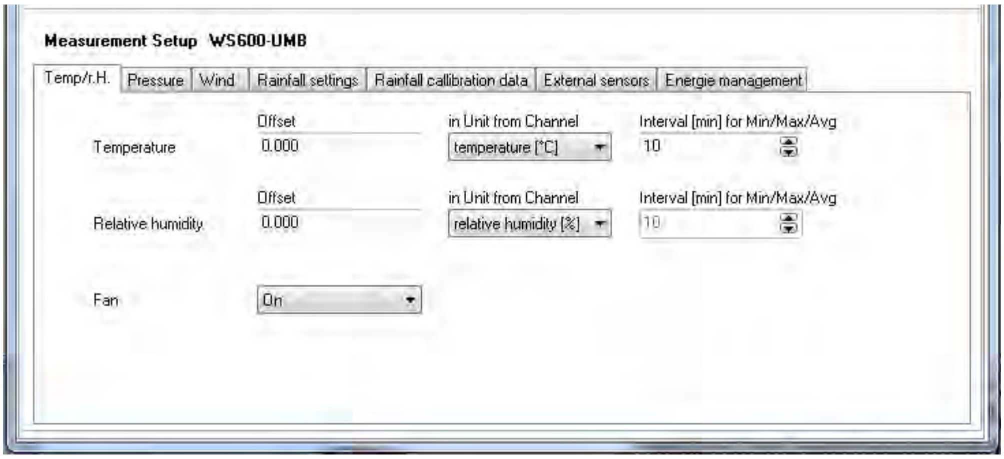


Figure 10: Temperature, Humidity and Fan Settings

Offset:	Absolute offset on the measurement in the unit of the accompanying channel (for on-site calibration).
Interval:	Time in minutes for the minimum, maximum and average value calculation interval.
Fan:	to reduce electrical power consumption, the fan can be switched off. **Note: if the fan is switched off, all heaters will also be switched off! With the fan switched off deviations in temperature and humidity measurement can occur by solar radiation!**

Note: In order to calculate dew point, absolute humidity and mixing ratio, the temperature and humidity measurement always requires the same interval. For this reason different intervals cannot be set.

10.2.5 Pressure,

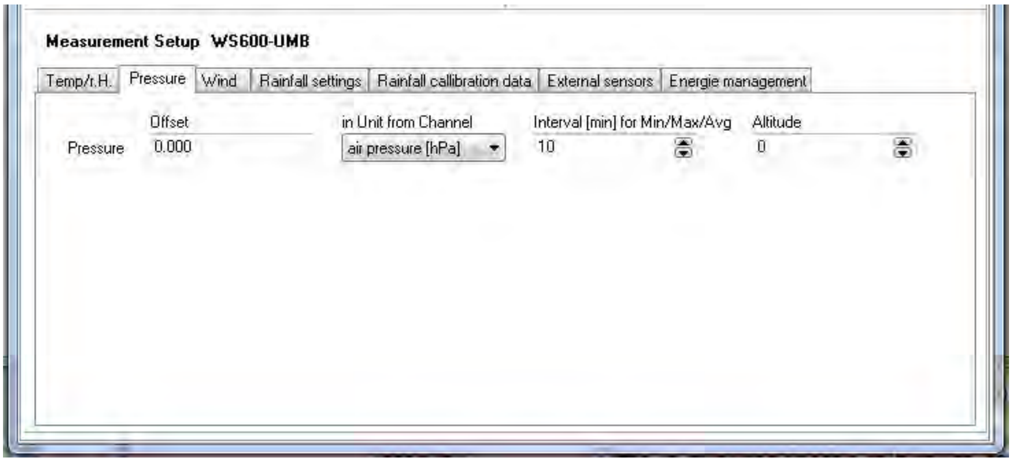


Figure 11: Pressure Settings

Offset: Absolute offset on the measurement in the unit of the accompanying channel.

Interval: Time in minutes for the minimum, maximum and average value calculation interval.

Altitude: Enter the local altitude in meters here for the correct calculation of relative air pressure (referenced to sea level).

10.2.6 Wind and Compass Settings

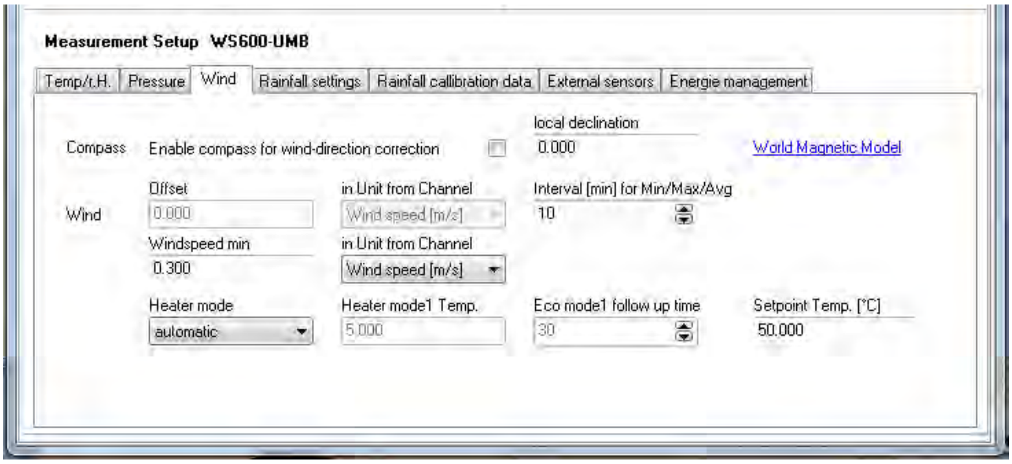


Figure 12: Wind Settings

Offset: Absolute offset on the measurement in the unit of the accompanying channel.

Interval: Time in minutes for the minimum, maximum and average value calculation interval.

Windspeed min: Approach velocity onto the wind meter with effect from which a measurement is transmitted, in the unit of the accompanying channel.

Heater mode: The device can be configured for heating in different operating modes. Configure as ‘automatic’ in normal operating mode. You can find a precise description of the operating modes on page 37.

Local declination: Dependent on the location of the installation; the local declination of the earth magnetic field has to be considered.

Enable Compass for wind-direction correction:
With activated compass correction all wind direction values will be corrected according to the alignment of the sensor, as evaluated by the compass.

Note: The offset is not used for the wind meter at present because on-site calibration is not possible in this case.

10.2.7 Precipitation Sensor Settings (Radar)

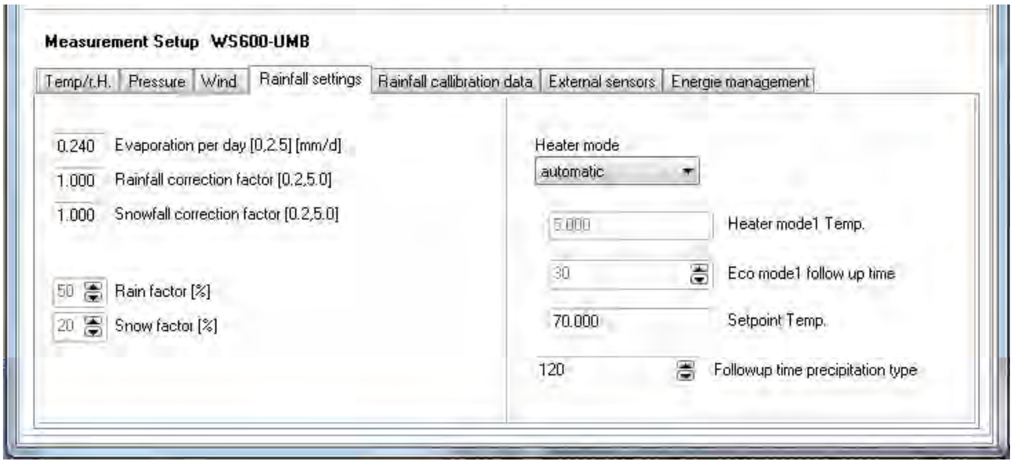


Figure 13: Precipitation Sensor Settings (Radar)

Heater mode: The device can be configured for heating in different operating modes. Configure as ‘automatic’ in normal operating mode. You can find a precise description of the operating modes on page 37.

Followup time precipitation type: for this time (in seconds) the detected precipitation type is shown; to cover all events, this time must be adjusted to the poll rate.

Note: All other parameters, especially those in the ‘Rainfall calibration data’ tab, may only be changed after consultation with the manufacturer, as they have a major influence on the functioning and accuracy of the sensor.

10.2.8 Precipitation Sensor Settings (Rain Gauge)

The rain gauge module can be operated with resolutions 0.2mm or 0.5mm. The setting ofthe resolution is to be done in two steps:

- Mechanical setting
- Configuration setting

The mechanical setting works by modifying the effective area of the funnel. The sensor is delivered with a reduction ring, which can be mounted on the funnel to reduce the area.

Funnel with reduction ring resolution 0.5mm

Funnel without reduction ring resolution 0.2mm

Then the resolution is set in the sensor configuration using the UMB Config Tool.

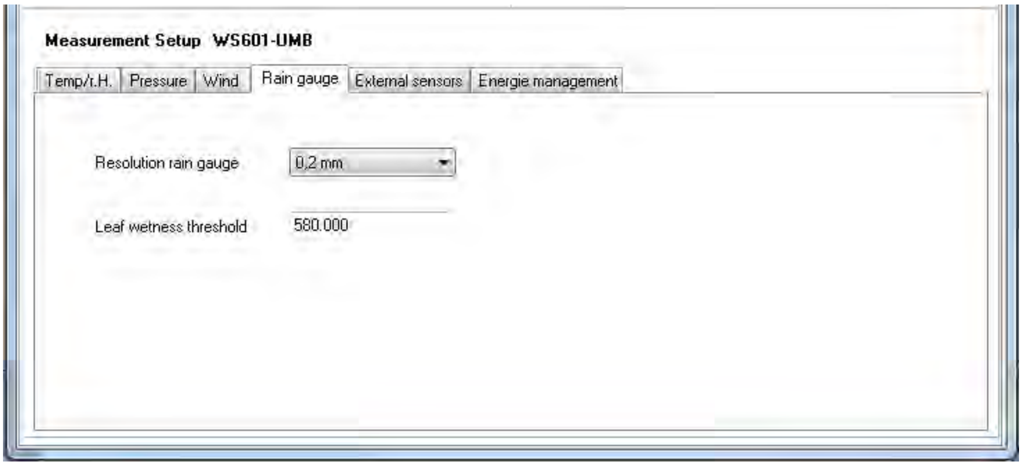


Figure 14: Precipitation Sensor Settings (Rain Gauge)

Caution: If mechanical setting and configuration setting do not conform, the sensor will deliver wrong precipitation values!

10.2.9 Energy Management

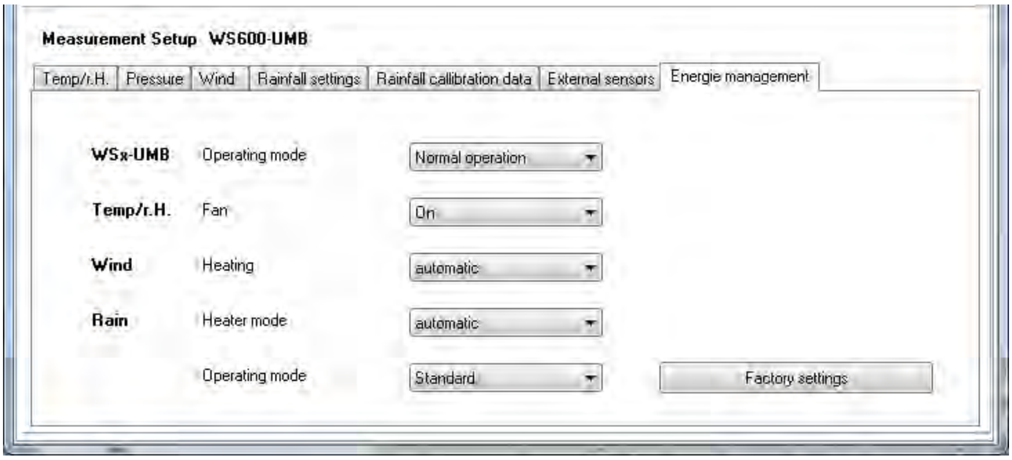


Figure 15: Energy Management Settings

By setting the operating and heating mode, the energy consumption of the weather station can be adapted to the circumstances of the installation.

The different settings are described in the following chapters:

- operating modes of compact weather station from page 35
- operating modes of the heating from page 37

10.2.10 Reset Precipitation Quantity

To reset the accumulated absolute precipitation quantity the UMB-Config-Tool offers the following function:

Options →WSx-UMB reset rain

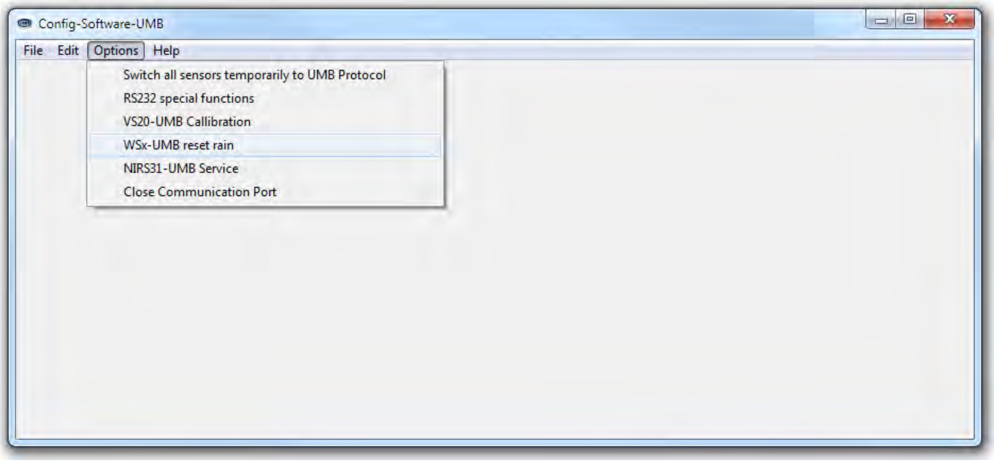
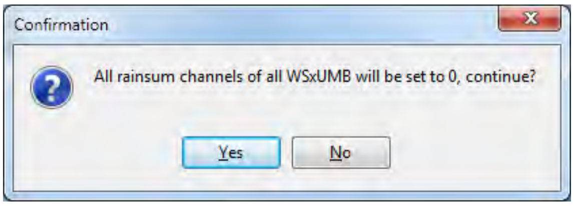


Figure 16: Reset Precipitation Quantity

Confirm the reset with 'Yes'



Note: The precipitation quantities are reset in ALL compact weather stations on the respective UMB network. The devices reboots after this function has been used.

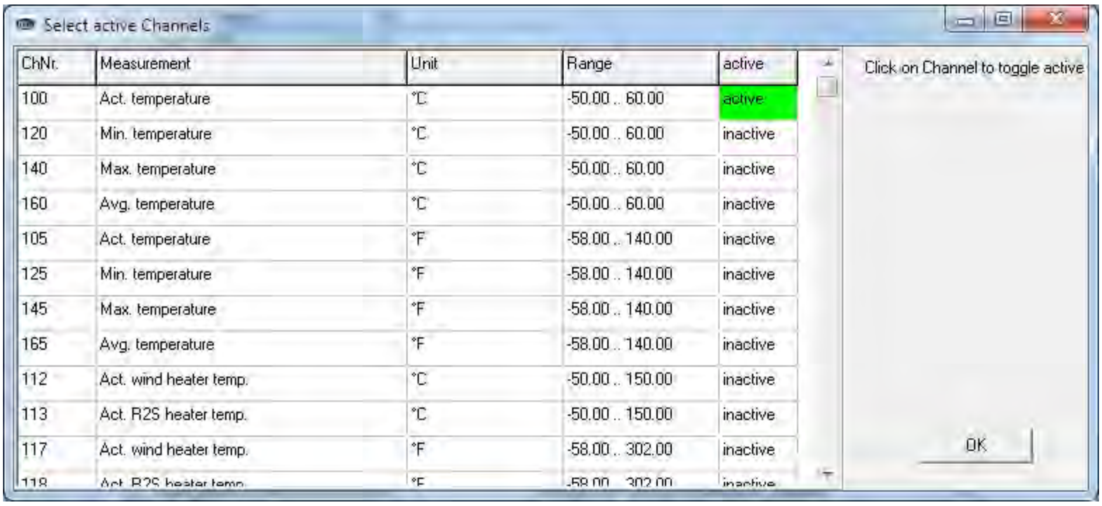
10.3 Function Test with UMB-Config-Tool

The functions of the compact weather station can be tested with the UMB-Config-Tool by polling various channels.

Note: All other devices which are used in the polling process, e.g. modems, LCOM etc., must be disconnected from the UMB network during configuration.

10.3.1 Channels for Measurement Polling

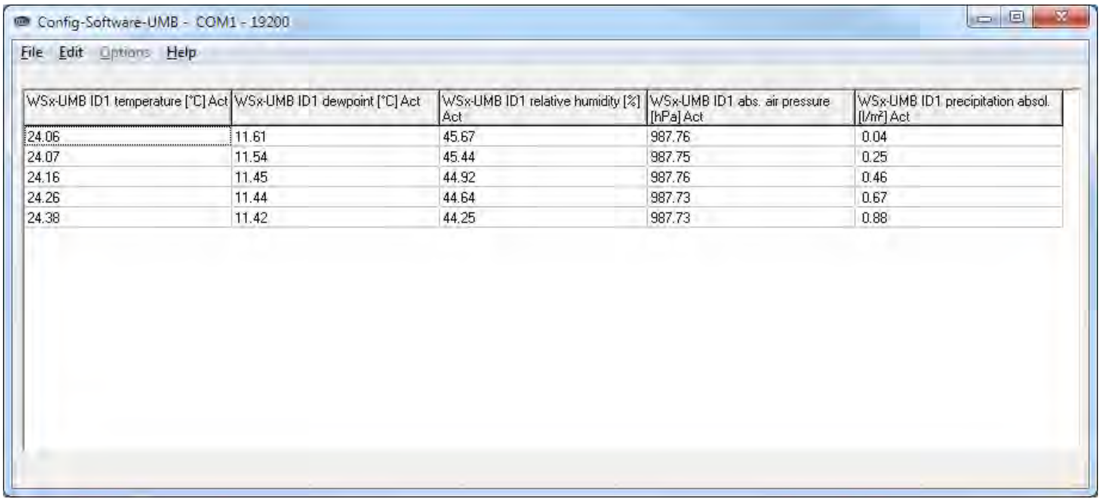
You can select the channel for measurement polling by the UMB-Config-Tool by clicking on the respective channel.



ChNr.	Measurement	Unit	Range	active
100	Act. temperature	°C	-50.00 .. 60.00	active
120	Min. temperature	°C	-50.00 .. 60.00	inactive
140	Max. temperature	°C	-50.00 .. 60.00	inactive
160	Avg. temperature	°C	-50.00 .. 60.00	inactive
105	Act. temperature	°F	-58.00 .. 140.00	inactive
125	Min. temperature	°F	-58.00 .. 140.00	inactive
145	Max. temperature	°F	-58.00 .. 140.00	inactive
165	Avg. temperature	°F	-58.00 .. 140.00	inactive
112	Act. wind heater temp.	°C	-50.00 .. 150.00	inactive
113	Act. R2S heater temp.	°C	-50.00 .. 150.00	inactive
117	Act. wind heater temp.	°F	-58.00 .. 302.00	inactive
118	Act. R2S heater temp.	°F	-58.00 .. 302.00	inactive

Figure 17 Measurement Polling Channels

10.3.2 Example of Measurement Polling



WSx-UMB ID1 temperature [°C] Act	WSx-UMB ID1 dewpoint [°C] Act	WSx-UMB ID1 relative humidity [%] Act	WSx-UMB ID1 abs. air pressure [hPa] Act	WSx-UMB ID1 precipitation absol. [l/m²] Act
24.06	11.61	45.67	987.76	0.04
24.07	11.54	45.44	987.75	0.25
24.16	11.45	44.92	987.76	0.46
24.26	11.44	44.64	987.73	0.67
24.38	11.42	44.25	987.73	0.88

Figure 18 Example of Measurement Polling

Note: The UMB Config Tool is provided for test and configuration purposes only. It is not suitable for the permanent acquisition of measurement data. We recommend the use of professional software solutions for this purpose, e.g. Lufft SmartView3.

10.4 Operating Modes of the Compact Weather Station

The power consumption of the weather station can be adjusted to the properties of the individual installation by setting the operation mode.

The operation of the power save modes however has certain constraints. These have to be considered when designing the installation.

In normal operation, where all specified properties of the compact weather station are fully available, the power consumption is mostly determined by heating and fan operation.

10.4.1 Power Saving Mode 1

Following measures are active in power saving mode 1:

- The ventilation of the temperature / humidity unit is switched off
- All heaters are switched off
- The radar rain sensor (WS600-UMB, WS400-UMB) is not working continuously. The sensor is activated once per minute for one second, if precipitation is detected, it remains turned on until the end of the event, otherwise it is deactivated after this one second again.

