

**TÜV RHEINLAND
ENERGIE UND UMWELT GMBH**



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 PM_{2.5}

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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

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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 PM₁₀ concentration as per “Air quality – Determination of the PM₁₀ 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}	PM₁₀
Daily limit DL (24 h)	Not defined	50 µg/m ³
Annual limit AL (1 a)	25 µg/m ³ *	40 µg/m ³

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

	PM_{2.5}	PM₁₀
Limit value	30 µg/m ³	50 µg/m ³

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.

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 PM_{2.5}, Report no.: 936/21227195/A

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 B₀, B₁, and B₂).

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 PM₁₀. Therefore, the following reference values are suggested for the measured component PM_{2.5}:

	PM_{2,5}	PM₁₀
B ₀	2 µg/m ³	2 µg/m ³
B ₁	25 µg/m ³	40 µg/m ³
B ₂	200 µg/m ³	200 µg/m ³

B₁ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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)

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 PM_{2.5}, Report no.: 936/21227195/A

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 PM₁₀ 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 PM₁₀ 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 206

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 244

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 45

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 PM_{2.5}, Report no.: 936/21227195/A

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

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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	Intercept	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 PM₁₀ 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 PM₁₀ and PM_{2,5}

Manufacturer:

PALAS GmbH, Karlsruhe

Field of application:

Continuous and parallel measurement of the PM₁₀ 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/m ³
PM _{2,5}	0 – 10,000	µg/m ³

Software version:

100380.0014.0001.0001.0011

Restrictions:

None

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 PM_{2.5}, Report no.: 936/21227195/A

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 PM₁₀ und PM_{2.5}.
3. One of the candidates did not meet the requirements in regard to the variation coefficient R² 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 PM₁₀ 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.gal1.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/A of 09th March 2015

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	78
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	79
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	82
4.1.4	Setup times and warm-up times	Shall be specified in the instruction manual.	Setup and warm-up times were determined.	yes	84
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	85
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	86
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	87

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	89
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	90
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	91
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	92
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	93
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	94
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	95
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	96

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	97
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	99
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	101
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/m ³ (PM ₁₀) and 8.7 x 10 ⁻⁴ µg/m ³ (PM _{2.5}) for System 1 (SN 0111), and 6.6 x 10 ⁻⁷ µg/m ³ (PM ₁₀) and 6.6 x 10 ⁻⁷ µg/m ³ (PM _{2.5}) for System 2 (SN 0112).	yes	103
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.	-	105

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".	-	106
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.	-	107
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.	-	108
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 $\pm 5\%$ 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 $-1.1 \times 10^{-5} \mu\text{g}/\text{m}^3$ for PM _{2.5} and $-1.1 \times 10^{-5} \mu\text{g}/\text{m}^3$ 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	109

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	113
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.	-	115
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.	-	116
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	117

Performance criterion	Specification	Test result	Fulfilled	Page
5.3.12 Long-term drift	<p>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.</p> <p>For PM:</p> <p>Zero point: within 24 h and within the maintenance interval a maximum of B₀.</p> <p>As reference point: within 24 h and within the maintenance interval a maximum 5 % of B₁.</p>	<p>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 B₀ = 2 µg/m³.</p> <p>For PM₁₀, 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 B₀ = 2 µg/m³.</p> <p>The sensitivity drift values that were determined during testing are max. -4.7 % for PM_{2.5} and -8.1 % for PM₁₀ in relation to the respective start value. Therefore, they exceed the permissible deviation of ± 5 % of B₁.</p> <p>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 PM₁₀). On the basis of the results obtained in the drift tests, a sensitivity check shall be carried out once a month.</p>	no	119
5.3.13 Short-term drift	<p>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.</p>	Not applicable.	-	128
5.3.14 Response time	<p>The response time (rise) of the measuring systems shall not exceed 180 s.</p> <p>The response time (fall) of the measuring systems shall not exceed 180 s.</p> <p>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.</p>	Not applicable.	-	129

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.	-	130
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.	-	131
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 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.	-	132
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.	-	133
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	134

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 $\geq 0,95$ 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	135
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 CI95 of max. 1.88 µg/m ³ is far below the permissible limit of 5 µg/m ³ .	yes	143
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	148
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/m ³ 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/m ³ 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	151
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	155

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	156
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	159
5.4.9 Determination of uncertainty between candidates u _{bs}	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/m ³ for PM _{2.5} and a maximum of 1.17 µg/m ³ for PM ₁₀ does not exceed the required value of 2.5 µg/m ³ .	yes	162
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	174

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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	197
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	205

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 u_{bs}	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 $\mu\text{g}/\text{m}^3$ for PM _{2.5} and a maximum of 1.19 $\mu\text{g}/\text{m}^3$ for PM ₁₀ does not exceed the required value of 2.5 $\mu\text{g}/\text{m}^3$.	yes	207
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	217
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	236

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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	<p>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).</p> <p>For PM:</p> <p>Zero point value for ΔT_u of 15 K between +5 °C and +20 °C or 20 K between +20 °C and +40 °C shall not exceed B0.</p> <p>The measurement value in the range of B1 shall not exceed $\pm 5\%$ for ΔT_u of 15 K between +5 °C and +20 °C or for 20 K between +20 °C and +40 °C</p>	<p>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 $5.5 \times 10^{-5} \mu\text{g}/\text{m}^3$ for PM_{2.5} and $5.7 \times 10^{-5} \mu\text{g}/\text{m}^3$ for PM₁₀</p> <p>At the reference point, no deviations > -2.2 % for PM_{2,5} respectively > -2.2 % for PM₁₀ related to the base value at 20 °C could be determined for an ambient temperature in the range of +5 °C to +40 °C.</p>	yes	244

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 PM₁₀ 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 PM₁₀ 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]

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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.

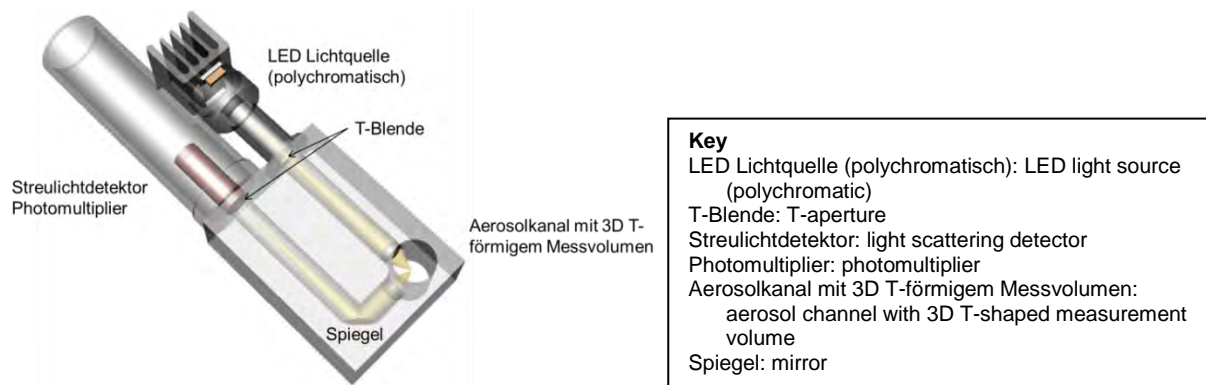


Figure 1: Design of the Fidas[®] sensor

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

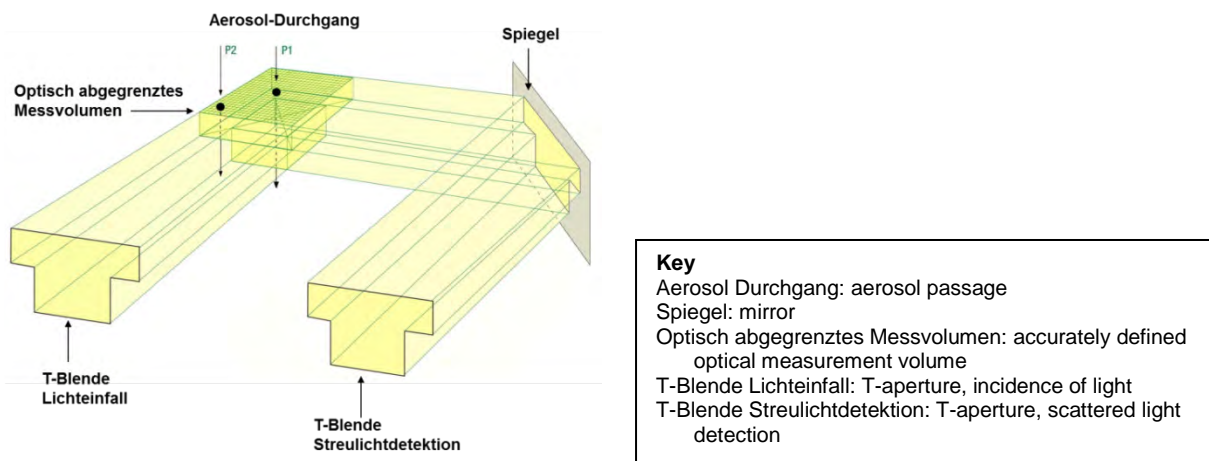


Figure 2: Graphical representation of the T-aperture

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.

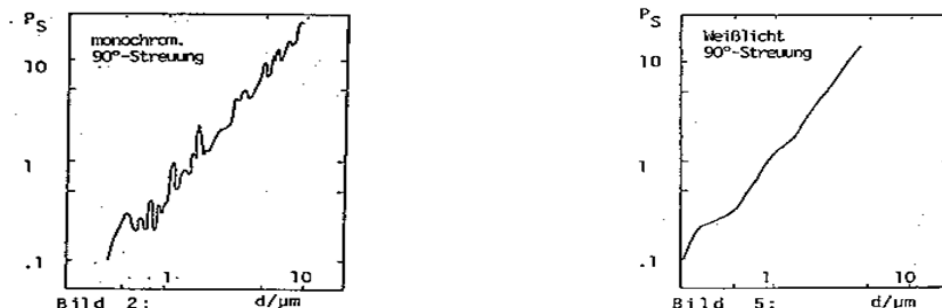


Figure 3: Calibration curve for 90° scattered light detection with monochromatic light source (left) and with polychromatic light source (right)

Each particle generates a scattered light impulse, detected at an angle of 85° to 90° degrees. The number concentration is deduced 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.