Note: This setting has the following restrictions:

- With the fan switched off deviations in temperature and humidity measurement can occur by solar radiation.
- Only limited winter operation is possible in this operating mode because any icing might prevent the correct operation of the rain sensor or wind meter.
- The rain detection may be delayed up to 2 minutes. Short events are possibly not detected. Thus, deviations in the accuracy of the precipitation quantity are possible.

Compared with normal operation the power consumption of a WS600-UMB can reduced to 10% even neglecting the heating. (during precipitation events the consumption is slightly higher, due to the rain sensor then permanently switched on, about 20% compared to normal operation).

10.4.2 Power Saving Mode 2

Power saving mode 2 permits another relevant reduction of the power consumption, but adds on the other hand more severe restrictions.

In this operation mode the station will be almost completely switched off and will wake up only by the data request for one measurement cycle. During measurement and data transmission the station will be switched on for about 10 – 15 sec. The total consumption will be mostly determined by the data request interval.

Note: This operating mode has following restrictions:

- All restrictions of power saving mode 1
- Power saving mode 2 is not available for devices with radar rain sensor (WS600-UMB, WS400-UMB). We recommend devices with tipping bucket rain gauge for low power applications.
- The calculation of average, minimum and maximum as well as precipitation intensity are not available. Only instantaneous values will be transmitted
- Communication protocol Modbus is not available
- When using the UMB protocol a certain request sequence and timing is required (s. Chap. 19.3.7). The interval length must be at least 15sec to make sure that the measurement and transmission cycle can be completed. Shorter interval could cause the device to stay in transmission state without starting a new measurement.

- The joint operation with other sensor in an UMB network is possible, but it has to be considered, that each telegram (even when addressed to another station) will cause the compact weather station to wake up for at least several seconds, thus increasing the total power consumption. The minimum interval length must be hold up under consideration of the telegrams with other addresses. Mixed operation of devices in power saving mode 2 with station in normal operation and fast request rates within the same UMB network is not possible.

10.5 Operating Modes for Equipment Heating

Heating is configured to ‘Automatic’ when the product is delivered. This is the recommended operating mode for heating the sensor.

You can set the following operating modes:

Heater Mode	WS200-UMB	WS400-UMB	WS500-UMB	WS501-UMB *)	WS600-UMB	WS601-UMB
Automatic	●	●	●	●	●	●
Off	●	●	●	●	●	●
Mode 1		●	●	●	●	●
Eco-Mode 1		●			●	

*) is also valid for WS502-UMB, WS503-UMB, WS504-UMB

Note: Model WS30x-UMB and WS401-UMB are not heated.

The rain sensor and wind meter settings must be adjusted in the respective configuration mask. The examples show the wind meter setting.

10.5.1 Automatic

In this operating mode, the sensor is maintained constantly at the control temperature, generally in order to prevent the effects of snow and ice.

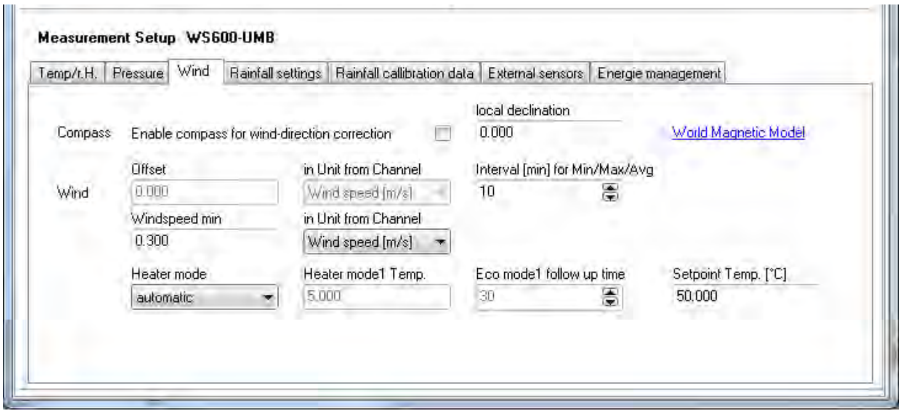


Figure 19: Operating Modes for Equipment Heating

Setpoint Temp.: The heating controls at this temperature (in °C)

The settings for the other values are not relevant.

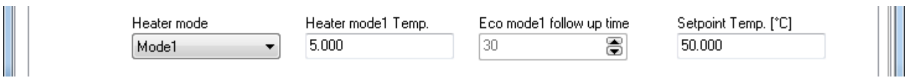
10.5.2 Off

In the ‘Off’ operating mode heating is completely disabled. Winter operation is not possible in this operating mode because any icing might prevent the correct operation of the rain sensor or wind meter.

The value settings are not relevant.

10.5.3 Mode 1

In ‘Mode 1’ operating mode heating is only enabled when the outside temperature falls below the HeatingMode1 temperature (in °C). In this mode power consumption can be reduced in frost-free situations with no great restriction on winter operation.



Setpoint Temp.: The heating controls at this temperature (in °C)

Heating mode1 Temp.: Threshold temperature (in °C) with effect from which air temperature heating is enabled

The ‘Eco Mode1 follow-up time’ setting is not relevant.

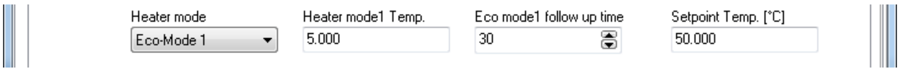
10.5.4 Eco-Mode 1

Eco Mode1 is an advanced energy saving mode.

Heating is only switched on when the following conditions are met:

- The outside temperature is below the threshold temperature and precipitation was detected. Heating then runs at the control temperature for 30 minutes (after the last precipitation event).
- When the outside temperature lies constantly below the threshold temperature and there was no heating for more than 20h, heating is switched on for 30 minutes as a precautionary measure in order to thaw any icing.

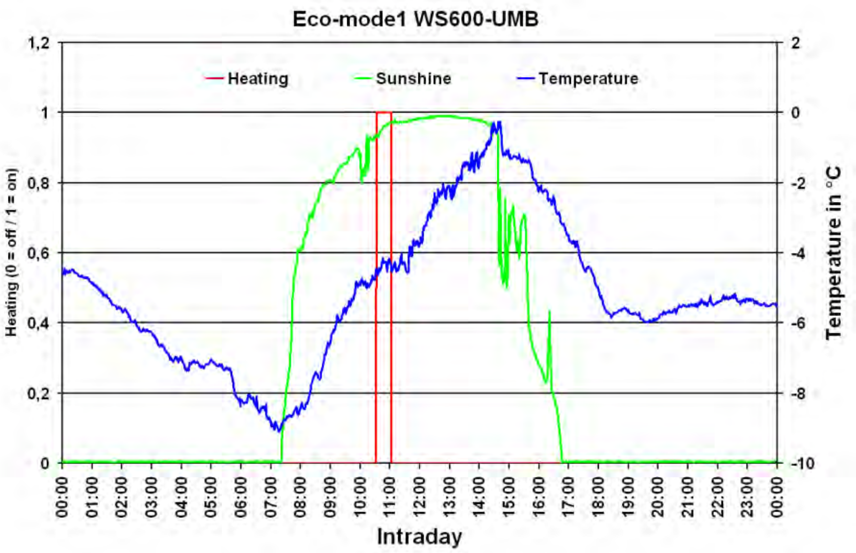
However, the precautionary 20h-heating only runs if the outside temperature was measured at below the threshold temperature for the entire period and conditions were constantly bright for at least 3 hours.



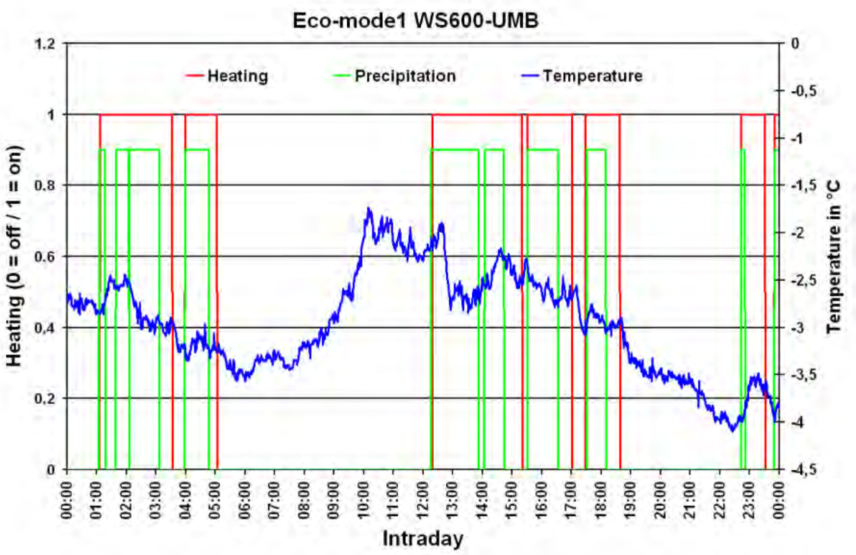
Setpoint Temp.:	The heating controls at this temperature (in °C)
Heating mode1 Temp.:	Threshold temperature (in °C) with effect from which heating is enabled
Eco mode1 follow-up time:	Follow-up time (in minutes)

Examples:

Outside temperature constantly below 5°C; no precipitation for more than 24h



Outside temperature constantly below 5°C; with precipitation



11 Firmware Update

To keep the sensor in accordance with the latest state-of-the-art, it is possible to carry out a firmware update on site with no need to remove the sensor and return it to the manufacturer.

The firmware update is carried out with the aid of the UMB-Config-Tool.

The description of the firmware update can be found in the instructions for the UMB-Config-Tool. Please download the latest firmware and UMB-Config-Tool from our website www.lufft.com and install it on a Windows® PC. You can find the instructions here:

Note: When a firmware update takes place, under certain circumstances the absolute precipitation quantities are reset (channel 600 – 660).

There is one firmware for the entire product family which supports all models (WSx_Release_Vxx.mot).

Important Note: please read the included text file in WSx_Release_Vxx.zip; it contains important information about the update!

12 Maintenance

In principle the equipment is maintenance-free.

However, it is recommended to carry out a functional test on an annual basis. When doing so, pay attention to the following points:

- Visual inspection of the equipment for soiling
- Check the sensors by carrying out a measurement request
- Check the operation of the fan (not on WS200-UMB)

In addition, an annual calibration check by the manufacturer is recommended for the humidity sensor (not on WS200-UMB). It is not possible to remove or replace the humidity sensor. The complete compact weather station must be sent to the manufacturer for testing.

Cleaning of the glass dome at regular intervals is suggested for devices with global radiation measurement. The length of the interval should be adapted to the local degree of pollution.

Devices with precipitation measurement by rain gauge (WS401-UMB, WS601-UMB): The rain gauge funnel needs to be cleaned at regular intervals (see below). The length of the interval should be adapted to the local degree of pollution.

Devices with leaf wetness sensor: Cleaning of the leaf wetness sensor at regular intervals is suggested. The length of the interval should be adapted to the local degree of pollution. A check and, if necessary, adjustment of the “Wet” threshold is recommended to include into the maintenance procedure.

12.1 Maintenance of the Rain Gauge

The function of the rain gauge will be significantly influenced by pollution of the funnel or the tipping bucket mechanism. Regular check and, if necessary, cleaning is required. The maintenance interval depends very much on local conditions and also on seasons (leaves, pollen, etc.) and therefore cannot be exactly defined here (it may be in the range of weeks).

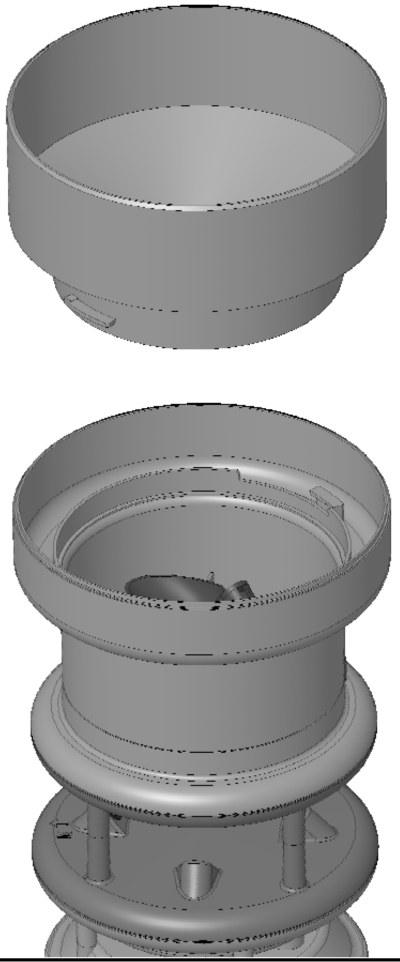


Figure 20: WS601-UMB with removed funnel

- Only clean when obviously polluted
- Avoid moving the tipping mechanism (otherwise wrong counts will occur)
- Use water, soft cloth and / or a soft brush for cleaning
- Unlock funnel by turning it to the left and lift it off
- Clean funnel, specially the sieve slots
- Check the inside of the rain gauge module for pollution, especially for spider webs and insects, if necessary, clean it
- Check tipping bucket for pollution, if necessary wash carefully with clean water. Caution: each movement of the bucket generates a counting pulse and thus may cause faulty precipitation amounts
- Check water drain, clean if necessary
- Put funnel back in place and lock it by turning it to the right

13 Technical Data

Power supply: 24VDC +/- 10%
12VDC with restrictions (see page 25)

Current consumption - sensor:

Mode[1]	Standard		Power Saving Mode 1		Power Saving Mode 2	
Supply	**24VDC[2]**	**12VDC**	**24VDC**	**12VDC**	**24VDC**	**12VDC**
WS200-UMB	16 mA	25 mA	15 mA	24 mA	4 mA	2 mA
WS300-UMB	135 mA	70 mA	7 mA	7 mA	4 mA	2 mA
WS301-UMB WS302-UMB WS303-UMB WS304-UMB	135 mA	70 mA	8 mA	8 mA	4 mA	2 mA
WS400-UMB	160 mA	110 mA	7 mA	7 mA	--	--
WS401-UMB	130 mA	65 mA	6 mA	6 mA	4 mA	2 mA
WS500-UMB	140 mA	80 mA	16 mA	25 mA	4 mA	2 mA
WS501-UMB WS502-UMB WS503-UMB WS504-UMB	145 mA	85 mA	16 mA	25 mA	4 mA	2 mA
WS600-UMB	160 mA	130 mA	16 mA	25 mA	--	--
WS601-UMB	140 mA	85 mA	15 mA	24 mA	4 mA	2 mA

Current consumption and power input - heating:

WS200-UMB	833 mA / 20VA at 24VDC
WS400-UMB	833 mA / 20VA at 24VDC
WS500-UMB, WS501-UMB, WS502-UMB WS503-UMB, WS504-UMB	833 mA / 20VA at 24VDC
WS600-UMB	1,7 A / 40VA at 24VDC
WS601-UMB	833mA / 20VA at 24VDC

Dimensions including mounting bracket:

WS200-UMB	Ø 150mm, height 194mm
WS300-UMB	Ø 150mm, height 223mm
WS301-UMB	Ø 150mm, height 268mm
WS302-UMB	Ø 150mm, height 253mm
WS303-UMB	Ø 150mm, height 328mm
WS304-UMB	Ø 150mm, height 313mm
WS400-UMB	Ø 150mm, height 279mm
WS401-UMB	Ø 164mm, height 380mm
WS500-UMB	Ø 150mm, height 287mm
WS501-UMB	Ø 150mm, height 332mm
WS502-UMB	Ø 150mm, height 377mm
WS503-UMB	Ø 150mm, height 392mm
WS504-UMB	Ø 150mm, height 317mm
WS600-UMB	Ø 150mm, height 343mm
WS601-UMB	Ø 164mm, height 445mm

Weight including mounting bracket, excluding connection cable:

WS200-UMB	ca. 0.8 kg
WS300-UMB	ca. 1.0 kg
WS400-UMB, WS301-UMB, WS302-UMB, WS303-UMB, WS304-UMB	ca. 1.3 kg
WS401-UMB	ca. 1.5 kg
WS500-UMB	ca. 1.2 kg
WS600-UMB, WS501-UMB, WS502-UMB, WS503-UMB, WS504-UMB	ca. 1.5 kg
WS601-UMB	ca. 1.7 kg

[1] Description of operating modes, see page 35
[2] Factory default, recommended setting

Fastening:	Stainless steel mast bracket for Ø 60 - 76mm	
Protection class:	III (SELV)	
Protection type:	IP66	

Storage Conditions

Permissible storage temperature:	-50°C ... +70°C
Permissible relative humidity:	0 ... 100% RH

Operating Conditions

Permissible operating temperature:	-50°C ... +60°C
Permissible relative humidity:	0 ... 100% RH
Permissible altitude above sea level:	N/A

RS485 interface, 2 wire, half-duplex

Data bits:	8	(SDI-12 mode: 7)
Stop bit:	1	
Parity:	No	(SDI-12 mode: even, Modbus mode none or even)
Tri-state:	2 bits after stop bit edge	
Adjustable baud rates:	1200, 2400, 4800, 9600, 14400, 19200[3], 28800, 57600	

(In SDI-12 mode, the interface is changed to meet the requirements of the standard.)

Housing:	Plastic (PC)

[3]Factory setting; baud rate for operation with ISOCON-UMB and firmware update.

13.1 Measuring Range / Accuracy

13.1.1 Air temperature

Measurement process:	NTC
Measuring range:	-50°C ... +60°C
Resolution:	0.1°C (-20°C...+50°C), otherwise 0.2°C
Sensor accuracy:	+/- 0.2°C (-20°C ... +50°C), otherwise +/-0.5°C (>-30°C)
Sampling rate:	1 minute
Units:	°C; °F

13.1.2 Humidity

Measurement process:	Capacitive
Measuring range:	0 ... 100% RH
Resolution:	0.1% RH
Accuracy:	+/- 2% RH
Sampling rate:	1 minute
Units:	% RH; g/m³; g/kg

13.1.3 Dewpoint Temperature

Measurement process:	Passive, calculated from temperature and humidity
Measuring range:	-50°C ... +60°C
Resolution:	0.1°C
Accuracy:	Computed +/- 0.7°C
Units:	°C; °F

13.1.4 Air Pressure

Measurement process:	MEMS sensor - capacitive
Measuring range:	300 ... 1200hPa
Resolution:	0.1hPa
Accuracy:	+/- 0.5hPa (0 … +40°C)
Sampling rate:	1 minute
Unit:	hPa

13.1.5 Wind Speed

Measurement process:	Ultrasonic
Measuring range:	0 … 75m/s (WS601-UMB: 0 … 30m/s)
Resolution:	0.1m/s
Accuracy:	±0.3 m/s or ±3% (0...35 m/s) ±5% (>35m/s) RMS
Response threshold:	0.3 m/s
Sampling rate:	10 seconds / 1 second with restrictions
Units:	m/s; km/h; mph; kts

13.1.6 Wind Direction

Measurement process:	Ultrasonic
Measuring range:	0 – 359.9°
Resolution:	0.1°
Accuracy:	< 3° (> 1m/s) RMSE
Response threshold:	0.3 m/s
Sampling rate:	10 seconds / 1 second with restrictions

13.1.7 Precipitation

13.1.7.1 WS400-UMB / WS600-UMB

Measurement process:	Radar sensor
Measuring range (drop size):	0.3 mm ... 5.0 mm
Liquid precipitation resolution:	0.01 mm
Precipitation types:	Rain, snow
Repeatability:	Typically > 90%
Response threshold:	0.01 mm
Sampling rate:	Event-dependent on reaching response threshold
Precipitation intensity:	0 … 200 mm/h; Sampling rate 1 minute

13.1.7.2 WS401-UMB / WS601-UMB

Measurement process:	Rain Gauge
Liquid precipitation resolution:	0.2 mm / 0.5mm (adjustable by reduction ring)
Precipitation types:	Rain
Accuracy:	2%
Sampling rate:	1 minute

13.1.8 Compass

Measurement process:	Integrated electronic compass
Measurement range:	0 ... 359°
Resolution:	1.0°
Accuracy:	+/- 10°
Sampling rate:	5 minutes

13.1.9 Global Radiation

Measurement Process	Thermopile pyranometer
Measurement Range	0.0 ... 1400.0 W/m²
Resolution	< 1W/m²
Sampling Rate	1 minute

13.1.9.1 WS301-UMB / WS501-UMB

Response time (95%)	18s
Non-stability(change/year)	<1%
Non-linearity (0 to 1000 W/m²)	<1%
Directional error (at 80° with 1000 W/m²)	<20 W/m²
Temperature dependence of sensitivity	<5% (-10 to +40°C)
Tilt error (at 1000 W/m²)	<1%
Spectral range (50% points)	300 ... 2800nm

13.1.9.2 WS302-UMB / WS502-UMB

Response time (95%)	<1s
Spectral range (50% points)	300 ... 1100nm

13.1.10 Leaf Wetness WLW100

Measurement process:	capacitive
Measuring range:	0 ... 1500 mV
Sampling rate:	1 minute

13.1.11 External Temperature SensorWT1 / WST1

Measurement process:	NTC
Measuring range:	-40°C ... +80°C
Resolution:	0.25°C
Sensor accuracy:	+/- 1°C (WST1: +/-0.3°C between -10°C ...+10°C)
Sampling rate:	1 minute
Units:	°C; °F

13.1.12 External Rain GaugeWTB100

Measurement process:	Rain Gauge with bounce-free reed contact (normally closed)
Liquid precipitation resolution:	0.2 mm / 0.5mm (adjustable by reduction ring)
Precipitation types:	Rain
Accuracy:	2%
Sampling rate:	1 minute

In principle, all rain sensors with bounce-free reed contact (normally open or normally closed) and with a resolution of 0.1 mm, 0.2 mm, 0.5 mm or 1.0 mm can be used.

13.2 Drawings

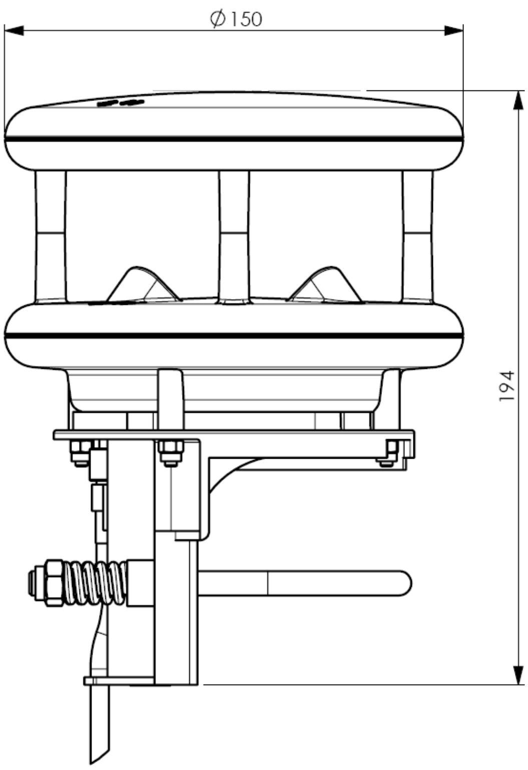


Figure 21: WS200-UMB

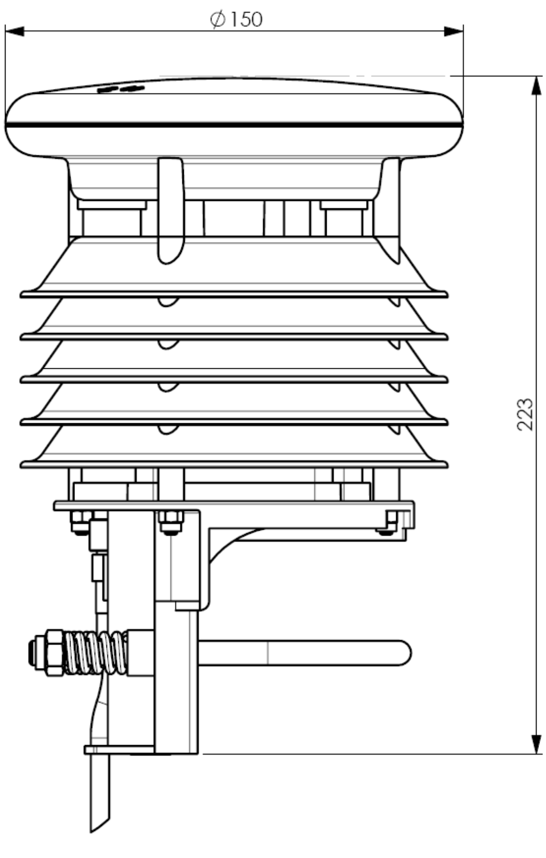


Figure 22: WS300-UMB

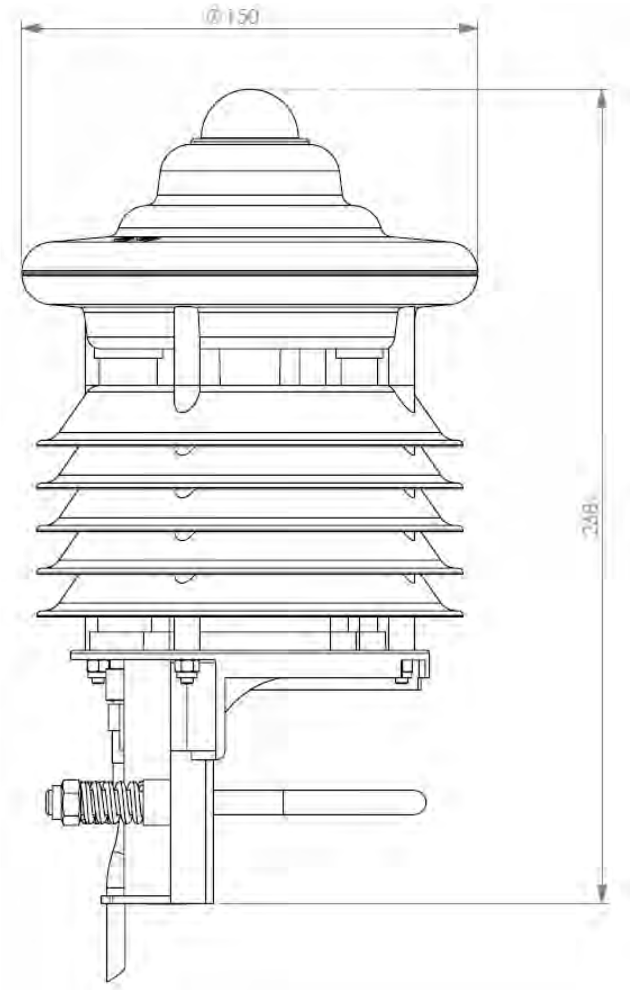


Figure 23: WS301-UMB

WS302-UMB, WS303-UMB und WS304-UMB are similar.

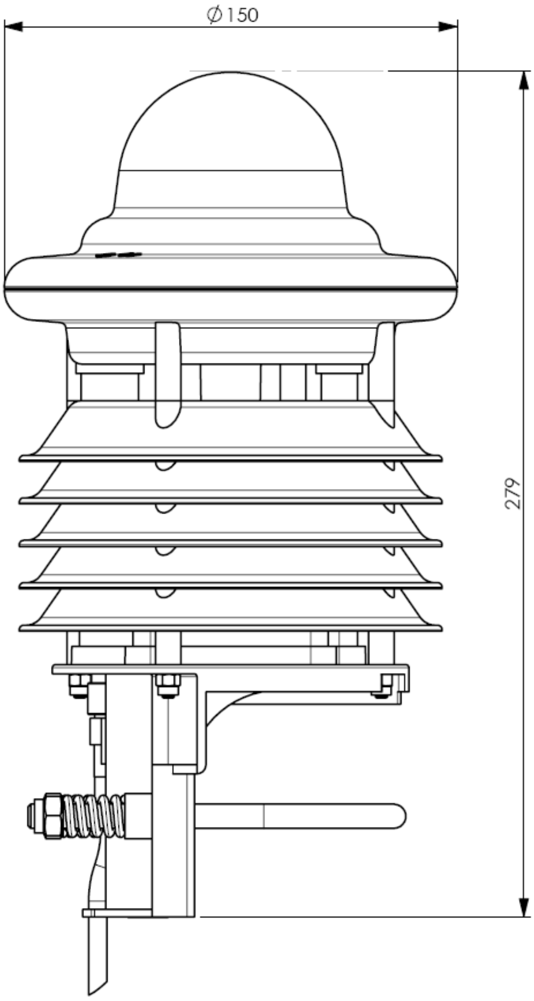


Figure 24: WS400-UMB

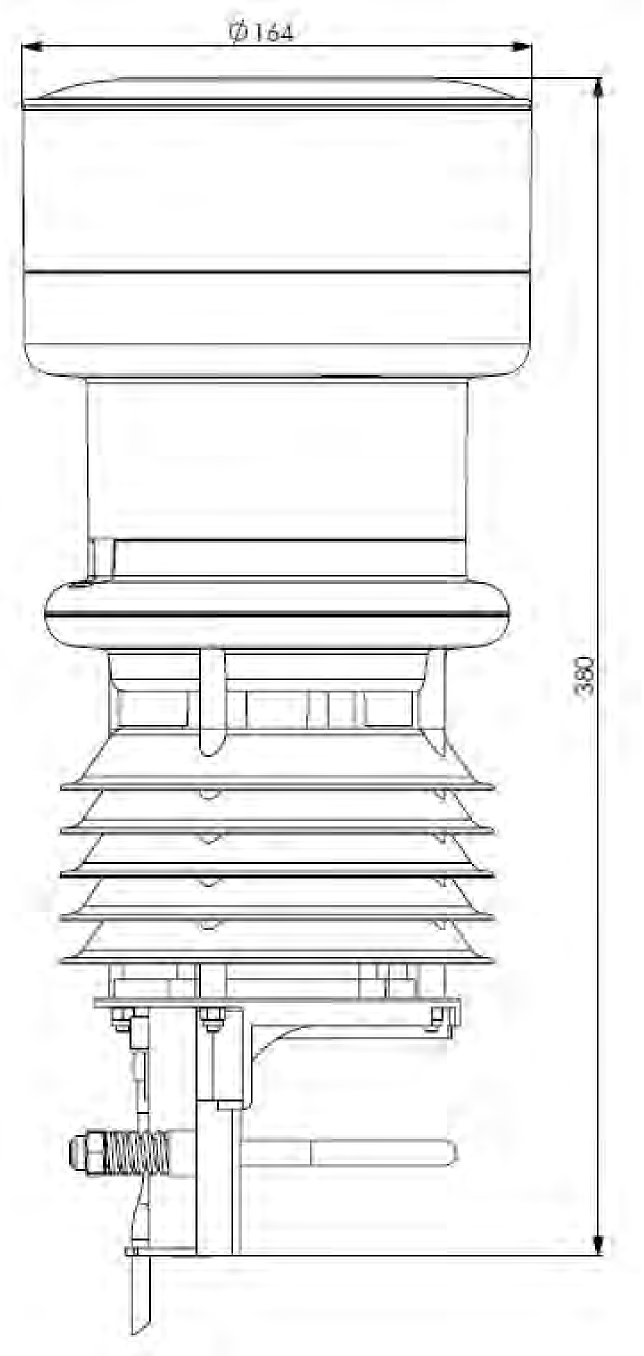


Figure 25: WS401-UMB

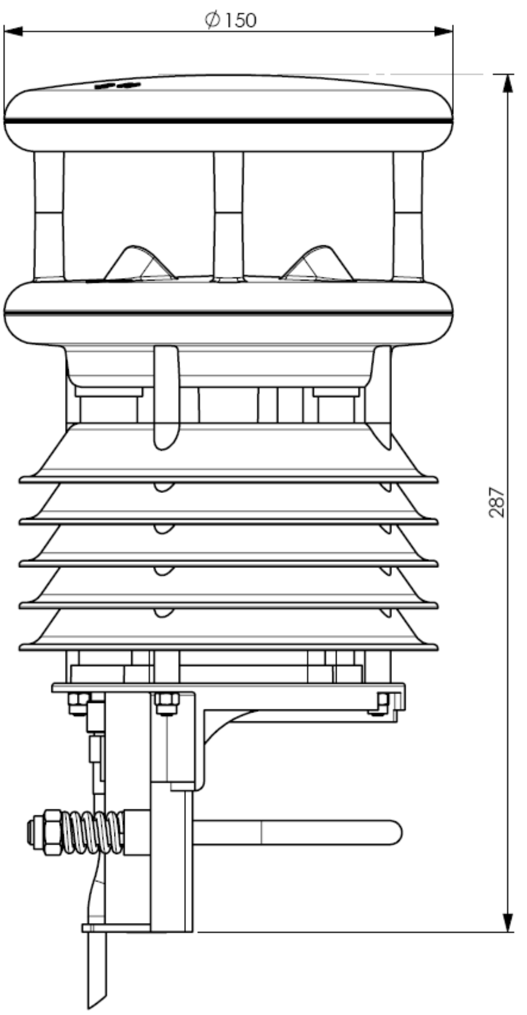


Figure 26: WS500-UMB

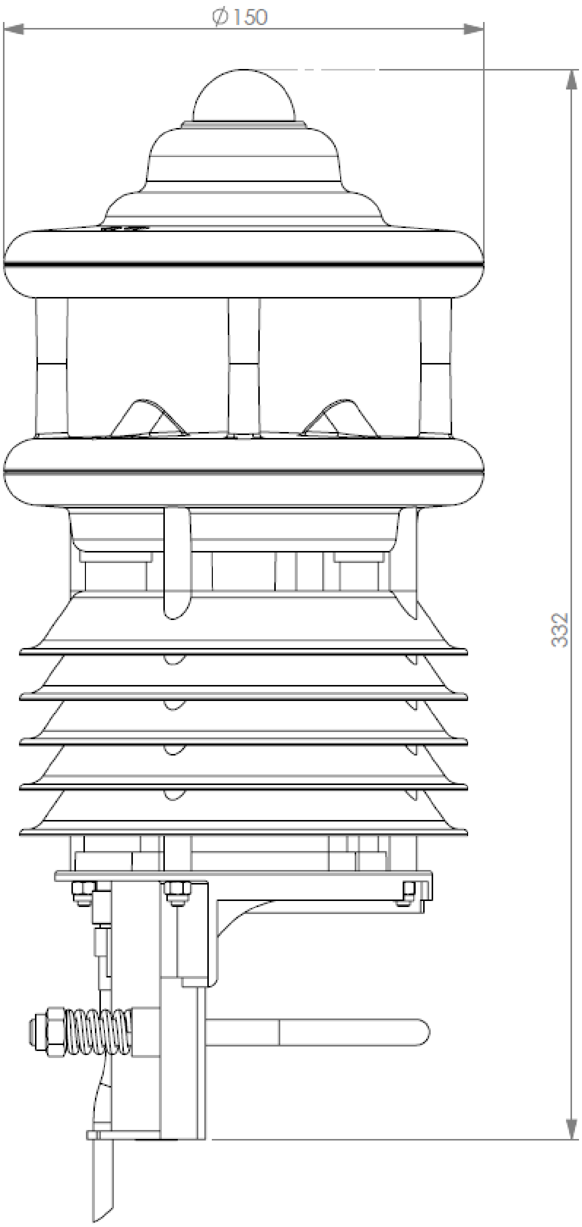


Figure 27: WS501-UMB

WS502-UMB, WS503-UMB und WS504-UMB are similar.

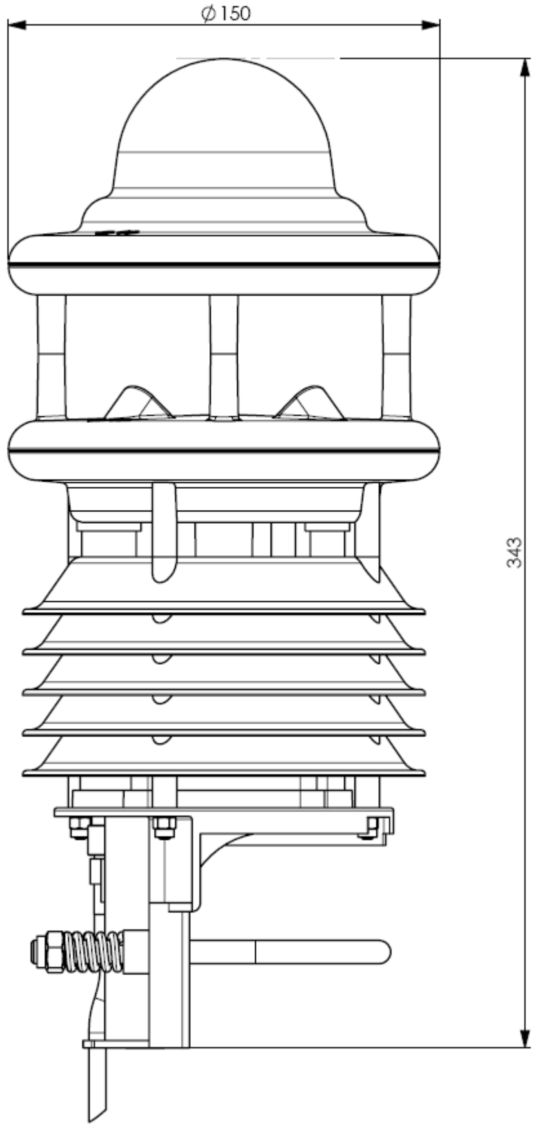


Figure 28: WS600-UMB

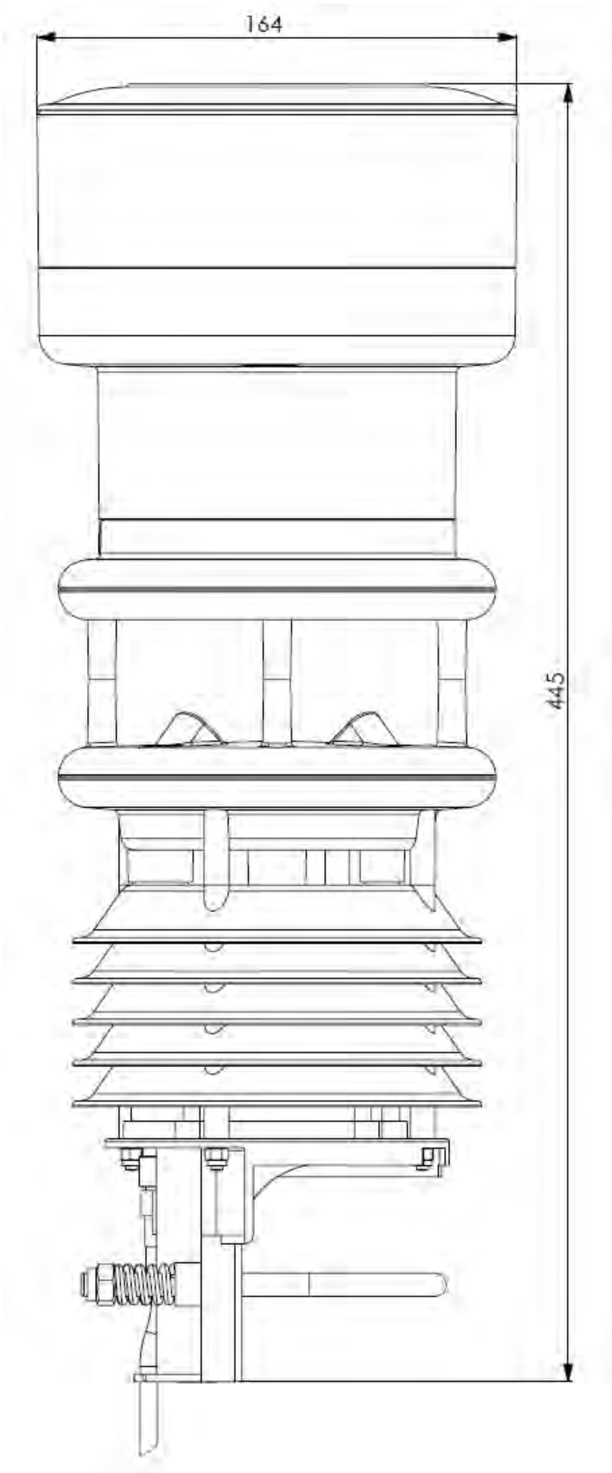


Figure 29: WS601-UMB

14 EC Certificate of Conformity

Product: **Compact Weather Station**

Type: **WS200-UMB (Order No.: 8371.U01)**
WS300-UMB (Order No.: 8372.U01)
WS301-UMB (Order No.: 8374.U01)
WS302-UMB (Order No.: 8374.U10)
WS303-UMB (Order No.: 8374.U11)
WS304-UMB (Order No.: 8374.U12)
WS400-UMB (Order No.: 8369.U01 / 8369.U02)
WS401-UMB (Order No.: 8377.U01)
WS500-UMB (Order No.: 8373.U01)
WS501-UMB (Order No.: 8375.U01)
WS502-UMB (Order No.: 8375.U10)
WS503-UMB (Order No.: 8375.U11)
WS504-UMB (Order No.: 8375.U12)
WS600-UMB (Order No.: 8370.U01 / 8370.U02)
WS601-UMB (Order No.: 8376.U01)

We herewith certify that the above mentioned equipment complies in design and construction with the Directives of the European Union and specifically the EMC Directive in accordance with 2004/108/EC and the RoHSDirective 2011/65/EU.