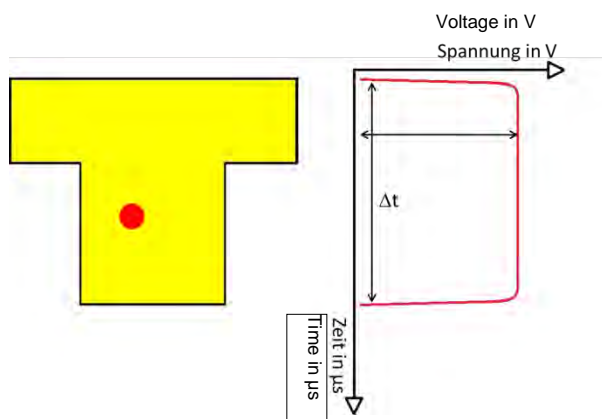


Figure 4: Measurement of scattered light signal at one single particle. Amplitude and signal length are being measured

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).

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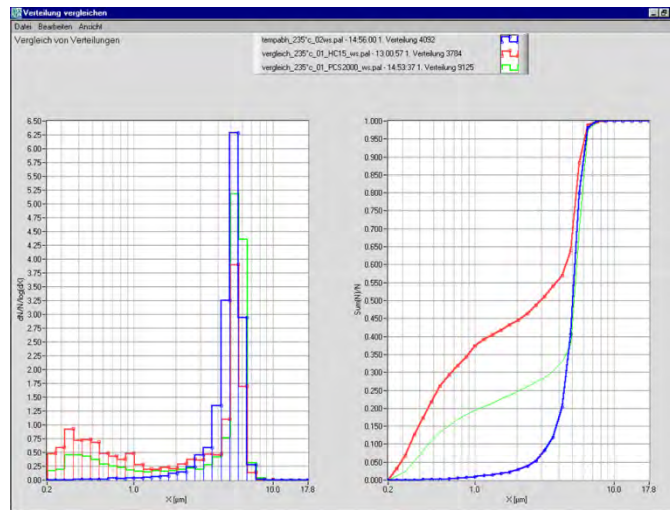


Figure 5: Comparison of an optical light scattering spectrometer with rectangular aperture (HC15, red) with an optical scattering light spectrometer with T-aperture (welas®, blue) upon application of monodisperse 5 µm particles

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).

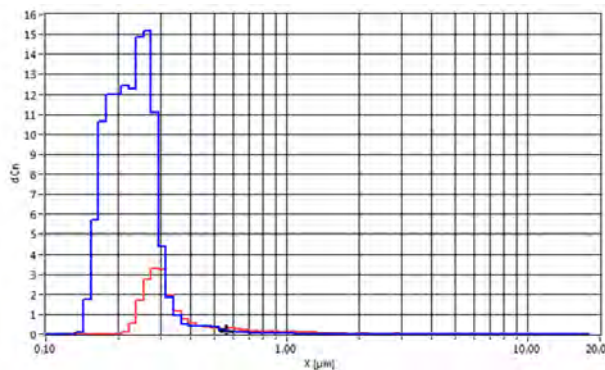


Figure 6: Comparison of results of a measurement carried out in close proximity to a street between the Fidas® measuring system (size range from 0.18 µm, blue curve) and another optical measuring system (size range from 0.25 µm, red curve)

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).

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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 IADS is regulated with regard to relative humidity and ambient temperature (measured with weather station WS600-UMB). The minimum temperature is 23 °C, the maximum temperature is 24 °C above ambient temperature at an heat output of max. 90 watts. 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.