The above mentioned equipment conforms to the following specific EMC Standards:

EN 61000-6-2:2005Part 6-2: Generic Standards - Immunity for Industrial Environments

EN 61000-4-2 (2009)	ESD
EN 61000-4-3 (2011)	Radiated electromagnetic field
EN 61000-4-4 (2010)	Burst
EN 61000-4-5 (2007)	Surge
EN 61000-4-6 (2009)	Conducted disturbances, induced by radio-frequency fields
EN 61000-4-8 (2010)	Power frequency magnetic field immunity
EN 61000-4-16 (2010)	conducted, common mode disturbances
EN 61000-4-29 (2001)	Short interruptions and voltage variations on d.c. input

EN 61000-6-3:2007Part 6-4: Generic Standards - Emission Standard for Industrial Environments

EN 55011:2009 + A1:2010 (2011)	Line-conducted disturbances
IEC / CISPR 11:2009 and changes 1:2010 Class B	
prEN 50147-3:2000	Radiated emission

Fellbach, 02.03.2012 Axel Schmitz-Hübsch

15 Fault Description

Error description	Cause - Remedy
Device does not allow polling / does not respond	- Check power supply - Check interface connection - Incorrect device ID → check ID; devices are delivered with ID 1.
The device measures precipitation but it is not raining	Check that the sensor was installed correctly in accordance with the instructions.
The measured temperature appears too high / measured humidity appears too low	Check the operation of the fan on the underside of the device.
Wind direction values are incorrect	Device is not correctly aligned → check that the device is aligned to the North.
Device transmits error value 24h (36d)	A channel is being polled that is not available on this device type; e.g. Channel 200 = humidity is being polled on a WS200-UMB.
Device transmits error value 28h (40d)	The device is in the initialization phase following startup→ the device delivers measurements after approx. 10 seconds.
Device transmits error value 50h (80d)	The device is being operated above the limit of the specified measuring range.
Device transmits error value 51h (81d)	The device is being operated below the limit of the specified measuring range.
Device transmits error value 55h (85d) during wind measurement	The device is unable to execute a valid measurement due to the ambient conditions. This may be due to the following reasons: - The device is being operated well above the limit of the specified measuring range - Very strong horizontal rain or snow - The wind meter sensors are very dirty → clean sensor - The wind meter sensors are iced over → check heating mode in the configuration and check heating function / connection - There are foreign objects within the measuring section of the wind meter - One of the wind meter's sensors is faulty → return device to manufacturer for repair
The quality of the wind measurement is not always100%	In normal operation the device should always transmit 90 – 100%. Values up to 50% do not represent a general problem. When the error value 55h (85d) is transmitted this value is 0%. If the device permanently transmits values below 50% this may mean that there is a fault.
Device transmits an error value not listed here	This may be due to a number of reasons → contact the manufacturer's technical support department.

16 Disposal

16.1 Within the EC

The device must be disposed of in accordance with European Directives 2002/96/EC and 2003/108/EC (waste electrical and electronic equipment). Waste equipment must not be disposed of as household waste! For environmentally sound recycling and the disposal of your waste equipment please contact a certified electronic waste disposal company.

16.2 Outside the EC

Please comply with the applicable regulations for the proper disposal of waste electrical and electronic equipment in your respective country.

17 Repair / Corrective Maintenance

Please arrange for any faulty equipment to be checked and, if necessary, repaired by the manufacturer exclusively. Do not open the equipment and do not under any circumstances attempt to carry out your own repairs.

In matters of guarantee or repair please contact:

G. Lufft Mess- und Regeltechnik GmbH

Gutenbergstraße 20
70736 Fellbach

P.O. Box 4252
70719 Fellbach

Germany

Phone: +49 711 51822-0
Hotline: +49 711 51822-52
Fax: +49 711 51822-41

E-mail: info@lufft.de

or your local distributor.

17.1 Technical Support

Our Hotline is available for technical questions via the following e-mail address:

hotline@lufft.de

You can also consult frequently asked questions at http://www.lufft.com/ (menu header: SUPPORT / FAQs).

18 External Sensors

18.1 Leaf Wetness Sensor WLW100

18.1.1 Connection of the Leaf Wetness Sensor

The optional leaf wetness sensor is connected inside the rain gauge module. The cable should not be shortened and be connected with the cable shoes as delivered to avoid contact corrosion.

- Unlock funnel by turning it left and lift it off
- Insert cable (A)
- Connect wires with cable shoes (B)
  Blank 1
  Red 2
  White 3
- Check that the tipping bucket is free to move; if necessary pull the cable back to the appropriate length
- Put funnel back in place and lock it by turning it to the right

Figure 30: Connection of the Leaf Wetness Sensor

18.1.2 Setting the Leaf Wetness Threshold

The leaf wetness sensor will, depending on the degree of wetness on the surface of the sensor leaf, output a voltage between ca. 500mV and 1200mV (UMB-Channel 710). The state wet / dry (UMB- Channel 711) is evaluated from this voltage using an adjustable threshold.

The threshold is pre-set to 580mV (factory setting). It should be checked after installation and, if necessary, adjusted.

Use the UMB Config Tool to measure channel 710 and collect values of the dry sensor for about 10min (see chapter 10.3 Function Test with UMB Config Tool).

The dry leaf value measured should be constant over the measurement interval. We re recommend to set the threshold about 20mV higher than the dry leaf voltage:

Example: measured (dry leaf): 577mV threshold setting**597mV**

The threshold value thus evaluated is set into the configuration using the UMB Config Tool.

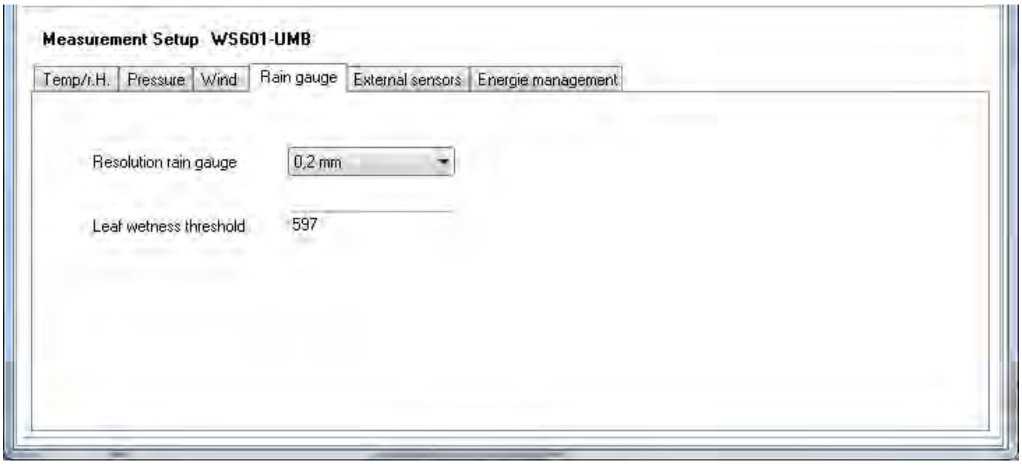


Figure 31: Setting the Leaf Wetness Threshold

Note: We recommend to check the threshold during maintenance and to adjust it if necessary. For the dry leaf measurement the sensor should be cleaned with clear water and carefully dried.

18.2 External Temperature and Precipitation Sensors

18.2.1 Connection of Temperature and Precipitation Sensors

Additional external sensor can cover the requirements of special measurement requirements or extend the functionality of compact weather stations.

Currently the accessory list includes external temperature sensors and the precipitation detection by tipping bucket rain gauge.

One input is available for this extension, so alternatively one temperature sensor or one precipitation sensor may be used.

The connection uses the standard connector plug of the weather station, so normally the external device will be connected at the end of the cable included with the delivery, in the control cabinet. As this cable is part of the measuring line care shall be taken when designing the cabling to avoid parasitic coupling etc. The cable should be as short as possible. In special cases, e.g. when the external sensor is mounted near to the compact weather station while the control cabinet is distant, the installation of an additional distribution box should be considered.

The external sensor is connected to pins 5 and 6 of the connector plug, i.e. the grey and pink wires of the standard cable.

All currently available sensors are unipolar, so the connection sequence is not relevant.

The weather station must be configured for the selected type of external sensor (temperature or precipitation) to enable the correct evaluation of the measurement data. The selection of the sensor type is done through the UMB Config Tool.

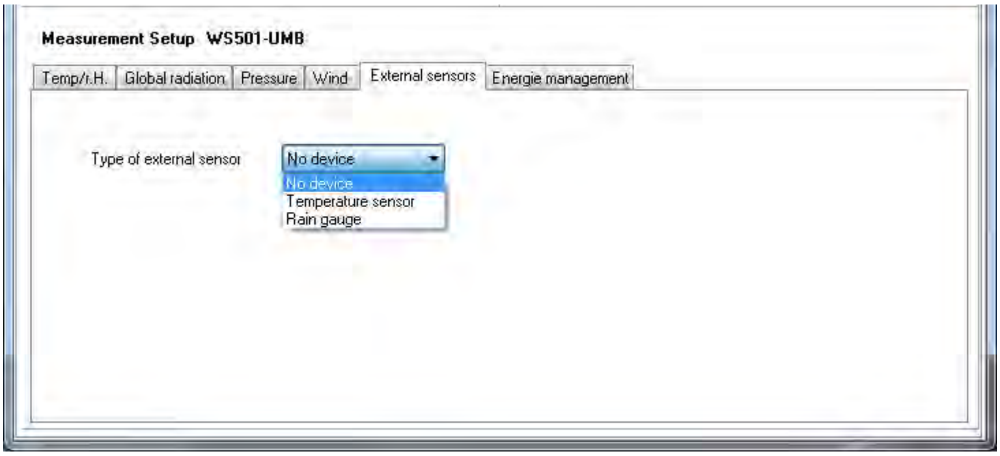


Figure 32: Setting type of external sensor

If the data from the channels of the sensor type currently not selected are requested, the station will respond with “invalid channel”.

18.2.2 External Temperature Sensor

All models of the WS family can be used with an external temperature sensor.

For different application various types of NTC sensor are in supply:

- WT1 for temperature acquisition of devices and surfaces
- WST1 for mounting in the road surface (road surface temperature)

Mounting / installation of the temperature sensors is shown in the sensor manual.

18.2.3 External Rain Gauge

All models of the WS family without integrated precipitation detection can be used with an external rain gauge. Models WS400-UMB, WS600-UMB, WS401-UMB, WS601-UMB with R2S sensor resp. integrated tipping bucket **cannot** be equipped with an external rain gauge.

The measurement values of the external rain gauge are on the same channels as the data of the internal precipitation sensors of WS400-UMB, WS600-UMB, WS401-UMB, and WS601-UMB.

The external rain gauge WTB100 uses the same technology as the integrated rain gauge of models WS401-UMB and WS601-UMB.

The resolution of the rain gauge WTB100can be modified by the reduction ring delivered with the sensor from 0.2mm to 0.5mm.

In principle, all rain sensors with bounce-free reed contact (normally open or normally closed) and with a resolution of 0.1 mm, 0.2 mm, 0.5 mm or 1.0 mm can be used.

Note: To get the correct amount of rain this “mechanical” selection must be also be set in compact weather stations configuration.

The setting is done with the UMB Config Tool by the same procedure as with WS401-UMB and WS601-UMB (s. Chap.10.2.8).

The WS601/401-UMB’s advices for installation (Chap.7.3.4) and maintenance (Chap.12.1) are as well valid for the external rain gauge.

Example with WS501-UMB and WTB100 without reduction ring:

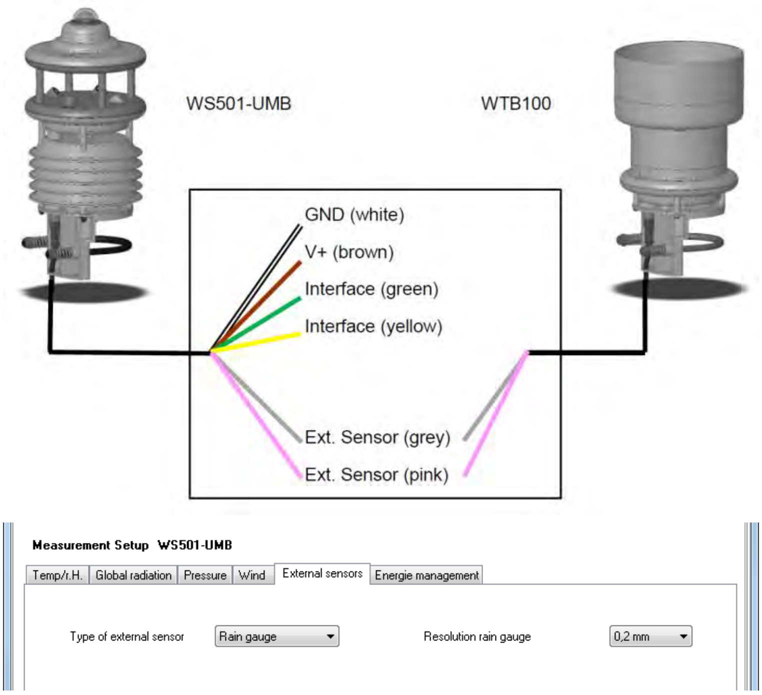


Figure 33: Example WS501-UMB and WTB100

19 Appendix

19.1 Channel List Summary

The channel assignment applies to online data requests in binary and ASCII protocol.

UMB Channel						Measuring Range		
act	min	max	avg	special	Measurement Variable (float32)	min	max	unit
Temperatures								
100	120	140	160		temperature	-50.0	60.0	°C
105	125	145	165		temperature	-58.0	140.0	°F
101					external temperature	-40.0	80.0	°C
106					external temperature	-40.0	176.0	°F
110	130	150	170		dewpoint	-50.0	60.0	°C
115	135	155	175		dewpoint	-58.0	140.0	°F
111					wind chill temperature	-60.0	70.0	°C
116					wind chill temperature	-76.0	158.0	°F
114					wet bulb temperature	-50.0	60.0	°C
119					wet bulb temperature	-58.0	140.0	°F
112					wind heater temp.	-50.0	150.0	°C
113					R2S heater temp.	-50.0	150.0	°C
117					wind heater temp.	-58.0	302.0	°F
118					R2S heater temp.	-58.0	302.0	°F
Humidity								
200	220	240	260		relative humidity	0.0	100.0	%
205	225	245	265		absolute humidity	0.0	1000.0	g/m³
210	230	250	270		mixing ratio	0.0	1000.0	g/kg
Enthalpy								
215					specific enthalpy	-100.0	1000.0	kJ/kg
Pressure								
300	320	340	360		abs. air pressure	300	1200	hPa
305	325	345	365		rel. air pressure	300	1200	hPa
Air Density								
310					air density	0.0	3.0	kg/m³
Wind								
				vect. avg				
400	420	440	460	480	wind speed	0	75.0	m/s
405	425	445	465	485	wind speed	0	270.0	km/h
410	430	450	470	490	wind speed	0	167.8	mph
415	435	455	475	495	wind speed	0	145.8	kts
401					wind speed fast	0	75.0	m/s
406					wind speed fast	0	270.0	km/h
411					wind speed fast	0	167.8	mph
416					wind speed fast	0	145.8	kts
403					wind speed standard deviation	0	75.0	m/s
413					wind speed standard deviation	0	167.8	mph
500	520	540		580	wind direction	0	359.9	°
501					wind direction fast	0	359.9	°
502					wind direction corr.	0	359,9	°
503					wind direction standard deviation	0	359.0	°
805					wind value quality	0	100.0	%
Compass								
510					compass heading	0	359	°

Precipitation Quantity			Range	Unit
600	float32	Precipitation Quantity - Absolute	0 … 100000	liters/m²
620	float32	Precipitation Quantity - Absolute	0 … 100000	mm
640	float32	Precipitation Quantity - Absolute	0 … 3937	inches
660	float32	Precipitation Quantity - Absolute	0 … 3937008	mil
605	float32	Precipitation Quantity - Differential	0 … 100000	liters/m²
625	float32	Precipitation Quantity - Differential	0 … 100000	mm
645	float32	Precipitation Quantity - Differential	0 … 3937	inches
665	float32	Precipitation Quantity - Differential	0 … 3937008	mil
Precipitation Type				
700	uint7	Precipitation Type	0 = No precipitation 40 = unspecified precipitation 60 = Liquid precipitation, e.g. rain 70 = Solid precipitation, e.g. snow	
Precipitation Intensity			**Range**	**unit**
800	float32	Precipitation Intensity	0 … 200.0	l/m²/h
820	float32	Precipitation Intensity	0 … 200.0	mm/h
840	float32	Precipitation Intensity	0 … 7.874	in/h
860	float32	Precipitation Intensity	0 … 7874	mil/h

act	min	max	avg	special	Measurement Variable (float32)	min	max	unit
Global Radiation								
900	920	940	960		Global Radiation	0	1400	W/m²
Leaf Wetness								
710	730	750	770		Leaf Wetness mV	0.0	1500.0	mV
711					Leaf Wetness State	0 = dry 1 = wet		

Note: The channels which are actually available are dependent on the WSxxx-UMB type in use.

19.2 Channel List Summary per TLS2002 FG3

The following channels are available specifically for data requests for further processing in TLS format. These channels are only available in the UMB-Binary protocol.

DE Type	UMB Channel	Meaning	Format	Range	Resolution	Coding
48	1048	Result message Air Temperature LT	16 bit	-30 ... +60°C	0.1°C	60.0 = 600d = 0258h 0.0 = 0d = 0000h -0.1 = -1d = FFFFh -30.0 = -300d = FED4h
53	1053	Result message Precipitation Intensity NI	16 bit	0 ... 200 mm/h	0.1 mm/h	0.0 = 0d = 0000h 200.0 = 2000d = 07D0h
54	1054	Result message Air Pressure LD	16 bit	800...1200 hPa	1 hPa	800 = 800d = 0320h 1200 = 1200d = 04B0h
55	1055	Result message Relative Humidity RLF	8 bit	10% ... 100%	1% RH	10% = 10d = 0Ah 100% = 100d = 64h
56	1056	Result message Wind Direction WR	16 bit	0 ... 359°	1°	0° (N) = 0d = 0000h 90° (O) = 90d = 005Ah 180° (S) = 180d = 00B4h 270° (W) = 270d = 010Eh FFFFh = not definable
57	1057	Result message Wind Speed. (average) WGM	16 bit	0.0 ... 60.0 m/s	0.1 m/s	0.0 = 0d = 0000h 60.0 = 600d = 0258h
64	1064	Result message Wind Speed (peak) WGS	16 bit	0.0 ... 60.0 m/s	0.1 m/s	0.0 = 0d = 0000h 60.0 = 600d = 0258h
66	1066	Result message Dewpoint Temperature TPT	16 bit	-30 ... +60°C	0.1°C	60.0 = 600d = 0258h 0.0 = 0d = 0000h -0.1 = -1d = FFFFh -30.0 = -300d = FED4h
71	1071	Result message Precipitation Type NS	8 bit			0 = No precipitation 40 = unspecified precipitation 60 = Liquid precipitation, e.g. rain 70 = Solid precipitation, e.g. snow

Note: The channels which are actually available are dependent on the WSxxx-UMB type in use.

The previous channels 1153 and 1253 are no longer supported. Channels 840 and 860 can be used in their place.

19.3 Communication in Binary Protocol

Only one example of an online data request is described in this operating manual. Please refer to the current version of the UMB Protocol for all commands and the exact mode of operation of the protocol (available for download at www.lufft.com).

Note: Communication with the sensor takes place in accordance with the master-slave principle, i.e. there may only be ONE requesting unit on a network.

19.3.1 Framing

The data frame is constructed as follows:

1	2	3 - 4	5 - 6	7	8	9	10	11 ... (8 + len) optional	9 + len	10 + len 11 + len	12 + len
SOH	<ver>	<to>	<from>	<len>	STX	<cmd>	<verc>	<payload>	ETX	<cs>	EOT

SOH Control character for the start of a frame (01h); 1 byte
<ver> Header version number, e.g.: V 1.0 →<ver> = 10h = 16d; 1 byte
<to> Receiver address; 2 bytes
<from> Sender address; 2 bytes
<len> Number of data bytes between STX and ETX; 1 byte
STX Control character for the start of payload transmission (02h); 1 byte
<cmd> Command; 1 byte
<verc> Version number of the command; 1 byte
<payload> Data bytes; 0 – 210 bytes
ETX Control character for the end of payload transmission (03h); 1 byte
<cs> Check sum, 16 bit CRC; 2 bytes
EOT Control character for the end of the frame (04h); 1 byte
Control characters: SOH (01h), STX (02h), ETX (03h), EOT (04h).

19.3.2 Addressing with Class and Device ID

Addressing takes place by way of a 16 bit address. This breaks down into a Class ID and a Device ID.

Address (2 bytes = 16 bit)				
Bits 15 – 12 (upper 4 bits)		**Bits 11 – 8 (middle 4 bits)**	**Bits 7 – 0 (lower 8 bits)**	
Class ID (0 to 15)		**Reserve**	**Device ID** (0 – 255)	
0	Broadcast		0	Broadcast
7	Compact Weather Station (WS200-UMB – WS600-UMB)		1 - 255	Available
15	Master or control devices			

ID = 0 is provided as broadcast for classes and devices. Thus it is possible to transmit a broadcast on a specific class. However this only makes sense if there is only one device of this class on the bus; or in the case of a command, e.g. reset.

19.3.3 Examples for Creating Addresses

If, for example, you want to address WS400-UMB with the device ID 001, this takes place as follows:

The class ID for the compact weather station is 7d = 7h;
the device ID is e.g. 001d = 001h

Putting the class and device IDs together gives the address 7001h (28673d).

19.3.4 Example of a Binary Protocol Request

If, for example, a compact weather station with the device ID 001 is to be polled from a PC for the current temperature, this takes place as follows:

Sensor:

The class ID for the compact weather stations 7 = 7h;

The device ID is 001 = 001h

Putting the class and device IDs together gives a target address of 7001h.

PC:

The class ID for the PC (master unit) is 15 = Fh;
the PC ID is e.g. 001d = 01h.

Putting the class and device IDs together gives a sender address of F001h.

The length <len> for the online data request command is 4d = 04h;

The command for the online data request is 23h;

The version number of the command is 1.0 = 10h.

The channel number is in <payload>; as can be seen from the channel list (page 61), the current temperature in °C in the channel is 100d = 0064h.

The calculated CRC is D961h.

The request to the device:

SOH	<ver>	<to>		<from>		<len>	STX	<cmd>	<verc>	<channel>		ETX	<cs>		EOT
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
01h	10h	01h	70h	01h	F0h	04h	02h	23h	10h	64h	00h	03h	61h	D9h	04h

The response from the device:

SOH	<ver>	<to>		<from>		<len>	STX	<cmd>	<verc>	<status>	<channel>		<typ>
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
01h	10h	01h	F0h	01h	70h	0Ah	02h	23h	10h	00h	64h	00h	16h

<value>				ETX	<cs>		EOT
15	**16**	**17**	**18**	**19**	**20**	**21**	**22**
00h	00h	B4h	41h	03h	C6h	22h	04h

Interpretation of the response:

<status> = 00h device o.k. (≠ 00h signifies error code; see page 66)

<typ> = Data type of the following value; 16h = float (4 bytes, IEEE format)

<value> = 41B40000h as a float value corresponds to 22.5

The temperature is therefore 22.5°C.

The correct data transmission can be checked with the aid of the check sum (22C6h).

Note: Little Endian (Intel, low byte first) applies when transmitting word and float variables of addresses or the CRC, for example. This means first the LowByte and then the HighByte.

19.3.5 Status and Error Codes in Binary Protocol

If a measurement request delivers the <status> 00h, the sensor is working correctly. You can find a complete list of additional codes in the description of the UMB protocol.

Extract from list:

<status>	Description
00h (0d)	Command successful; no error; all o.k.
10h (16d)	Unknown command; not supported by this device
11h (17d)	Invalid parameter
24h (36d)	Invalid channel
28h (40d)	Device not ready; e.g. initialization / calibration running
50h (80d)	Measurement variable (+offset) is outside the set display range
51h (81d)	
52h (82d)	Measurement value (physical) is outside the measuring range (e.g. ADC over range)
53h (83d)	
54h (84d)	Error in measurement data or no valid data available
55h (85d)	Device / sensor is unable to execute valid measurement due to ambient conditions

19.3.6 CRC Calculation

CRC is calculated according to the following rules:

Norm: CRC-CCITT

Polynomial: 1021h = $x^{16} + x^{12} + x^5 + 1$ (LSB first mode)

Start value: FFFFh

You can find further information in the description of a CRC calculation in UMB Protocol.

19.3.7 Data Request in Power Saving Mode 2

When in power saving mode2 the processor of the compact weather station will be usually in sleep state. For the acquisition of measurement data a certain command sequence and a certain timing is required:

- „Wake Up“ bei sending a <Break>, any character or any telegram (a telegram will not be properly detected and get no response, because the UART is just starting)
- 1000msec pause for the processor start up
- Activation of the measurement cycle by (any) valid telegram addressed to this station
- 2000msec pause for the execution of the measurement sequence
- Request of the measurement results

Example of a Request Sequence:

```
Command Data Request (0x23), Channel 100
       No response
Wait 1 sec
Command Data Request (0x23), Channel 100
       Discard data
Wait 2 sec
CommandMultiData Request (0x2F), Ch. 100, 200, 300, 620, 605, 700
       Store data
```

19.4 Communication in ASCII Protocol

Text-based communication with devices is possible using ASCII protocol.

To do this, in the device configuration, interface settings, the protocol mode must be set to ASCII (see page 29).

ASCII protocol is network-compatible and serves exclusively for online data requests. The device will not respond to incomprehensible ASCII commands.

Note: The use of binary protocol is recommended for lengthy transmission routes (e.g. network, GPRS/UMTS), as ASCII protocol is unable to detect transmission errors (not CRC-secured).

Note: TLS channels are not available in ASCII protocol.

19.4.1 Structure

An ASCII command is introduced by the '&' character and completed by the CR (0Dh) sign. There is a space character (20h) between the individual blocks in each case; this is represented by an underscore character '_'. Characters that represent an ASCII value are in ordinary inverted commas.

19.4.2 Summary of ASCII Commands

Command	Function	BC	AZ
M	Online data request		l
X	Switches to binary protocol		k
R	Triggers software reset	●	k
D	Software reset with delay	●	k
I	Device information		k

These operating instructions describe the online data request only. You can find the description of the other commands in the UMB protocol.

19.4.3 Online Data Request (M)

Description: By way of this command, a measurement value is requested from a specific channel.

Request: '&'_<ID>^{5}_'M'_<channel>^{5} CR

Response: '$'_<ID>^{5}_'M'_<channel>^{5}_<value>^{5} CR

<ID>^{5} Device address (5 decimal places with leading zeros)

<channel>^{5} Indicates the channel number (5 decimal places with leading zeros)

<value>^{5} Measurement value (5 decimal places with leading zeros); a measurement value standardized to 0 – 65520d. Various error codes are defined from 65521d – 65535d.

Example:

Request: &_28673_M_00100

By way of this request, channel 100 of the device with address 28673 is interrogated (compact weather station with device ID 001).

Response: $_28673_M_00100_34785

This channel outputs a temperature from –50 to +60°C, which is calculated as follows:

0d	corresponds to	-50°C
65520d	corresponds to	+60°C
36789d	corresponds to	[+60°C – (-50°C)] / 65520 * 34785 +(-50°C) = 8.4°C

Note: TLS channels are not available in ASCII protocol.

19.4.4 Standardization of Measurement Values in ASCII Protocol

The standardization of measurement values from 0d – 65520d corresponds to the measuring range of the respective measurement variable.

Measurement Variable	Measuring Range		
	Min	Max	Unit
Temperature			
Temperature Dew point Wet Bulb Temperature	-50.0	60.0	°C
	-58.0	140.0	°F
External Temperature	-40.0	80.0	°C
	-40.0	176.0	°F
Wind chill temperature	-60.0	70.0	°C
	-76.0	158.0	°F
Humidity			
Relative humidity	0.0	100.0	%
Absolute humidity Mixing ratio	0.0	1000.0	g/m³ g/kg
Specific Enthalpy	-100.0	1000.0	kJ/kg
Pressure			
Relative air pressure Absolute air pressure	300.0	1200.0	hPa
Air Density			
air density	0.0	3.0	kg/m³
Wind			
Wind speed	0.0	75.0	m/s
	0.0	270.0	km/h
	0.0	167.8	mph
	0.0	145.8	kts
Wind direction	0.0	359.9	°
wind value quality	0.0	100.0	%
Rain			
Quantity	0.0	6552.0	litres / m²
	0.0	6552.0	mm
	0.0	257.9	inches
	0.0	257952.7	mil
Quantity since last request	0.0	655.2	litres / m²
	0.0	655.2	mm
	0.0	25.79	inches
	0.0	25795.2	mil
Precipitation type	0 = No precipitation 40 = Precipitation 60 = Liquid precipitation, e.g. rain 70 = Solid precipitation, e.g. snow		
Precipitation intensity	0.0	200.0	l/m²/h
	0.0	200.0	mm/h
	0.0	7.874	in/h
	0.0	7874	mil/h
Global Radiation			
Global Radiation	0.0	1400.0	W/m²
Leaf Wetness			
Leaf Wetness mV	0.0	1500.0	mV
Leaf Wetness State	0 = dry 1 = wet		

19.4.5 Error Codes in the ASCII Protocol

Various error codes are defined from 65521d – 65535d in addition to the standardisation for the transmission of measurement values.

<code>	Description
65521d	Invalid Channel
65523d	Value Overflow
65524d	Value Underflow
65525d	Error in measurement data or no valid data available
65526d	Device / sensor is unable to execute valid measurement due to ambient conditions
65534d	Invalid Calibration
65535d	Unknown Error

19.5 Communication in Terminal Mode

It is possible to communicate with a device in a very simple text-based manner using the terminal mode.

To do this, in the device configuration, interface settings, the protocol mode must be set to terminal (see page 29).

Note: In the case of communication in the terminal mode, only one single unit may be connected to the interface, as this protocol is **NOT** network-compatible. It is used for very simple measurement value requests.

Note: The use of binary protocol is recommended for lengthy transmission routes (e.g. network, GPRS/UMTS), as it is not possible to detect transmission errors in terminal mode (not CRC-secured).

Note: In the terminal mode, measurement values are not available in all units. Furthermore, status and error messages are not transmitted.

19.5.1 Structure

A terminal consists of an ASCII character and a numeric character. The command is completed with the <CR> sign. There is no echo on entry.

The individual values in the response are separated by a semi-colon (;). The response is completed with <CR><LF>.

An invalid terminal command is acknowledged with ‘FAILED’. Control commands are acknowledged with ‘OK’.

The command to which the response relates is given at the beginning of each response.

Note: No response times are specified in the terminal mode.

19.5.2 Terminal Commands

The terminal commands transmit the following values or have the following functions:

`E0<CR>`	Temperature in °C	Ta	C	(Channel 100)
	Dew point temperature in °C	Tp	C	(Channel 110)
	Wind chill temperature in °C	Tw	C	(Channel 111)
	Relative humidity in %	Hr	P	(Channel 200)
	Relative air pressure in hPa	Pa	H	(Channel 305)
	Wind speed in m/s	Sa	M	(Channel 400)
	Wind direction in °	Da	D	(Channel 500)
	Precipitation quantity in mm	Ra	M	(Channel 620)
	Precipitation type	Rt	N	(Channel 700)
	Precipitation intensity in mm/h	Ri	M	(Channel 820)
`E1<CR>`	Temperature in °F	Ta	F	(Channel 105)
	Dew point temperature in °F	Tp	F	(Channel 115)
	Wind chill temperature in °F	Tw	F	(Channel 116)
	Relative humidity in %	Hr	P	(Channel 200)
	Relative air pressure in hPa	Pa	H	(Channel 305)
	Wind speed in mph	Sa	S	(Channel 410)
	Wind direction in °	Da	D	(Channel 500)
	Precipitation quantity in inches	Ra	I	(Channel 640)
	Precipitation type	Rt	N	(Channel 700)
	Precipitation intensity in inches/h	Ri	I	(Channel 840)
`E2<CR>`	Act. wind speed in m/s	Sa	M	(Channel 400)
	Min. wind speed in m/s	Sn	M	(Channel 420)
	Max. wind speed in m/s	Sx	M	(Channel 440)
	Avg. wind speed in m/s	Sg	M	(Channel 460)
	Vct. wind speed in m/s	Sv	M	(Channel 480)
	Act. wind direction in °	Da	D	(Channel 500)
	Min. wind direction in °	Dn	D	(Channel 520)
	Max. wind direction in °	Dx	D	(Channel 540)
	Vct. wind direction in °	Dv	D	(Channel 580)
`E3<CR>`	Act. wind speed in mph	Sa	S	(Channel 410)
	Min. wind speed in mph	Sn	S	(Channel 430)
	Max. wind speed in mph	Sx	S	(Channel 450)
	Avg. wind speed in mph	Sg	S	(Channel 470)
	Vct. wind speed in mph	Sv	S	(Channel 490)
	Act. wind direction in °	Da	D	(Channel 500)
	Min. wind direction in °	Dn	D	(Channel 520)
	Max. wind direction in °	Dx	D	(Channel 540)
	Vectorial wind direction in °	Dv	D	(Channel 580)
`E4<CR>`	Act. Compass heading in °	Ca	D	(Channel 510)
	Act. Global Radiation in W/m²	Ga	W	(Channel 900)
	Min. Global Radiation in W/m²	Gn	W	(Channel 920)
	Max. Global Radiation in W/m²	Gx	W	(Channel 940)
	Avg. Global Radiation in W/m²	Gg	W	(Channel 960)
	Act. Specific Enthalpy in KJ/Kg	Ea	J	(Channel 215)
	Act. Wet Bulb Temperature in °C	Ba	C	(Channel 114)
	Act. Wet Bulb Temperature in °F	Ba	F	(Channel 119)
	Act. Air Density in kg/m³	Ad	G	(Channel 310)
`E5<CR>`	act. Leaf Wetness mV	La	X	(Channel 710)
	act. Leaf Wetness State	Lb	X	(Channel 711)
	external temperature (act) °C	Te	C	(Channel 101)
	external temperature (act) °F	Te	F	(Channel 106)
	Reserve	Xx	X	
	Reserve	Xx	X	
	Reserve	Xx	X	
	Reserve	Xx	X	
	Reserve	Xx	X	

`Mx<CR>` Displays the same values as `Ex<CR>`, but without additional information such as the measurement variable and unit

`I0<CR>` Serial number; date of manufacture; project number; parts list version; SPLAN version; hardware version; firmware version; E2 version; device version

`I1<CR>` Outputs the device description

R0<CR>	Executes a device reset
R1<CR>	Resets the accumulated rain quantity and executes a device reset
X0<CR>	Temporarily switches to UMB binary protocol

Examples:

E0<CR>	E0;Ta+024.9C;Tp+012.2C;Tw+026.8C;Hr+045.0P;Pa+0980.6H; Sa+005.1M;Da+156.6D;Ra+00042.24M;Rt+060N;Ri+002.6M;
M0<CR>	M0;+024.9;+012.2;+026.8;+045.0;+0980.6; +005.1;+156.6;+00042.24;+060;+002.6;
E2<CR>	E2;Sa+005.1M;Sn+001.1M;Sx+007.1M;Sg+005.1M;Sv+005.0M; Da+156.6D;Dn+166.6D;Dx+176.6D;Dv+156.6D;
M2<CR>	M2;+005.1;+001.1;+007.1;+005.1;+005.0; +156.6;+166.6;+176.6;+156.6;
I0<CR>	I0;001;0109;0701;004;005;001;016;011;00002;<CR><LF>
R0<CR>	R0;OK;<CR><LF>

19.6 Communication in SDI-12 Mode

The communication in the SDI-12 mode of the WSxxx-UMB is conforming to the standard defined in ‚SDI-12 A Serial-Digital Interface Standard for Microprocessor-Based Sensors Version 1.3 January 12, 2009‘ . The station may be operated in bus mode together with other SDI-12 sensors, connected to one SDI master (logger).

19.6.1 Preconditions for SDI-12 Operation

As the interface settings defined in the SDI-12 standard are significantly different from the UMB default settings the related parameters have to be set properly by the UMB Config Tool (latest version!).

The protocol mode of the station has to be set to “SDI-12”. This will automatically set the baud rate to 1200.

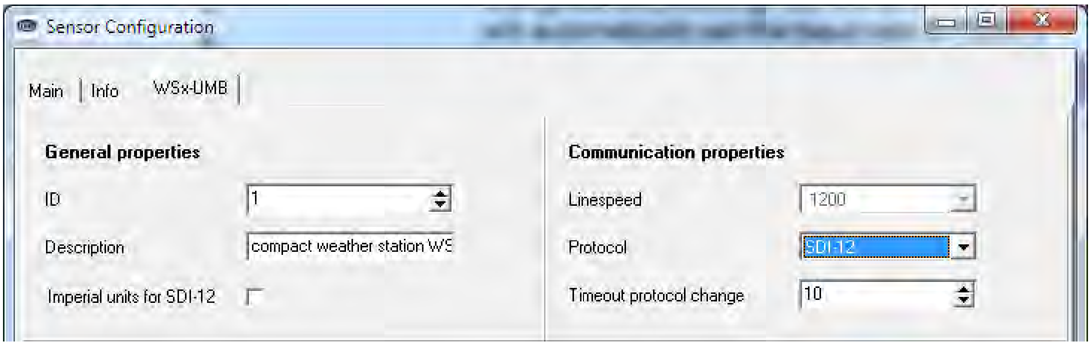
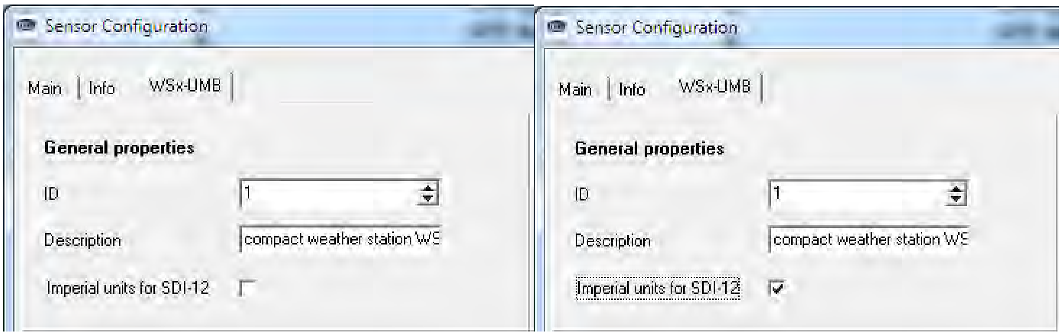


Figure 34: Sensor Configuration SDI-12

Measurement data can be transmitted alternatively in metric or US units. The selection is done by the UMB Config Tool.



Metric units US units

Figure 35: Sensor Configuration SDI-12 Units

When operating the device in SDI-12 mode it is basically no more possible to access the device with the UMB Config Tool, due to the different interface parameter settings. To enable configuration access nevertheless the interface is operated in standard UMB mode (19200 8N1) for the first 5 seconds after reset / power on. During this time the UMB device ID, if unequal 1, is set to 200, so access will be possible even if the device ID is unknown. If a valid UMB telegram is received within this 5 sec, the device will stay in UMB mode for the configured time out (several minutes) so that the configuration can be modified.

- Connect the PC to the WSxxx-UMB through an RS-485 converter
- Start the UMB Config Tool and create a WSxxx-UMB with the address (1 or 200) of the actual device and activate at least one sensor. Start the measurement (will report connection error at first)
- Reset the device (Power off / on)
- When measurement values are received the measurement can be terminated, the interface is now open for configuration.

19.6.2 Command Set

For details of the SDI-12 protocol please refer to the above mentioned standard document.

Following commands are available for devices of the WS family:

Note: The examples in the following sections use italics to print the requests from the logger (*0V!*)

Command	Function
?!	Address search (Wildcard request, one device only on bus!)
a!	Request device active?
aI!	Request device identification
aAb!	Address change to b (0 … 9, A …Z, a … z)
aM!	Measurement basic minimal data set
aM1!	Measurement temperatures
aM2!	Measurement humidity
aM3!	Measurement air pressure
aM4!	Measurement wind
aM5!	Measurement compass
aM6!	Measurement precipitation
aM7!	Measurement global radiation
aM8!	Measurement external temperature
aMC!	Measurement, basic minimal data set, transmit values with CRC
aMC1! ... aMC8!	Measurement (assignment of values as for aMn! commands), transmit values with CRC
aC!	Concurrent measurement, full basic data set
aC1! ... aC8!	Concurrent measurement, assignment of values as for aMn! commands, partly extended data sets
aCC!	Concurrent measurement, transmit values with CRC
aCC1! ... aCC8!	Concurrent measurement, assignment of values as for aMn! commands, partly extended data sets, transmit values with CRC
aD0!	Data request buffer 0
aD1!	Data request buffer 1
aD2!	Data request buffer 2
aD3!	Data request buffer 3
aD4!	Data request buffer 4
aR0!	Data request from continuous measurement, data set 0
aR1!	Data request from continuous measurement, data set 1
aR2!	Data request from continuous measurement, data set 2
aR3!	Data request from continuous measurement, data set 3
aR4!	Data request from continuous measurement, data set 4
aRC0!	Data request from continuous measurement, data set 0 with CRC
aRC1!	Data request from continuous measurement, data set 1 with CRC
aRC2!	Data request from continuous measurement, data set 2 with CRC
aRC3!	Data request from continuous measurement, data set 3 with CRC
aRC4!	Data request from continuous measurement, data set 4 with CRC
aV!	Command verification: Evaluate sensor status and heating temperatures, data request with aD0!, aD1!
aXU<m/u>!	Change the unit system for SDI data
aXH+nnnn!	Set local altitude of the device for calculation of rel. air pressure

Command	Function
aXD+nnn.n!	Set local compass deviation
aXL<n/s/w>!	Set power saving mode
aXMn!	Set the heating mode of the device
aXA<t/p/w>+nn!	Integration time for average and min/max evaluation
aXC!	Clear the abs. precipitation amount (includes a device reset)
aXR!	Device reset

The composition of the minimal and the full basic data set depends on the variant (WS200 ... WS600) of the device in question (see below). The same applies to the availability of the additional measurement commands (aM1!, aC1! etc.)