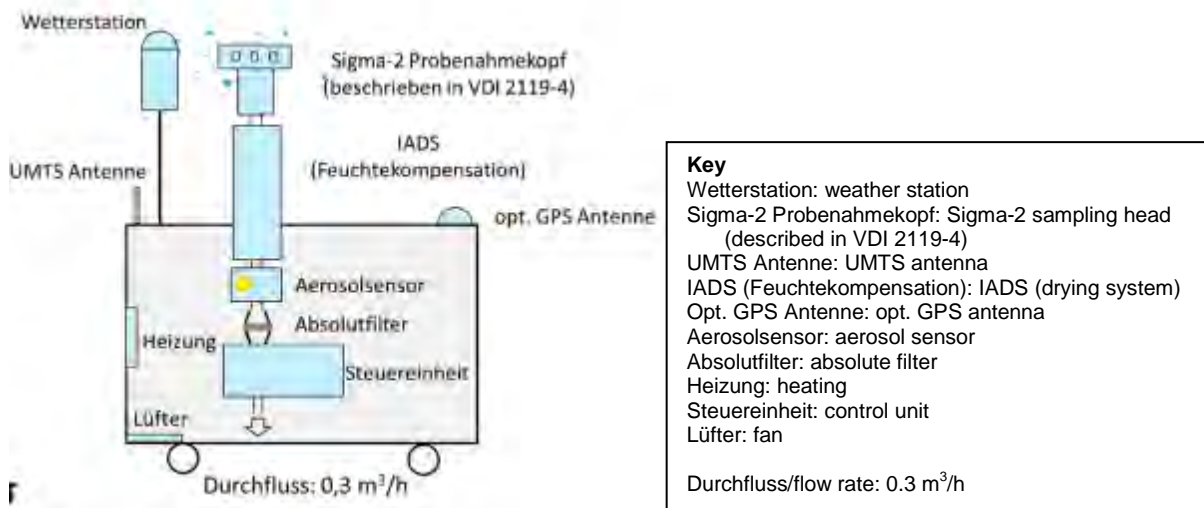


Figure 7: Schematic view of the Fidas® 200 S

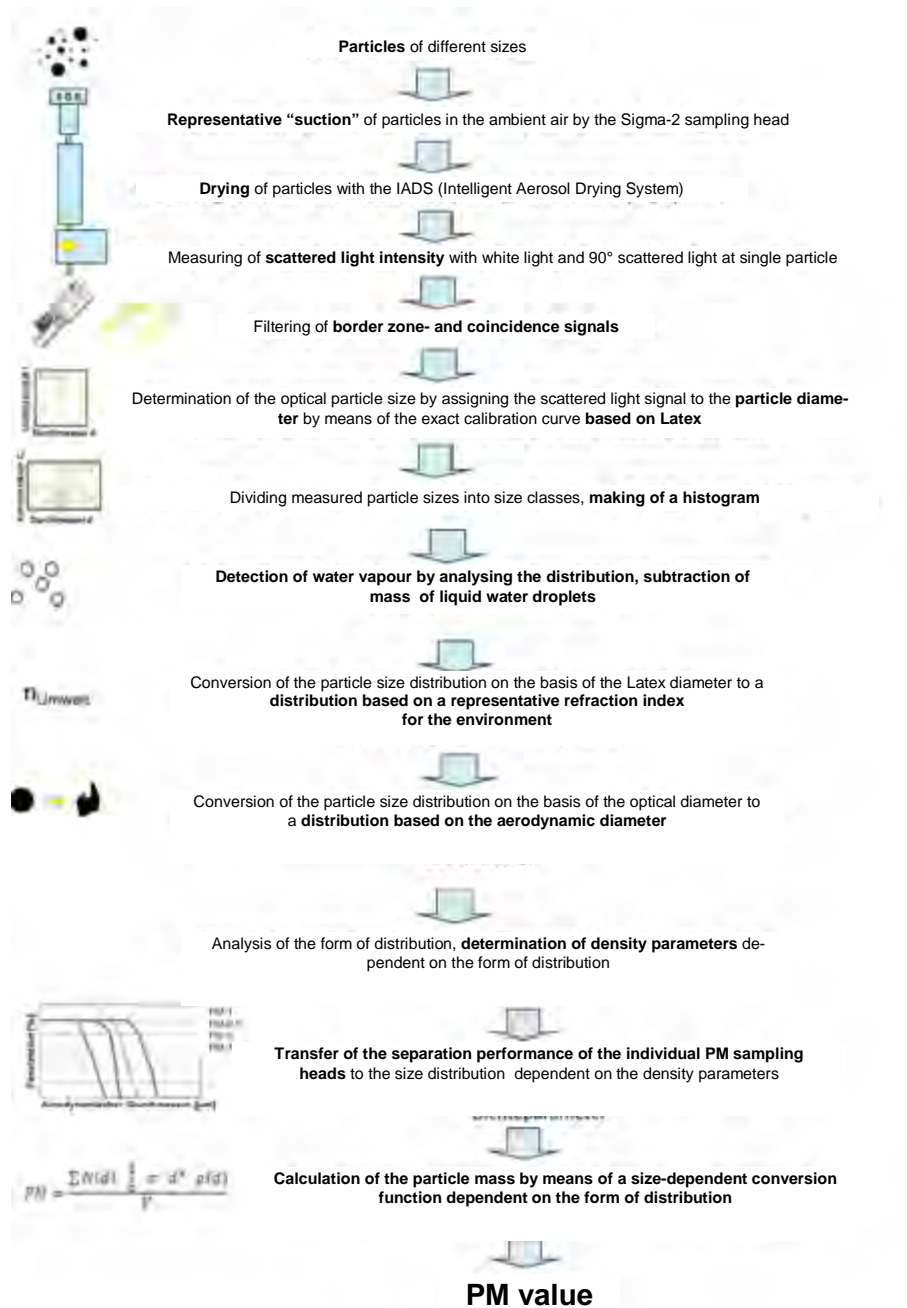


Figure 8: Overview of the measurement steps of the Fidas® 200 S / Fidas® 200

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.

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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.

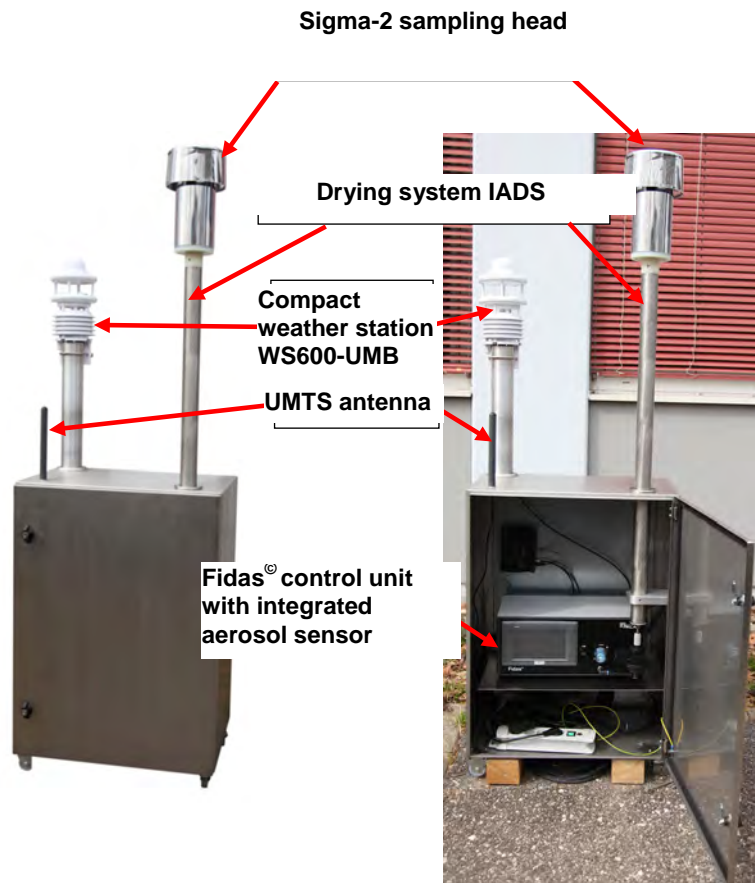


Figure 9 Overview Fidas[®] 200 S complete system (=Fidas[®] 200 in weatherproof housing)



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

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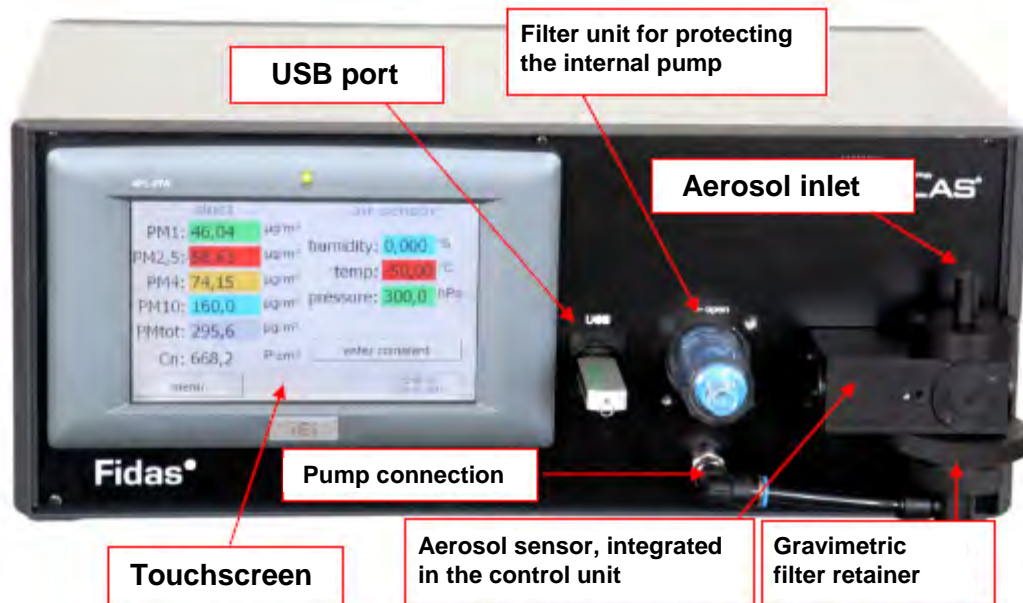


Figure 12: Control unit of the Fidas[®] 200 S / Fidas[®] 200



Figure 13: Weather station WS600-UMB

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

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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.

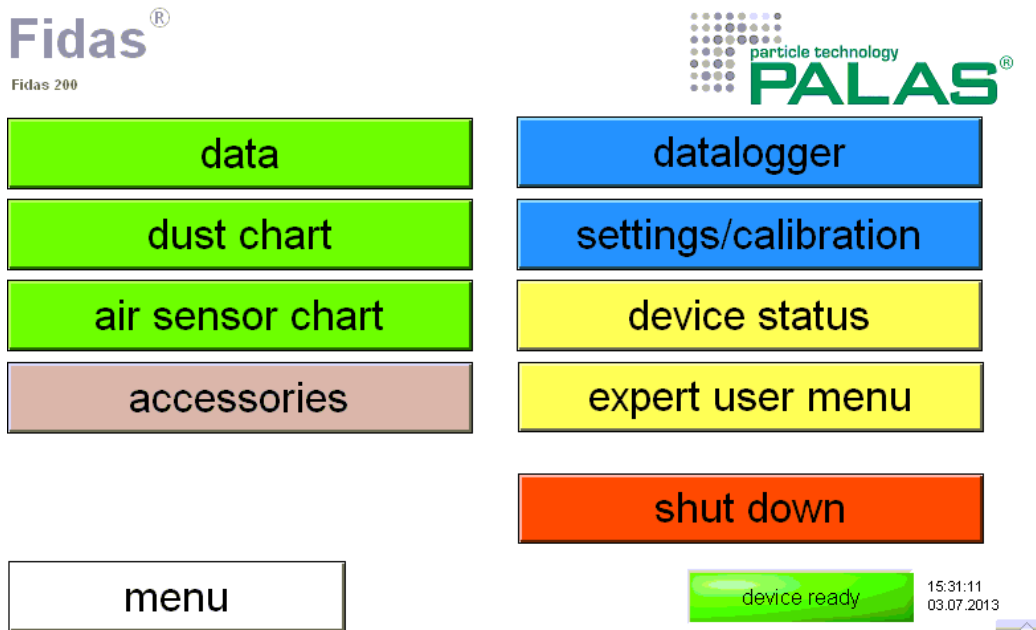


Figure 15: Main menu

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”.