Due the applied measurement processes the devices of the WS family will, different from other sensors described in the SDI-12 document, in **normal operation mode** always measure continuously. This causes some special properties while in this mode:

- The device does not need a "Wakeup" and does not have a sleep mode. So the reactions to "Break" signals and any related timings are inapplicable. "Break" will be ignored by WS devices.
- Data requested with M- or C- commands are always available immediately. The device will always respond with `a000n` resp. `a000nn`. This means the device will not send any service request and will ignore measurement abort signals. The logger should request the data immediately.
- M- and C- command only differ in the number of values made available in the buffers (in both cases the maximum permitted by the standards of 9 resp. 20).
- We recommend to use the commands for continuous measurement (R-commands) to request the data.
- When in **power saving mode 2** the device will wake up by a „Break" signal. Other functions of the „Break" signal are not implemented.
- When in **power saving mode 2**the device responds to M or C commands with `a002n` resp. `a002nn` and holds the data available within 2 seconds. It will not send a service request, signals to abort the measurement are ignored.
- For the reduced data set in power saving mode 2 a unified data buffer structure for all device models has been defined. Depending on the individual model unused channels will be set to the "invalid" marker 999.9.

19.6.3 Address Configuration

UMB Device-ID and SDI-12 Address are connected, but the different address ranges and the fact, that UMB ID's are integer numbers, while SDI-12 addresses are ASCII characters, have to be considered.

The SDI-12 address is built from the UMB device ID as follows:

UMB Device ID 1 (default) corresponds to SDI-12 Address '0' (SDI-12 default).

Changing the SDI12 address by SDI12 setting command also modifies the UMB device ID accordingly.

Valid Address Ranges:

UMB (dec)			SDI-12 (ASCII)		
1	to	10	'0'	to	'9'
18	to	43	'A'	to	'Z'
50	to	75	'a'	to	'z'

19.6.4 Data Messages

In the interest of simplified evaluation the assignment of measurement values to data buffers '0' ... '9' has been defined unified for all measurement commands. For this reason the responses to C-requests have been restricted to 35 characters, not using the 75 characters permitted for these requests

Currently buffers '0' to '4' are in use.

As with M-requests max. 9 values may be transmitted; the base data set of 9 values has been assigned to buffers '0' and '1'. Buffers '2' to '4' contain further measurement values. This definition guaranties the compatibility to loggers designed according to older versions of the SDI-12 standard.

The buffer assignment depends on the device variant (WS200-UMB ... WS600-UMB).

The complete set of measurement values, as defined for the UMB protocol has been made available also in the SDI-12 environment. They can be accessed using the additional M and C commands (aM1! ... aM8!, aMC1! ... aMC8!, aC1! ... aC8!, aCC1! ... aCC8!) (see below).

If the measurement value is not available for some reason, e.g. sensor failure, this is indicated by a value of +999.0. or -999.9 The logger can then evaluate the reason of failure by a aV! Verification request. The following tables show the measurement values in the sequence they are arranged in the telegram (see example).

Depending on the configuration of the device the values will be transmitted in metric or US units.

Note: The configured system of units is not indicated in the data messages. The logger may request this setting with the I-command and adjust the evaluation of the data messages accordingly

Example: M Request from a WS600-UMB station

0M!

00009<CR><LF> 9 measurement values are available

0D0!

0+13.5+85.7+1017.0+2.5+3.7<CR><LF>

Air temperature 13.5°C, rel. humidity 85.7%, rel. air pressure 1017hPa
avg. wind speed 2.5m/s, max wind speed 3.7m/s.

0D1!

0+43.7+9.8+60+4.4<CR><LF>

Wind direction 43.7° wet bulb temperature 9.8°C,
type of precipitation 60 (rain), precipitation intensity 4.4mm/h

Example: C Request from a WS600-UMB station

0M!

`000020<CR><LF>` 20 measurement values are available

0D0!

`0+13.5+85.7+1017+2.5+3.7<CR><LF>`

air temperature 13.5°C, rel. humidity 85.7%, rel. air pressure 1017hPa
avg. wind speed 2.5m/s, max wind speed 3.7m/s.

0D1!

`0+43.7+9.8+60+4.4<CR><LF>`

wind direction 43.7° wet bulb temperature 9.8°C,
type of precipitation 60 (rain), precipitation intensity 4.4mm/h

0D2!

`0+11.2+10.3+1.10<CR><LF>`

dewpoint 11.2°C, wind chill temperature 10,3°C
diff. precipitation 1.10mm

0D3!

`0+3.2+0.0+3.5+100.0<CR><LF>`

act. wind speed 3,2m/s, min. wind speed 0.0 m/s
vect. avg. wind speed 3.5m/s, quality of wind values 100%

0D4!

`0+43.7+41.3+45.7+29.3<CR><LF>`

act. wind direction 43,7°, min. wind direction 41,3°,
max. wind direction 45,7°, specific enthalpy29,3kJ/kg

19.6.4.1 Buffer assignment Basic Data Set WS600-UMB

Device configured for measurement values in metric units:

Measurement value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Air Pressure	305	300.0	1200.0	hPa
Wind Speed (avg)	460	0.0	75.0	m/s
Wind Speed (max)	440	0.0	75.0	m/s
Buffer ‘1’				
Wind Direction (vct)	580	0.0	359.9	°
Wet Bulb Temperature (act)	114	-50.0	60.0	°C
Precipitation Type	700	0, 60, 70		
Precipitation Intensity	820	0.0	200.0	mm/h
Buffer ‘2’				
Dew Point (act)	110	-50.0	60.0	°C
Wind chill Temperature (act)	111	-60.0	70.0	°C
Amount of Precip. difference	625	0.00	100000.00	mm
Buffer ‘3’				
Wind Speed (act)	400	0.0	75.0	m/s
Wind Speed (min)	420	0.0	75.0	m/s
Wind Speed (vct)	480	0.0	75.0	m/s
Wind Quality	805	0.0	100.0	%
Buffer ‘4’				
Wind Direction (act)	500	0.0	359.9	°
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

Example: Request Buffer ‘0’

0D0!

`0+13.5+85.7+2.5+3.7<CR><LF>`

Air Temperature 13.5°C, rel. Humidity 85.7%, average wind speed 2.5m/s, peak wind speed 3.7m/s

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Air Pressure	305	300.0	1200.0	hPa
Wind Speed (avg)	470	0.0	167.8	mph
Wind Speed (max)	450	0.0	167.8	mph
Buffer ‘1’				
Wind Direction (vct)	580	0.0	359.9	°
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Precipitation Type	700	0, 60, 70		
Precipitation Intensity	840	0.000	7.874	in/h
Buffer ‘2’				
Dew Point (act)	115	-58.0	140.0	°F
Wind chill Temperature (act)	116	-76.0	158.0	°F
Amount of Precip. difference	645	0.0000	3937.0000	in
Buffer ‘3’				
Wind Speed (act)	410	0.0	167.8	mph
Wind Speed (min)	430	0.0	167.8	mph
Wind Speed (vct)	490	0.0	167.8	mph
Wind Quality	805	0.0	100.0	%
Puffer ‘4’				
Wind Direction(act)	500	0.0	359.9	°
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

19.6.4.2 Buffer Assignment Basic Data Set WS500-UMB

Device configured for measurement values in metric units:

Measurement value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Air Pressure	305	300.0	1200.0	hPa
Wind Speed (avg)	460	0.0	75.0	m/s
Wind Speed (max)	440	0.0	75.0	m/s
Buffer ‘1’				
Wind Direction (vct)	580	0.0	359.9	°
Wet Bulb Temperature (act)	114	0.0	359.9	°C
Dew Point (act)	110	-50.0	60.0	°C
Wind chill Temperature (act)	111	-60.0	70.0	°C
Buffer ‘2’				
Wind Speed (act)	400	0.0	75.0	m/s
Wind Speed (min)	420	0.0	75.0	m/s
Wind Speed (vct)	480	0.0	75.0	m/s
Wind Quality	805	0.0	100.0	%
Buffer ‘3’				
Wind Direction (act)	500	0.0	359.9	°
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

Example: Request Buffer ‘0’

0D0!

`0+13.5+85.7+2.5+3.7<CR><LF>`

Air Temperature 13.5°C, rel. Humidity 85.7%, average wind speed 2.5m/s, peak wind speed 3.7m/s

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Air Pressure	305	300.0	1200.0	hPa
Wind Speed (avg)	470	0.0	167.8	mph
Wind Speed (max)	450	0.0	167.8	mph
Buffer ‘1’				
Wind Direction (vct)	580	0.0	359.9	°
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Dew Point (act)	115	-58.0	140.0	°F
Wind chill Temperature (act)	116	-76.0	158.0	°F
Buffer ‘2’				
Wind Speed (act)	410	0.0	167.8	mph
Wind Speed (min)	430	0.0	167.8	mph
Wind Speed (vct)	490	0.0	167.8	mph
Wind Quality	805	0.0	100.0	%
Puffer ‘3’				
Wind Direction(act)	500	0.0	359.9	°
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

19.6.4.3 Buffer Assignment Basic Data Set WS400-UMB

Device configured for measurement in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air Temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100,0	%
Dew Point (act)	110	-50.0	60.0	°C
Abs. Air Pressure(act)	300	300.0	1200.0	hPa
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Buffer ‘1’				
Precipitation Type	700	0, 60, 70		
Precipitation Intensity	820	0.0	200.0	mm/h
Amount of Precip. Difference	625	0.00	100000.00	mm
Amount of Precip. Absolute	620	0.0	100000.0	mm
Buffer ‘2’				
Air Temperature (min)	120	-50.0	60.0	°C
Air Temperature (max)	140	-50.0	60.0	°C
Air Temperature (avg)	160	-50.0	60.0	°C
Rel. Humidity (min)	220	0.0	100.0	%
Rel. Humidity (max)	240	0.0	100.0	%
Buffer ‘3’				
Rel. Humidity (avg)	260	0.0	100.0	%
Rel. Air Pressure(min)	325	300.0	1200.0	hPa
Rel. Rel. Humidity (max)	345	300.0	1200.0	hPa
Rel. Rel. Humidity (avg)	365	300.0	1200.0	hPa
Wet Bulb Temperature (act)	114	-50.0	60.0	°C
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

Example: Request Buffer ‘0’

0D0!

`0+13.5+85.7+11.2+1017.0+1001.0`

Air temperature 13.5°C, rel. humidity 85.7%, dew point 11.2°C, rel. air pressure 1017.0hPa, abs. pressure 1001.0hPa

Device configured for measurement in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Dew Point (act)	115	-58.0	14.0	°F
Abs. Air Pressure(act)	300	300.0	1200.0	hPa
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Buffer '1'				
Precipitation Type	700	0, 60, 70		
Precipitation Intensity	840	0.000	7.874	in/h
Amount of Precip. Difference	645	0.0000	3937.0000	in
Amount of Precip. Absolute	640	0.000	3937.000	in
Buffer '2'				
Air Temperature (min)	125	-58.0	140.0	°F
Air Temperature (max)	145	-58.0	140.0	°F
Air Temperature (avg)	165	-58.0	140.0	°F
Rel. Humidity (min)	220	0.0	100.0	%
Rel. Humidity (max)	240	0.0	100.0	%
Buffer '3'				
Rel. Humidity (avg)	260	0.0	100.0	%
Rel. Air Pressure(min)	325	300.0	1200.0	hPa
Rel. Rel. Humidity (max)	345	300.0	1200.0	hPa
Rel. Rel. Humidity (avg)	365	300.0	1200.0	hPa
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Specific Enthalpy	215	-100.0	1000.0	kJ/kg

19.6.4.4 Buffer Assignment Basic Data Set WS300-UMB

Device configured for measurement in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Puffer ‘0’				
Air Temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100.0	%
Dew Point (act)	110	-50.0	60.0	°C
Abs. Air Pressure(act)	300	300.0	1200.0	hPa
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Puffer ‘1’				
Air Temperature (min)	120	-50.0	60.0	°C
Air Temperature (max)	140	-50.0	60.0	°C
Air Temperature (avg)	160	-50.0	60.0	°C
Rel. Humidity (avg)	260	0.0	100.0	%
Puffer ‘2’				
Rel. Humidity (min)	220	0.0	100,0	%
Rel. Humidity (max)	240	0.0	100,0	%
Rel. Air Pressure (min)	325	300.0	1200.0	hPa
Rel. Air Pressure (max)	345	300.0	1200.0	hPa
Rel. Air Pressure (avg)	365	300.0	1200.0	hPa
Puffer ‘3’				
Abs. Humidity (min)	225	0.0	1000.0	g/m³
Abs. Humidity (max)	245	0.0	1000.0	g/m³
Abs. Humidity (avg)	265	0.0	1000.0	g/m³
Puffer ‘4’				
Wet Bulb Temperature (act)	114	-50.0	60.0	°C
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

Example: Request buffer ‘0’

0D0!

```
0+13.5+85.7+11.2+1017.0+1001.0
```

Air temperature 13.5°C, rel. humidity 85.7%, dew point 11.2°C, rel. air pressure 1017.0hPa, abs. pressure 1001.0hPa

Device configured for measurement in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Dew Point (act)	115	-58.0	140.0	°F
Abs. Air Pressure(act)	300	300.0	1200.0	hPa
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Buffer ‘1’				
Air Temperature (min)	125	-58.0	140.0	°F
Air Temperature (max)	145	-58.0	140.0	°F
Air Temperature (avg)	165	-58.0	140.0	°F
Rel. Humidity (avg)	260	0.0	100.0	%
Buffer ‘2’				
Rel. Humidity (min)	220	0.0	100,0	%
Rel. Humidity (max)	240	0.0	100,0	%
Rel. Air Pressure (min)	325	300.0	1200.0	hPa
Rel. Air Pressure (max)	345	300.0	1200.0	hPa
Rel. Air Pressure (avg)	365	300.0	1200.0	hPa
Buffer ‘3’				
Abs. Humidity (min)	225	0.0	1000.0	g/m³
Abs. Humidity (max)	245	0.0	1000.0	g/m³
Abs. Humidity (avg)	265	0.0	1000.0	g/m³
Buffer ‘4’				
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

19.6.4.5 Buffer Assignment Basic Data Set WS200-UMB

Device configured for measurement values in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Wind Speed (avg)	460	0.0	75.0	m/s
Wind Speed (max)	440	0.0	75.0	m/s
Wind Direction (vct)	580	0.0	359.9	°
Wind Direction (act)	500	0.0	359.9	°
Compass Heading(act)	510	0.0	359.0	°
Buffer ‘1’				
Wind Speed (act)	400	0.0	75.0	m/s
Wind Speed (min)	420	0.0	75.0	m/s
Wind Speed (vct)	480	0.0	75.0	m/s
Wind Quality	805	0.0	100.0	%
Buffer ‘2’				
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Wind Direction corr. (act)	502	0.0	359.9	°

Example: Request Buffer ‘0’

0D0!

`0+2.5+3.7+45.5+37.8+10.3<CR><LF>`

Avg. wind speed 2.5m/s, peak wind speed 3.7m/s, avg wind direction (vect.) 45.5°, wind direction (act.) 37.8°, compass heading 10.3°

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Wind Speed (avg)	470	0.0	167.8	mph
Wind Speed (max)	450	0.0	167.8	mph
Wind Direction (vct)	580	0.0	359.9	°
Wind Direction (act)	500	0.0	359.9	°
Compass Heading(act)	510	0.0	359.0	°
Buffer '1'				
Wind Speed (act)	410	0.0	167.8	mph
Wind Speed (min)	430	0.0	167.8	mph
Wind Speed (vct)	490	0.0	167.8	mph
Wind Quality	805	0.0	100.0	%
Buffer '2'				
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Wind Direction corr. (act)	502	0.0	359.9	°

19.6.4.6 Buffer Assignment Basic Data Set WS501-UMB, WS502-UMB, WS503-UMB, WS504-UMB

Device configured for measurement values in metric units:

Measurement value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Air Pressure	305	300.0	1200.0	hPa
Wind Speed (avg)	460	0.0	75.0	m/s
Wind Speed (max)	440	0.0	75.0	m/s
Buffer ‘1’				
Wind Direction (vct)	580	0.0	359.9	°
Global Radiation (act)	900	0.0	1400.0	W/m²
Dew Point (act)	110	-50.0	60.0	°C
Wind Chill Temperature (act)	111	-60.0	70.0	°C
Buffer ‘2’				
Wind Speed (act)	400	0.0	75.0	m/s
Wind Speed (min)	420	0.0	75.0	m/s
Wind Speed (vct)	480	0.0	75.0	m/s
Wind Quality	805	0.0	100.0	%
Buffer ‘3’				
Wind Direction (act)	500	0.0	359.9	°
Wet Bulb Temperature (act)	114	-50.0	60.0	°C
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg
Buffer ‘4’				
Global Radiation (min)	920	0.0	1400.0	W/m²
Global Radiation (max)	940	0.0	1400.0	W/m²
Global Radiation (avg)	960	0.0	1400.0	W/m²

Example: Request Buffer ‘0’

0D0!

```
0+13.5+85.7+2.5+3.7<CR><LF>
```

Air Temperature 13.5°C, rel. Humidity 85.7%, average wind speed 2.5m/s, peak wind speed 3.7m/s

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Air Pressure	305	300.0	1200.0	hPa
Wind Speed (avg)	470	0.0	167.8	mph
Wind Speed (max)	450	0.0	167.8	mph
Buffer '1'				
Wind Direction (vct)	580	0.0	359.9	°
Global Radiation (act)	900	0.0	1400.0	W/m²
Dew Point (act)	115	-58.0	140.0	°F
Windchill Temperature (act)	116	-76.0	158.0	°F
Buffer '2'				
Wind Speed (act)	410	0.0	167.8	mph
Wind Speed (min)	430	0.0	167.8	mph
Wind Speed (vct)	490	0.0	167.8	mph
Wind Quality	805	0.0	100.0	%
Puffer '3'				
Wind Direction(act)	500	0.0	359.9	°
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg
Buffer '4'				
Global Radiation (min)	920	0.0	1400.0	W/m²
Global Radiation (max)	940	0.0	1400.0	W/m²
Global Radiation (avg)	960	0.0	1400.0	W/m²

19.6.4.7 Buffer Assignment Basic Data Set WS301-UMB, WS302-UMB, WS303-UMB, WS304-UMB

Device configured for measurement in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Puffer ‘0’				
Air Temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100.0	%
Dew Point (act)	110	-50.0	60.0	°C
Global Radiation(act)	900	0.0	1400.0	W/m²
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Puffer ‘1’				
Air Temperature (min)	120	-50.0	60.0	°C
Air Temperature (max)	140	-50.0	60.0	°C
Air Temperature (avg)	160	-50.0	60.0	°C
Rel. Humidity (avg)	260	0.0	100.0	%
Puffer ‘2’				
Rel. Humidity (min)	220	0.0	100,0	%
Rel. Humidity (max)	240	0.0	100,0	%
Rel. Air Pressure (min)	325	300.0	1200.0	hPa
Rel. Air Pressure (max)	345	300.0	1200.0	hPa
Rel. Air Pressure (avg)	365	300.0	1200.0	hPa
Puffer ‘3’				
Abs. Humidity (act)	205	0.0	1000.0	g/m³
Wet Bulb Temperature (act)	114	-50.0	60.0	°C
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg
Puffer ‘4’				
Global Radiation (min)	920	0.0	1400.0	W/m²
Global Radiation (max)	940	0.0	1400.0	W/m²
Global Radiation (avg)	960	0.0	1400.0	W/m²

Example: Request buffer ‘0’

0D0!

`0+13.5+85.7+11.2+1017.0+780.0`

Air temperature 13.5°C, rel. humidity 85.7%, dew point 11.2°C, rel. air pressure 1017.0hPa, global radiation 780.0W/m²

Device configured for measurement in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Dew Point (act)	115	-58.0	140.0	°F
Global Radiation(act)	900	0.0	1400.0	W/m²
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Buffer ‘1’				
Air Temperature (min)	125	-58.0	140.0	°F
Air Temperature (max)	145	-58.0	140.0	°F
Air Temperature (avg)	165	-58.0	140.0	°F
Rel. Humidity (avg)	260	0.0	100.0	%
Buffer ‘2’				
Rel. Humidity (min)	220	0.0	100,0	%
Rel. Humidity (max)	240	0.0	100,0	%
Rel. Air Pressure (min)	325	300.0	1200.0	hPa
Rel. Air Pressure (max)	345	300.0	1200.0	hPa
Rel. Air Pressure (avg)	365	300.0	1200.0	hPa
Buffer ‘3’				
Abs. Humidity (act)	205	0.0	1000.0	g/m³
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg
Buffer ‘4’				
Global Radiation (min)	920	0.0	1400.0	W/m²
Global Radiation (max)	940	0.0	1400.0	W/m²
Global Radiation (avg)	960	0.0	1400.0	W/m²

19.6.4.8 Buffer assignment Basic Data Set WS601-UMB

Device configured for measurement values in metric units:

Measurement value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Air Pressure	305	300.0	1200.0	hPa
Wind Speed (avg)	460	0.0	75.0	m/s
Wind Speed (max)	440	0.0	75.0	m/s
Buffer ‘1’				
Wind Direction (vct)	580	0.0	359.9	°
Leaf Wetness State (act)	711	0 / 1		
Precipitation Type	700	0, 40		
Precipitation Intensity	820	0.0	200.0	mm/h
Buffer ‘2’				
Dew Point (act)	110	-50.0	60.0	°C
Wind chill Temperature (act)	111	-60.0	70.0	°C
Amount of Precip. difference	625	0.00	100000.00	mm
Buffer ‘3’				
Wind Speed (act)	400	0.0	75.0	m/s
Wind Speed (min)	420	0.0	75.0	m/s
Wind Speed (vct)	480	0.0	75.0	m/s
Wet Bulb Temperature (act)	114	-50.0	60.0	°C
Buffer ‘4’				
Wind Direction (act)	500	0.0	359.9	°
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

Example: Request Buffer ‘0’

0D0!