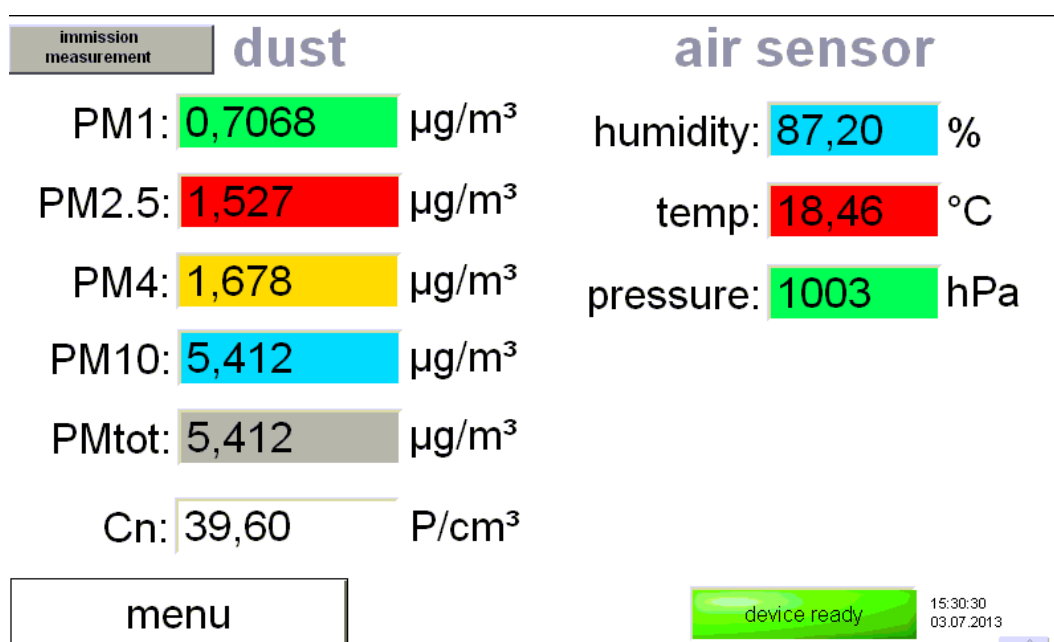


Figure 16: “data” menu

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.

device status

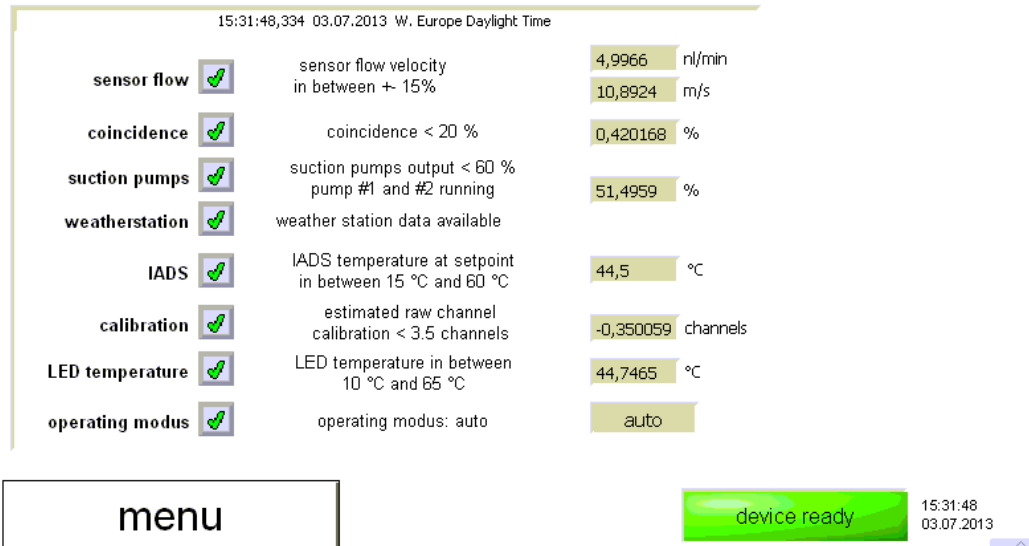


Figure 17: “device status” menu

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. |

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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.

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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

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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 $0.93 \mu\text{m}$) 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.

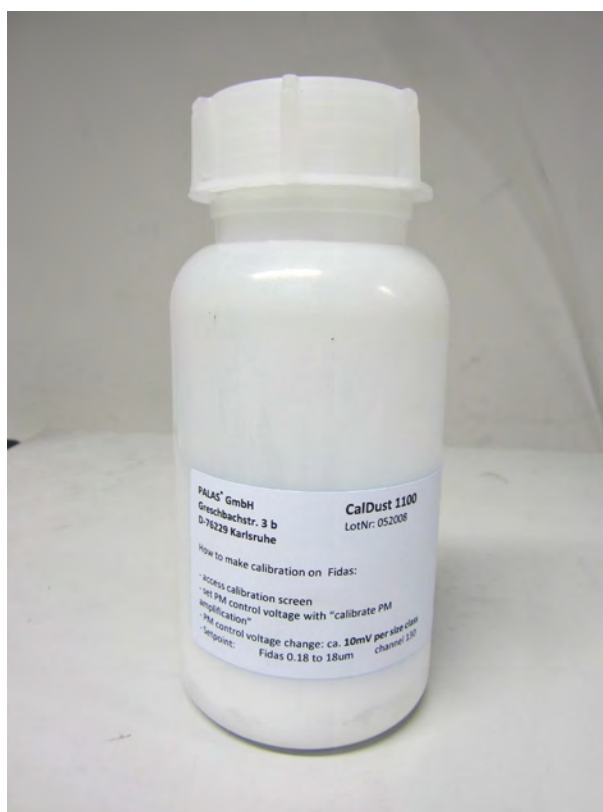


Figure 19: CalDust 1100 for verification / calibration of sensitivity

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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 manufacturer, 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 explicit 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 30 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	<p>1 x RS232 port for communication via Modbus for remote enquiry of measured values and external control of the measuring system (WebAccess)</p> <p>1 x Ethernet port for connecting to a network or PC for data transmission as well as remote control, for instance via TeamViewer software</p> <p>1 x USB port on the front side of the device, enables direct downloading of data for processing at an external PC</p> <p>1 x USB port on the rear side of the device to connect, for instance, printer, keyboard, mouse or USB flash drive</p>
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 PM₁₀ 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.

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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)

channel shift	PM2,5		PM10	
	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 PM₁₀ 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.

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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 Rain-wise (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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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: *Additional 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.

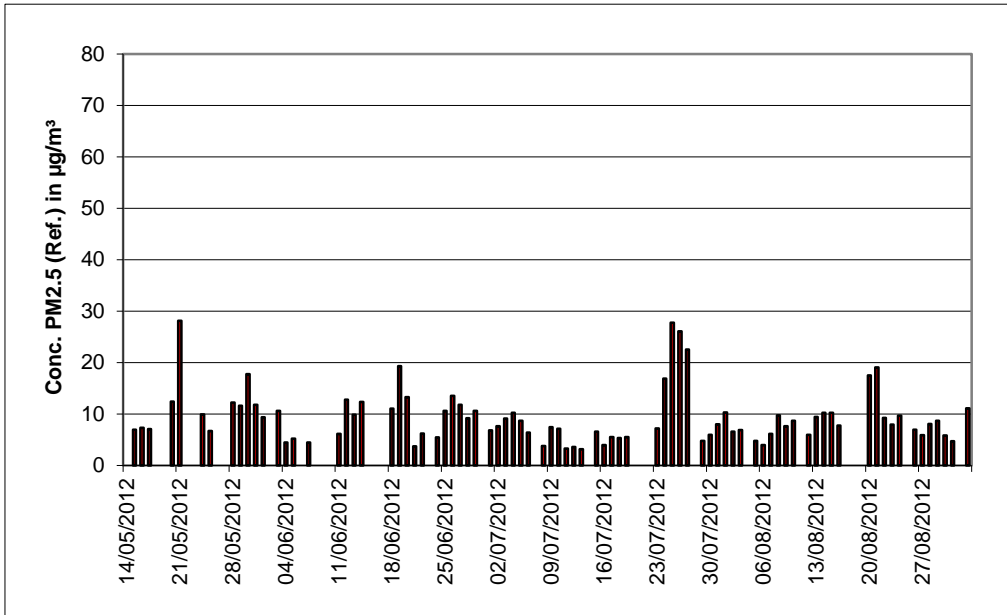


Figure 20: Course of PM_{2.5} concentrations (reference) at test site "Cologne, summer"