`0+13.5+85.7+2.5+3.7<CR><LF>`

Air Temperature 13.5°C, rel. Humidity 85.7%, average wind speed 2.5m/s, peak wind speed 3.7m/s

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Air Pressure	305	300.0	1200.0	hPa
Wind Speed (avg)	470	0.0	167.8	mph
Wind Speed (max)	450	0.0	167.8	mph
Buffer '1'				
Wind Direction (vct)	580	0.0	359.9	°
Leaf Wetness State (act)	711	0 / 1		
Precipitation Type	700	0, 60, 70		
Precipitation Intensity	840	0.000	7.874	in/h
Buffer '2'				
Dew Point (act)	115	-58.0	140.0	°F
Wind chill Temperature (act)	116	-76.0	158.0	°F
Amount of Precip. difference	645	0.0000	3937.0000	in
Buffer '3'				
Wind Speed (act)	410	0.0	167.8	mph
Wind Speed (min)	430	0.0	167.8	mph
Wind Speed (vct)	490	0.0	167.8	mph
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Puffer '4'				
Wind Direction(act)	500	0.0	359.9	°
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

19.6.4.9 Buffer Assignment Basic Data Set WS401-UMB

Device configured for measurement in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air Temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100,0	%
Dew Point (act)	110	-50.0	60.0	°C
Leaf Wetness State (act)	711	0 / 1		
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Buffer ‘1’				
Precipitation Type	700	0, 40		
Precipitation Intensity	820	0.0	200.0	mm/h
Amount of Precip. Difference	625	0.00	100000.00	mm
Amount of Precip. Absolute	620	0.0	100000.0	mm
Buffer ‘2’				
Air Temperature (min)	120	-50.0	60.0	°C
Air Temperature (max)	140	-50.0	60.0	°C
Air Temperature (avg)	160	-50.0	60.0	°C
Rel. Humidity (min)	220	0.0	100.0	%
Rel. Humidity (max)	240	0.0	100.0	%
Buffer ‘3’				
Rel. Humidity (avg)	260	0.0	100.0	%
Rel. Air Pressure(min)	325	300.0	1200.0	hPa
Rel. Rel. Humidity (max)	345	300.0	1200.0	hPa
Rel. Rel. Humidity (avg)	365	300.0	1200.0	hPa
Wet Bulb Temperature (act)	114	-50.0	60.0	°C
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg

Example: Request Buffer ‘0’

0D0!

`0+13.5+85.7+11.2+1017.0+1001.0`

Air temperature 13.5°C, rel. humidity 85.7%, dew point 11.2°C, rel. air pressure 1017.0hPa, abs. pressure 1001.0hPa

Device configured for measurement in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Dew Point (act)	115	-58.0	14.0	°F
Leaf Wetness State (act)	711	0 / 1		
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Buffer '1'				
Precipitation Type	700	0, 40		
Precipitation Intensity	840	0.000	7.874	in/h
Amount of Precip. Difference	645	0.0000	3937.0000	in
Amount of Precip. Absolute	640	0.000	3937.000	in
Buffer '2'				
Air Temperature (min)	125	-58.0	140.0	°F
Air Temperature (max)	145	-58.0	140.0	°F
Air Temperature (avg)	165	-58.0	140.0	°F
Rel. Humidity (min)	220	0.0	100.0	%
Rel. Humidity (max)	240	0.0	100.0	%
Buffer '3'				
Rel. Humidity (avg)	260	0.0	100.0	%
Rel. Air Pressure(min)	325	300.0	1200.0	hPa
Rel. Rel. Humidity (max)	345	300.0	1200.0	hPa
Rel. Rel. Humidity (avg)	365	300.0	1200.0	hPa
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Specific Enthalpy	215	-100.0	1000.0	kJ/kg

19.6.4.10 Buffer Assignment Basic Data Set Power Saving Mode 2 (all Models)

Device configured for measurement in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Air Temperature (act)	100	-50.0	60.0	°C
Rel. Humidity (act)	200	0.0	100.0	%
Amount of Precip. Difference	625	0.00	100000.00	mm
Rel. Air Pressure(act)	305	300.0	1200.0	hPa
Wind Speed (act)	400	0.0	75.0	m/s
Buffer '1'				
Wind Direction(act)	500	0.0	359.9	°
Global Radiation	900	0.0	1400.0	W/m^2
Leaf Wetness State (act)	711	0 / 1		
External Temperature	101	-20.0	80.0	°C
Buffer '2'				
Amount of Precip. Absolute	620	0.0	100000.0	mm
Dew point (act)	110	-50.0	60.0	°C
Abs. Humidity (act)	205	0.0	1000.0	g/m³
Mixing Ratio(act)	210	0.0	1000.0	g/kg
Abs. Air Pressure(act)	300	300.0	1200.0	hPa
Buffer '3'				
Wet Bulb Temperature (act)	114	-50.0	60.0	°C
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg
Air Density	310	0.000	3.000	kg/m3
Compass (act)	510	0.0	359.0	°

Example: Request Buffer '0'

0D0!

```
0+13.5+85.7+0.2+1017.0+1.8
```

Air temperature 13.5°C, rel. humidity 85.7%, precipitation 0.2°C, rel. air pressure 1017.0hPa, wind speed1.8m/s

Device configured for measurement in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Air Temperature (act)	105	-58.0	140.0	°F
Rel. Humidity (act)	200	0.0	100.0	%
Amount of Precip. Difference	645	0.0000	3937.0000	in
Rel. Air Pressure(act)	305	300.0	12000	hPa
Wind Speed (act)	410	0.0	167.8	mph
Buffer '1'				
Wind Direction(act)	500	0.0	359.9	°
Global Radiation	900	0.0	1400.0	W/m^2
Leaf Wetness State (act)	711	0 / 1		
External Temperature	106	-4.0	176.0	°F
Buffer '2'				
Amount of Precip. Absolute	640	0.000	3937.000	in
Dew point (act)	115	-58.0	140.0	°F
Abs. Humidity (act)	205	0.0	1000.0	g/m^3
Mixing Ratio(act)	210	0.0	1000.0	g/kg
Abs. Air Pressure(act)	300	300.0	1200.0	hPa
Buffer '3'				
Wet Bulb Temperature (act)	119	-58.0	140.0	°F
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg
Air Density	310	0.000	3.000	kg/m3
Compass (act)	510	0.0	359.0	°

19.6.5 Additional Measurement Commands

With the additional measurement commands

aM1! … aM6!

aMC1! … aMC6! (M-Command, data transmission with CRC)

aC1! … aC6!

aCC1! … aCC6! (C- Command, data transmission with CRC)

The complete data sets of the compact weather station, as defined for the UMB protocol are available in a SDI-12 environment as well.

The measurement values are ordered according to sensor types.

Equally to the base data sets max. 9 values can be requested with an additional M command, while an additional C request allows for up to 20 values.

The buffer assignment as documented in the following paragraphs has consequently been structured in a way that with each M command the buffers D0 and D1 are used. If the respective sensor type has more values available the buffers D2 up to D4 will be occupied if required.

M1 / C1	Temperature	M: 8 Values	C: 8 Values
M2 / C2	Humidity	M: 8 Values	C: 12 Values
M3 / C3	Air Pressure	M: 8 Values	C: 8 Values
M4 / C4	Wind	M: 9 Values	C: 12 Values
M5 / C5	Compass	M: 1 Values	C: 1 Values
M6 / C6:	Precipitation, Leaf Wetness	M: 9 Values	C: 9 Values
M7 / C7	Global Radiation	M: 4 Values	C: 4 Values

If the sensor type requested with the measurement command is not available with the actual variant of the compact weather station (WS200-UMB ... WS600-UMB) the station will respond with

`a0000<CR><LF>` resp.

`a00000<CR><LF>`

19.6.5.1 Buffer Assignment Additional Measurement Commands M1 / C1: Temperature

Device configured for measurement values in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air Temperature (act)	100	-50.0	60.0	°C
Air Temperature (min)	120	-50.0	60.0	°C
Air Temperature (max)	140	-50.0	60.0	°C
Air Temperature (avg)	160	-50.0	60.0	°C
Dew Point (act)	110	-50.0	60.0	°C
Buffer ‘1’				
Dew Point (min)	130	-50.0	60.0	°C
Dew Point (max)	150	-50.0	60.0	°C
Dew Point (avg)	170	-50.0	60.0	°C
Wet Bulb Temperature (act)	114	-50.0	60.0	°C

Example: Request with M command

```
0M1!
00008<CR><LF>
0D0!
0+12.5+10.7+13.5+11.8+5.3<CR><LF>
0D1!
0+4.2+5.9+5.6+9.8<CR><LF>
```

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Air Temperature (act)	105	-58.0	140.0	°F
Air Temperature (min)	125	-58.0	140.0	°F
Air Temperature (max)	145	-58.0	140.0	°F
Air Temperature (avg)	165	-58.0	140.0	°F
Dew Point (act)	115	-58.0	140.0	°F
Buffer ‘1’				
Dew Point (min)	135	-58.0	140.0	°F
Dew Point (max)	155	-58.0	140.0	°F
Dew Point (avg)	175	-58.0	140.0	°F
Wet Bulb Temperature (act)	119	-58.0	140.0	°F

19.6.5.2 Buffer Assignment Additional Measurement Commands M2 / C2: Humidity

Device configured for measurement values in metric or US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Rel. Humidity (act)	200	0.0	100.0	%
Rel. Humidity (min)	220	0.0	100.0	%
Rel. Humidity (max)	240	0.0	100.0	%
Rel. Humidity (avg)	260	0.0	100.0	%
Puffer ‘1’				
Abs. Humidity (act)	205	0.0	1000.0	g/m³
Abs. Humidity (min)	225	0.0	1000.0	g/m³
Abs. Humidity (max)	245	0.0	1000.0	g/m³
Abs. Humidity (avg)	265	0.0	1000.0	g/m³
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg
Puffer ‘2’				
Mixing Ratio(act)	210	0.0	1000.0	g/kg
Mixing Ratio (min)	230	0.0	1000.0	g/kg
Mixing Ratio (max)	250	0.0	1000.0	g/kg
Mixing Ratio (avg)	270	0.0	1000.0	g/kg

Example: Request with M command

```
0M2!
00008<CR><LF>
0D0!
0+48.5+48.2+48.8+48.5<CR><LF>
0D1!
0+5.7+5.5+5.9+5.7+29.3<CR><LF>
```

Example: Request with C command

```
0C2!
000012<CR><LF>
0D0!
0+48.5+48.2+48.8+48.5<CR><LF>
0D1!
0+5.7+5.5+5.9+5.7+29.3<CR><LF>
0D2!
0+4.6+4.4+5.0+4.6<CR><LF>
```

19.6.5.3 Buffer Assignment Additional Measurement Commands M3 / C3: Air Pressure

Device configured for measurement values in metric or US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Abs. Air Pressure(act)	300	300.0	1200.0	hPa
Abs. Air Pressure (min)	320	300.0	1200.0	hPa
Abs. Air Pressure (max)	340	300.0	1200.0	hPa
Abs. Air Pressure (avg)	360	300.0	1200.0	hPa
Air Density (act)	310	0.000	3.000	kg/m3
Puffer ‘1’				
Rel. Air Pressure (act)	305	300.0	1200.0	hPa
Rel. Air Pressure (min)	325	300.0	1200.0	hPa
Rel. Air Pressure (max)	345	300.0	1200.0	hPa
Rel. Air Pressure (avg)	365	300.0	1200.0	hPa

Example: Request with M command

```
0M3!
00009<CR><LF>
0D0!
0+1001.0+1000.0+1002.0+1001.0+1.119<CR><LF>
0D1!
0+1017.0+1016.0+1018.0+1017.0<CR><LF>
```

Example: Request with C command

```
0C3!
000009<CR><LF>
0D0!
0+1001.0+1000.0+1002.0+1001.0+1.119<CR><LF>
0D1!
0+1017.0+1016.0+1018.0+1017.0<CR><LF>
```

19.6.5.4 Buffer Assignment Additional Measurement Commands M4 / C4: Wind

Device configured for measurement values in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Wind Speed (act)	400	0.0	75.0	m/s
Wind Speed (min)	420	0.0	75.0	m/s
Wind Speed (max)	440	0.0	75.0	m/s
Wind Speed (avg)	460	0.0	75.0	m/s
Wind Speed (vct)	480	0.0	75.0	m/s
Puffer '1'				
Wind Direction (act)	500	0.0	359.9	°
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Wind Direction (vct)	580	0.0	359.9	°
Puffer '2'				
Wind Direction corr. (act)	502	0.0	359.9	°
Wind Quality	805	0.0	100.0	%
Wind Chill Temperature (act)	111	-60.0	70.0	°C
Wind Speed Standard Dev.	403	0.0	60.0	m/s
Wind Direction Standard Dev.	503	0.0	359.9	°

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Wind Speed (act)	410	0.0	167.8	mph
Wind Speed (min)	430	0.0	167.8	mph
Wind Speed (max)	450	0.0	167.8	mph
Wind Speed (avg)	470	0.0	167.8	mph
Wind Speed (vct)	490	0.0	167.8	mph
Puffer '1'				
Wind Direction (act)	500	0.0	359.9	°
Wind Direction (min)	520	0.0	359.9	°
Wind Direction (max)	540	0.0	359.9	°
Wind Direction (vct)	580	0.0	359.9	°
Puffer '2'				
Wind Direction corr. (act)	502	0.0	359.9	°
Wind Quality	805	0.0	100.0	%
Wind chill Temperature (act)	116	-76.0	158.0	°F
Wind Speed Standard Dev.	413	0.0	167.8	mph
Wind Direction Standard Dev.	503	0.0	359.9	°

19.6.5.5 Buffer Assignment Additional Measurement Commands M5 / C5: Compass

Device configured for measurement values in metric or US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer '0'				
Compass (act)	510	0.0	359.0	°

Example: Request with M command

0M5!

00001<CR><LF>

0D0!

0+348.0<CR><LF>

Example: Request with C command

0C5!

000001<CR><LF>

0D0!

0+348.0<CR><LF>

19.6.5.6 Buffer Assignment Additional Measurement Commands M6 / C6: Precipitation and Leaf Wetness

Device configured for measurement values in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Precip. Amount absolute	620	0.0	100000.0	mm
Precip. Amount difference	625	0.00	100000.00	mm
Precipitation Intensity	820	0.0	200.0	mm/h
Precipitation Type	700	0, 40, 60, 70		
Buffer ‘1’				
Leaf Wetness mV (act)	710	0,0	1500,0	mV
Leaf Wetness mV (min)	730	0,0	1500,0	mV
Leaf Wetness mV (max)	750	0,0	1500,0	mV
Leaf Wetness mV (avg)	770	0,0	1500,0	mV
Leaf Wetness State	711	0 / 1		

Example: Request with M command

```
0M6!
00009<CR><LF>
0D0!
0+1324.5+1.10+4.4+60<CR><LF>
0D1!
0+603.5+562.4+847.4+623.8+1<CR><LF>
```

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Precip. Amount absolute	640	0.000	3937.000	In
Precip. Amount difference	645	0.0000	3937.0000	In
Precipitation Intensity	840	0.000	7.874	in/h
Precipitation Type	700	0, 60, 70		
Buffer ‘1’				
Leaf Wetness mV (act)	710	0,0	1500,0	mV
Leaf Wetness mV (min)	730	0,0	1500,0	mV
Leaf Wetness mV (max)	750	0,0	1500,0	mV
Leaf Wetness mV (avg)	770	0,0	1500,0	mV
Leaf Wetness State	711	0 / 1		

19.6.5.7 Buffer Assignment Additional Measurement Commands M7 / C7: Global Radiation

Device configured for measurement values in metric or US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
Global Radiation (act)	900	0.0	1400.0	W/m²
Global Radiation (min)	920	0.0	1400.0	W/m²
Global Radiation (max)	940	0.0	1400.0	W/m²
Global Radiation (avg)	960	0.0	1400.0	W/m²

Example: Request with M Command

```
0M7!
00004<CR><LF>
0D0!
0+780.0+135.0+920.0+530.0<CR><LF>
```

19.6.5.8 Buffer Assignment Additional Measurement Commands M8 / C8: External Temperature

Device configured for measurement values in metric units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
External Temperature (act)	101	-40.0	80.0	°C

Example: Request with M Command

0M8!

`00001<CR><LF>`

0D0!

`0+13.5<CR><LF>`

Device configured for measurement values in US units:

Measurement Value	UMB Channel	Min	Max	Unit
Buffer ‘0’				
External Temperature (act)	106	-40.0	176.0	°F

19.6.6 Message Device Identification

The device responds to the identification request with following message (example for SDI-12 device address ‘0’:

0I!

013Lufft.deWSx00ynnn

x: device type (4, 5, 6, 2, 3)

y: Metric / US units (m = metric, u = US)

nnn: Software version

i.e. for a WS600-UMB, configured for US units:

0I!

013Lufft.deWS600u022

19.6.7 Message Verification

The command verification aV! is used to evaluate status information of the device. The device responds with

a0005<CR<LF>

to the request, i.e. 5 values are available in the buffers.

The first 3 “measurement values”, transmitted in buffer ‘0’ contain the status information of the measurement channels.

The status data of the channels are assembled to form “fake measurement values”, where each digit represents one status. See below for the coding of states. Generally each sensor has two status values, one for the direct value and another for the measurement value buffer used for the evaluation of the average, min, and max values.

The last two values, transmitted in buffer ‘1’, show the heating temperatures of wind and precipitation sensor.

Buffer ‘0’				
Status group1: +nnnn	Air temperature, air temperature buffer, dew point, dew point buffer			
Status group1: +nnnnnn (WS401 / WS601 only)	Air temperature, air temperature buffer, dew point, dew point buffer, leaf wetness status, leaf wetness buffer status			
Status group 2: +nnnnnn	Rel. Humidity, rel. Humidity buffer, abs. Humidity, abs humidity buffer, mixing ration, mixing ration buffer			
Status group 3: +nnnnnn	Air pressure, air pressure buffer, wind, wind buffer, compass, precipitation (WS301/501 transmits the global radiation status instead of the precipitation status)			
Buffer ‘1’, device configured for metric units				
Measurement value	UMB Channel	min	max	Unit
Heating temp. Wind sensor	112	-50	+150	°C
Heating temp. Precip. sensor	113	-50	+150	°C
Puffer ‘1’, device configured for US units				
Heating temp. Wind sensor	117	-58	+302	°F
Heating temp. Precip. sensor	118	-58	+302	°F

Sensor status codes:

Sensor status	Code
OK	0
UNGLTG_KANAL	1
E2_CAL_ERROR E2_CRC_KAL_ERR FLASH_CRC_ERR FLASH_WRITE_ERR FLASH_FLOAT_ERR	2
MEAS_ERROR	3
MEAS_UNABLE	4
INIT_ERROR	5
VALUE_OVERFLOW CHANNEL_OVERRANGE	6
VALUE_UNDERFLOW CHANNEL_UNDERRANGE	7
BUSY	8
other sensor status	9

Example (WS600-UMB, SDI-12 Address ‘0’, no error):

```
0V!
00005<CR><LF>
0D0!
0+0000+000000+00000<CR><LF>
0D1!
0+73.0+65.3<CR><LF>
```

Example (WS600-UMB, SDI-12 Address ‘0’, compass failure):

```
0V!
00005<CR><LF>
0D0!
0+0000+000000+000030<CR><LF>
0D1!
0+73.0+65.3<CR><LF>
```

19.6.8 Message Change of Unit System

The command is used to change the unit system used for the SDI12 data between metric and US units. It is implemented as manufacturer specific X command.

Command: `aXU<u/m>!`

Response: `aU<u/m><CR><LF>`

u : US units

m: metric units

Example: change to metric units, SDI-12 address '0'

`0XUm!`

`0Um<CR><LF>`

19.6.9 Message: Setting of the Averaging Interval Length

The avg, min, max and vct values of the measurement values are evaluated over a floating interval with a length of 1 to 10 min. The length of this interval can be adjusted separately for the groups temperature / humidity, air pressure and wind. (The averaging algorithm is not applied to precipitation and compass).

Command: `aXA<t/p/w/r>+nn!`

t : Temperature and Humidity

p: Air pressure

w: Wind

r: Global radiation

nn: Interval in minutes, valid range: 1 bis 10

Response: `aXA<t/p/w/r>+nn<CR><LF>`

The response to the attempt of setting of an invalid interval length is

`aXAf<CR><LF>`

Example: Setting the interval for temperature and humidity to 5 minutes

`0XAt+5!`

`0XAt+5<CR><LF>`

19.6.10 Message: Setting of the Local Altitude

For the calculation of the relative air pressure the local altitude of the device is required.

Command: `aXH+nnnn!`

nnnn: local altitude of the sensor in m

Response: `aXH+nnnn<CR><LF>`

The response to the attempt of setting of an invalid altitude (-100 < altitude < 5000) is

`aXHf<CR><LF>`

Example: The altitude of the installation location is 135m above sea level

`0XH+135!`

`0XH+135<CR><LF>`

19.6.11 Setting of the Local Magnetic Declination

For exact compass heading the local magnetic declination must be set.

Command: aXD+nnn.n!

nnn.n: local magnetic declination at installation site in ° *)

Response: aXD+nnn.n<CR><LF>

The response to the attempt of setting of an invalid altitude (-180.0<declination<+180.0) is

aXDf<CR><LF>

Example: The declination at the installation location is -5.3°

0XD-5.3!

0XD-5.3<CR><LF>

*) The magnetic declination is available from various web sites, e.g.
http://www.ngdc.noaa.gov/geomag-web/#declination

19.6.12 Message: Activation / Deactivation of Compass Correction

The correction of the wind direction by the compass bearing can be activated or deactivated.

Command: aXW<c/u>!

c: wind direction is corrected by the compass bearing

u: wind direction is not corrected

Response: aXW<c/u><CR><LF>

The response to the attempt of setting an invalid option is

aXWf<CR><LF>

Example: Compass correction of wind direction is activated

0XWc!

0XWc<CR><LF>

19.6.13 Message: Setting the Power Saving Mode

For installations with limited power supply the compact weather station may be operated in power saving mode (see Chap. 35).

Note: Operation in power saving mode has some functional restrictions!

Command: aXL<n/s/w>!

n: Normal Operation

s: Power saving mode 1 (Heating/Fan off)

w: Power saving mode 2 (Sleep mode)

Response: aXL<n/s/w><CR><LF>

The response is followed by the station reset, i.e. the station will be offline for a few seconds.

The response to the selection of an invalid option or of an invalid combination of mode and device model is

aXLf<CR><LF>

Example: The station shall be set to power saving mode 2

0XLw!

0XLw<CR><LF>

19.6.14 Message: Setting the Heating Mode

The heating of the precipitation and the wind sensors can be configured in different operation modes (see chapter 10.4). Depending on the actual variant of the compact weather station (WS200 ...WS600) only certain combinations of operating modes are available. The station evaluates the valid combinations from the station heating mode requested in the command automatically.

Command: `aXMn!`

n: Heating Operating Mode (0: Automatic, 1: Mode 1, 2: Off, 3: Eco Mode 1)

Response: `aXMnm<CR><LF>`

n: Selected Heating Mode Wind Sensor

m: Selected Heating Mode Precipitation Sensor

The response to the attempt of setting an invalid operation mode is

`aXMf<CR><LF>`

Example: A WS400-UMB shall be set to Mode 1

`0XM1!`

`0XM21<CR><LF>`

As the WS400-UMB does not have a wind sensor the heating mode wind is automatically set to 2 (= off).

19.6.15 Message: Setting of the Leaf Wetness Threshold

The parameter to be set defines the voltage threshold for the leaf wetness sensor (WS401-UMB and WS601-UMB only, see p. 58), where the leaf wetness state changes between 0 and 1. With SDI12 operation, the voltage value required for the evaluation of the correct threshold setting is retrieved with the aM6! command (see p.105).

Command: `aXB+nnn.n!`

nnn.n: threshold for leaf wetness state in mV

Response: `aXB+nnn.n<CR><LF>`

The response to the attempt of setting of an invalid threshold (200.0<=threshold<=1200.0) is

`aXBf<CR><LF>`

Example: The leaf wetness voltage measured in dry condition is 613mV. The recommended setting of the threshold is 633mV

`0XB+633.0!`

`0XD+633.0<CR><LF>`

19.6.16 Message: Setting of the Rain Gauge Resolution

The resolution of the tipping bucket rain gauge of WS401-UMB and WS601-UMB, as well as the resolution of an optional external rain gauge connected to a model without internal precipitation measurement can be mechanically adjusted (see p. 31). The mechanical resolution must be set in the sensor configuration.

Command: aXK+n!

n: resolution of the rain gauge in 1/10mm, valid settings 1, 2, 5, 10 (0.1mm, 0.2mm, 0.5mm, 1.0mm)

Response: aXK+n<CR><LF>

The response to the attempt of setting of an invalid resolution is

aXKf<CR><LF>

Example: The mechanical resolution of the rain gauge is 0.2mm

0XK+2!

0XK+2<CR><LF>

19.6.17 Message: Clearing the Absolute Precipitation Amount

The command clears the accumulated absolute precipitation amount to 0.0mm. At the same time a station reset is applied.

Command: aXC!

Response: aXCok<CR><LF>

The response is followed by the station reset, i.e. the station will be offline for a few seconds.

Example:

0XC!

0XCok<CR><LF>

19.6.18 Message: Station Reset

The command initiates a station reset.

Command: aXR!

Response: aXRok<CR><LF>

The response is followed by the station reset, i.e. the station will be offline for a few seconds.

Example:

0XR!

0XRok<CR><LF>

19.7 Communication in Modbus Mode

For a simpler integration of WS family Compact Weather Stations into a PLC environment the Modbus communication protocol has been made available.

Measurement values are mapped to Modbus Input Registers. The range of values available is basically the same as for the UMB protocol, including different unit systems.

In the interest of simple and safe integration the use of register pairs for floating point values or 32 bit integers, which is not part of the Modbus standard, has not been applied. All measurement values are mapped to 16bit integers using suitable scaling factors.

19.7.1 Modbus Communication Parameters

The WSxxx-UMB can be configured for MODBUS-RTU or for MODBUS-ASCII.

The base configuration has to be done using the UMB Config Tool.

When selecting MODBUS RTU or MODBUS-ASCII with the UMB Config Tool, communication parameters 19200 Bd, even parity, will be preselected.

Modbus operating modes:	MODBUS-RTU, MODBUS-ASCII
Baud rate:	19200 (9600, 4800 or lower)
Interface Setting	8E1, 8N1

NOTE: The Modbus communication has been tested for a poll rate of 1 sec. The proper function of the Compact Weather Station with higher Modbus poll rates has not been tested.

We suggest to set the poll rate to 10 sec or slower, as, with the exception of the channels „wind speed / wind directions fast“, which are provided for special purposes, the update rate of the data is >= 10sec. Anyway for most of the weather data significant changes have tob e expected more in the range of minutes.

19.7.2 Addressing

The Modbus address is deducted from the the UMB device ID (see Chap. 19.3.2).

A device with UMB device ID 1 also has the UMB address 1, etc..

The valid address range of Modbus from 1 to 247 is smaller than that of the UMB device IDs. If a UMB device ID > 247 has been selected, the Modbus address will be set to 247.

19.7.3 Modbus Functions

The functions of conformance class 0 and 1 have been implemented as far as they are applicable for WSxxx-UMB, i.e. all functions operating on register level.

	Conformance Class 0	
0x03	Read Holding Registers	Selected configuration settings
0x16	Write Multiple Registers	Selected configuration settings
	Conformance Class 1	
0x04	Read Input Registers	Measurement values and status information
0x06	Write Single Register	Selected configuration settings
0x07	Read Exception Status	Currently not used
	Diagnostics	
0x11	Report Slave ID	(responds also to broadcast address)

19.7.3.1 Function 0x03 Read Holding Registers

The Holding Registers are used to make a selected set of adjustable parameters available for Modbus access. As for the measurement values the parameters are mapped to 16bit integers.

Reg. No.	Reg. Addr	Function	Values	Scale
1	0	Local Altitude	Altitude in m, for calculation of relative air pressure Value range -100 … 5000	1.0
2	1	Deviation	Local deviation for the correction of compass heading. Value range -3599 … 3599 (equalling -359.9° … +359.9°)	10.0
3	2	Averaging Interval TFF	Interval for averaging and min/max evaluation in minutes Value range 1 … 10	1.0
4	3	Averaging Interval Air Pressure	Interval for averaging and min/max evaluation in minutes Value range 1 … 10	1.0
5	4	Averaging Interval Wind	Interval for averaging and min/max evaluation in minutes Value range 1 … 10	1.0
6	5	Averaging Interval Global Radiation	Interval for averaging and min/max evaluation in minutes Value range 1 … 10	1.0
7	6	Heating Mode	High-Byte: Heating Mode Wind Low-Byte Heating Mode R2S Value range of each byte 0 … 3 (Details s. 10.4)	
8	7	Reset abs. Rain	(Function only when writing to the register, reading will give 0 always)	
9	8	Station reset	(Function only when writing to the register, reading will give 0 always)	

Heating Modes (see 10.5):

Automatic 0
Mode 1 1
Off 2
Eco 1 3

19.7.3.2 Function 0x06 Write Holding Register, 0x10 Write Multiple Registers

By writing into the holding registers selected parameters of the WSxxx-UMB can be adjusted through Modbus.

Register assignment see19.7.3.1

The transmitted values will be checked for plausibility. Illegal values will not be accepted and cause a Modbus exception.

When writing the value 0x3247 (12871d) to register no. 8 (reg. addr. 7) the stored absolute rain amount will be set to 0. Subsequently a station reset will be initiated.

When writing the value 0x3247 (12871d) to register no. 9 (reg. addr. 8) a station reset will be initiated.

19.7.3.3 Function 0x04 Read Input Registers

The input registers are containing the measurement values of the compact weather station and the related status information.

The measurement values are mapped to the 16bit registers using scaling factors (0 … max. 65530 for unsigned values, -32762 … 32762 for signed values).

Values 65535 (0xffff) resp. 32767 are used for the indication of erroneous or not available measurement values. A more detailed specification of the error can be evaluated from the status registers.

The assignment of values to the available register addresses (0 … 124) has been arranged in a way so that the user can read the most frequently used data with few (ideally only one) register block requests

Following blocks have been defined:

- Status information
- Frequently used values which are independent of the unit system (met./ imp.) in use
- Frequently used values in metric units
- Frequently used values in imperial units
- Other measurement values

When using the metric unit system the first three blocks can the supply all data usually required with one request.

There is no difference in the register assignment between the sub types of the WS family. If, dependent on the type, some value is not available, this will be indicated by setting the register to the error value.

For detailed information about measurement ranges, units etc. please refer to the related description of the UMB channels (Chapter 6 and 19.1)

Reg. No.	Reg. Addr.	Value (UMB Channel)	Range	Scaling Factor, Remarks
		Status Information		
1	0	Identification	High Byte: WS-Type (2,3,4,5,6) Low Byte: Software Version	
2	1	Device Status		
3	2	Sensor Status 1	Air temperature buffer, air temperature, dew point buffer, dew point(high byte -> low byte, see table below)	Coding 4 bit per status, see below
4	3	Sensor Status 2	Rel. humidity buffer, rel. humidity, abs. humidity buffer, abs. humidity(high byte -> low byte, see table below)	Coding 4 bit per status, see below
5	4	Sensor Status 3	Mixing ratio buffer, mixing ration, air press. buffer, air press. (high byte -> low byte, see table below)	Coding 4 bit per status, see below
6	5	Sensor Status 4	Wind, wind buffer, precipitation, compass(high byte -> low byte, see table below)	Coding 4 bit per status, see below
7	6	Sensor Status 5	Global radiation buffer, global radiation, leaf wetness buffer, leaf wetness (high byte -> low byte, see table below)	Coding 4 bit per status, see below
8	7	Sensor Status 6	External temperature (see table below)	
9	8	Reserve		
10	9		Diagnostic: run time in 10sec steps	

Reg. No.	Reg. Addr.	Value (UMB Channel)	Range	Scaling Factor, signed/unsigned, Remarks
		Values Independent of the Unit System		
11	10	200	Relative Humidity (act.)	Factor 10, s
12	11	220	Relative Humidity (min.)	Factor 10, s
13	12	240	Relative Humidity (max.)	Factor 10, s
14	13	260	Relative Humidity (avg.)	Factor 10, s
15	14	305	Rel. Air Pressure (act.)	Factor 10, s
16	15	325	Rel. Air Pressure (min.)	Factor 10, s
17	16	345	Rel. Air Pressure (max.)	Factor 10, s
18	17	365	Rel. Air Pressure (avg.)	Factor 10, s
19	18	500	Wind Direction (act.)	Factor 10, s
20	19	520	Wind Direction (min.)	Factor 10, s
21	20	540	Wind Direction (max.)	Factor 10, s
22	21	580	Wind Direction (vct.)	Factor 10, s
23	22	501	Wind Direction fast	Factor 10, s
24	23	502	Wind Direction compass corr.	Factor 10, s
25	24	510	Compass	Factor 10, s
26	25	805	Precipitation Type	Factor 1, s
27	26	700	Wind Measurement Quality	Factor 1, u
28	27	900	Global Radiation	Factor 10, s
29	28	920	Global Radiation	Factor 10, s
30	29	940	Global Radiation	Factor 10, s
31	30	960	Global Radiation	Factor 10, s

Reg. No.	Reg. Addr.	Value (UMB Channel)	Range	Scaling Factor, signed/unsigned Remarks
		Values in Metric Units		
32	31	100	Air Temperature °C (act.)	Factor 10, s
33	32	120	Air Temperature °C (min.)	Factor 10, s
34	33	140	Air Temperature °C (max.)	Factor 10, s
35	34	160	Air Temperature °C (avg.)	Factor 10, s
36	35	110	Dew Point °C (akt.)	Factor 10, s
37	36	130	Dew Point °C (min.)	Factor 10, s
38	37	150	Dew Point °C (max.)	Factor 10, s
39	38	170	Dew Point °C (avg.)	Factor 10, s
40	39	111	Wind Chill-Temperature °C	Factor 10, s
41	40	112	Heating Temperature Wind °C	Factor 10, s
42	41	113	Heating Temperature R2S °C	Factor 10, s
43	42	400	Wind Speed m/s (akt.)	Factor 10, s
44	43	420	Wind Speed m/s (min.)	Factor 10, s
45	44	440	Wind Speed m/s (max.)	Factor 10, s
46	45	460	Wind Speed m/s (avg.)	Factor 10, s
47	46	480	Wind Speed m/s (vct.)	Factor 10, s
48	47	401	Wind Speed fast m/s	Factor 10, s
49	48	620	Precipitation abs. mm	Factor 100, u, limited to 655.34mm
50	49	620	Precipitation diff. mm	Factor 100, u, limited to 100.00mm
51	50	820	Precipitation intens. mm/h	Factor 100, u, limited to 200.00mm/h

Reg. No.	Reg. Addr.	Value (UMB Channel)	Range	Scaling Factor, signed/unsigned Remarks
		Values in US Units		
52	51	105	Air Temperature °F (act.)	Factor 10, s
53	52	125	Air Temperature °F (min.)	Factor 10, s
54	53	145	Air Temperature °F (max.)	Factor 10, s
55	54	165	Air Temperature °F (avg.)	Factor 10, s
56	55	115	Dew Point °F (act.)	Factor 10, s
57	56	135	Dew Point °F (min.)	Factor 10, s
58	57	155	Dew Point °F (max.)	Factor 10, s
59	58	175	Dew Point °F (avg.)	Factor 10, s
60	59	116	Wind Chill-Temperature °F	Factor 10, s
61	60	117	Heating Temperature Wind °F	Factor 10, s
62	61	118	Heating Temperature R2S °F	Factor 10, s
63	62	410	Wind Speed mph (act.)	Factor 10, s
64	63	430	Wind Speed mph (min.)	Factor 10, s
65	64	450	Wind Speed mph (max.)	Factor 10, s
66	65	470	Wind Speed mph (avg.)	Factor 10, s
67	66	490	Wind Speed mph (vct.)	Factor 10, s
68	67	411	Wind Speed fast mph	Factor 10, s
69	68	640	Precipitation abs. In	Factor 1000, u, limited to 25.800 in
70	69	640	Precipitation diff. in	Factor 10000, u, limited to 3.9370in
71	70	840	Precipitation Intens. in/h	Factor 10000, u, limited to 6.5534 in

Reg. No.	Reg. Addr.	Value (UMB Channel)	Range	Scaling Factor, signed/unsigned, Remarks
		Further Values		
	71	205	Absolute Humidity (act.)	Factor 10, s
73	72	225	Absolute Humidity (min.)	Factor 10, s
74	73	245	Absolute Humidity (max.)	Factor 10, s
75	74	265	Absolute Humidity (avg.)	Factor 10, s
76	75	210	Mixing Ratio (act.)	Factor 10, s
77	76	230	Mixing Ratio (min.)	Factor 10, s
78	77	250	Mixing Ratio (max.)	Factor 10, s
79	78	270	Mixing Ratio (avg.)	Factor 10, s
80	79	300	Abs. Air Pressure (act.)	Factor 10, s
81	80	320	Abs. Air Pressure (min.)	Factor 10, s
82	81	340	Abs. Air Pressure (max.)	Factor 10, s
83	82	360	Abs. Air Pressure (avg.)	Factor 10, s
84	83	405	Wind Speed km/h (act.)	Factor 10, s
85	84	425	Wind Speed km/h (min.)	Factor 10, s
86	85	445	Wind Speed km/h (max.)	Factor 10, s
87	86	465	Wind Speed km/h (avg.)	Factor 10, s
88	87	485	Wind Speed km/h (vct.)	Factor 10, s
89	88	415	Wind Speed kts (act.)	Factor 10, s
90	89	435	Wind Speed kts (min.)	Factor 10, s
91	90	455	Wind Speed kts (max.)	Factor 10 , s
92	91	475	Wind Speed kts (avg.)	Factor 10, s
93	92	495	Wind Speed kts (vct.)	Factor 10, s
94	93	406	Wind Speed fast km/h	Factor 10, s
95	94	416	Wind Speed fast kts	Factor 10, s
96	95	403	Wind Speed Std. Dev. m/s	Factor 100, s
97	96	413	Wind Speed Std. Dev. mph	Factor 100, s
98	97	503	Wind Dir. Standard Dev.	Factor 100, s
99	98	114	Wet Bulb Temp. °C (act)	Factor 10, s
100	99	119	Wet Bulb Temp. °F (act)	Factor 10, s
101	100	215	Specific Enthalpy (act)	Factor 10, s
102	101	310	Air Density (act)	Factor 1000, s
103	102	710	Leaf Wetness mV (act)	Factor 1, s
104	103	730	Leaf Wetness mV (min)	Factor 1, s
105	104	750	Leaf Wetness mV (max)	Factor 1, s
106	105	770	Leaf Wetness mV (avg)	Factor 1, s
107	106	711	Leaf Wetness State (act)	Factor 1, s
108	107	101	External Temperature °C (act)	Factor 10, s
109	108	109	External Temperature °F (act)	Factor 10, s
		Reserved		

Sensor Status:
Each register holds 4 sensor status coded with 4 bits per status, so that together they build one 16bit number. The sequence defined in the table above is to understand as from most significant half byte to least significant half byte. Most of the sensors have two status values, one for the sensor itself and the current measurement value, another one for the buffer, from which average, min. And max values are evaluated.

Assignment of Status Information to Status Register

Register	Byte	Half-Byte	Status
Sensor Status 1	High	High	Temperature Buffer
		Low	Temperature
	Low	High	Dewpoint Buffer
		Low	Dewpoint
Sensor Status 2	High	High	Rel. Humidity Buffer
		Low	Rel. Humidity
	Low	High	Abs. Humidity Buffer
		Low	Abs. Humidity
Sensor Status 3	High	High	Mixing Ratio Buffer
		Low	Mixing Ratio
	Low	High	Air Pressure Buffer
		Low	Air Pressure
Sensor Status 4	High	High	Wind Buffer
		Low	Wind
	Low	High	Precipitation
		Low	Compass
Sensor Status 5	High	High	Global Radiation Buffer
		Low	Global Radiation
	Low	High	Leaf Wetness Buffer
		Low	Leaf Wetness
Sensor Status 6	High	High	
		Low	External Temperature
	Low	High	
		Low	

Example Sensor Status 1:

Temperature buffer status, temperature status, dewpoint buffer status, dewpoint status

High Byte		Low Byte	
High	Low	High	Low
Temperature-Buffer	Temperature	Dew point-Buffer	Dew point
5	3	0	7

The example values above (for illustration only, the given combination will not occur in reality) are combined to the register value 0x5307 = 21255.

The single status are retrieved from the register as integer part of

Status 1 = register / 4096

Status 2 = (register / 256) AND 0x000F

Status 3 = (register / 16) AND 0x000F

Status 4 = register AND 0x000F

Following table shows the status coding:

Coding of Sensor Status:

Sensor State	Code
OK	0
UNGLTG_KANAL	1
E2_CAL_ERROR E2_CRC_KAL_ERR FLASH_CRC_ERR FLASH_WRITE_ERR FLASH_FLOAT_ERR	2
MEAS_ERROR, MEAS_UNABLE	3
INIT_ERROR	4
VALUE_OVERFLOW CHANNEL_OVERRANGE VALUE_UNDERFLOW CHANNEL_UNDERRANGE	5
BUSY	6
Other Sensor State	7

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