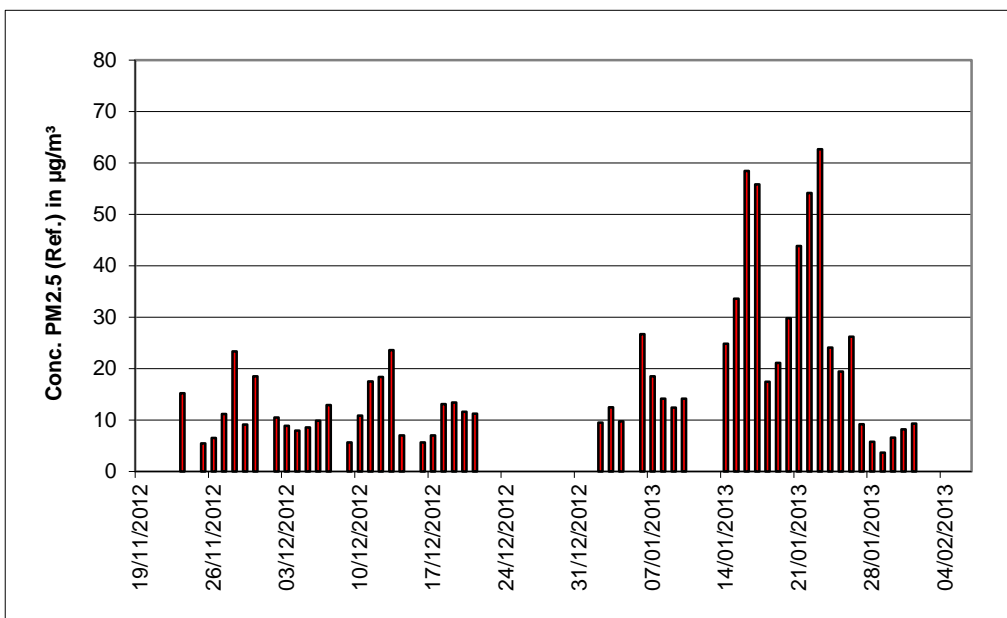


Figure 21: Course of PM_{2.5} concentrations (reference) at test site "Cologne, winter"

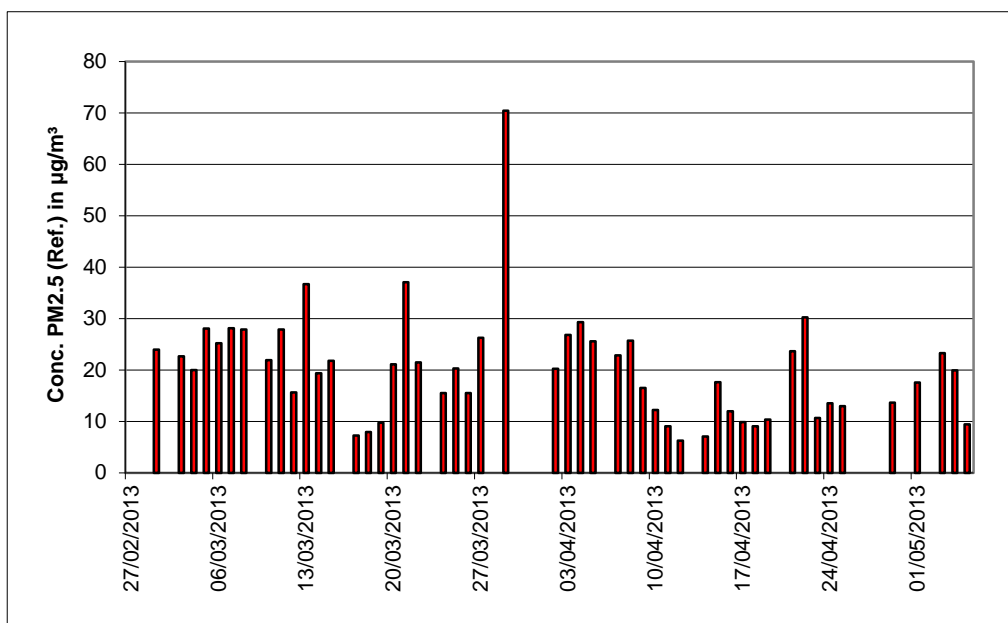


Figure 22: Course of PM_{2.5} concentrations (reference) at test site "Bonn, winter"

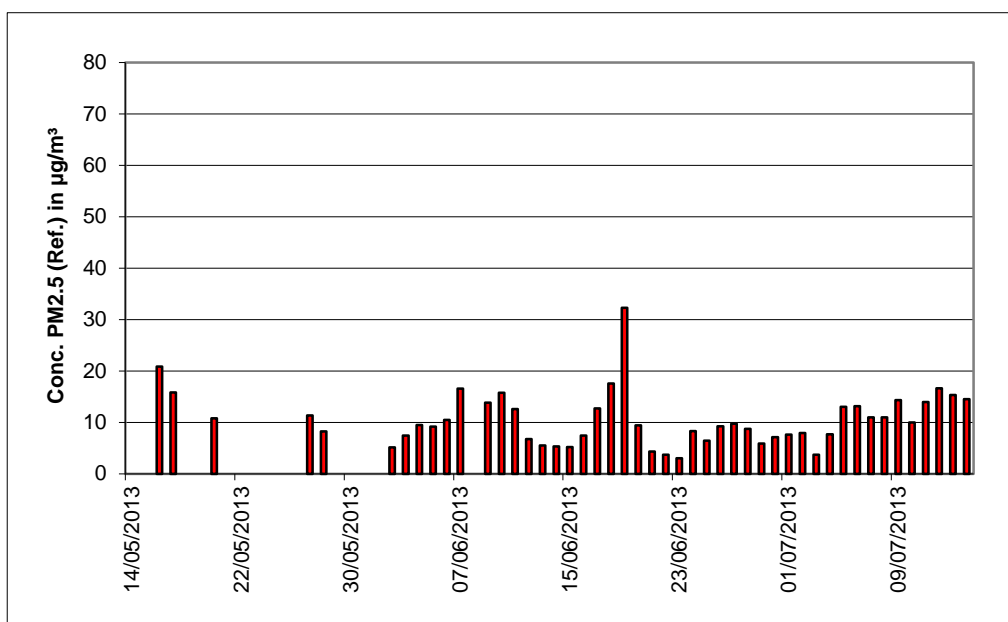


Figure 23: Course of PM_{2.5} concentrations (reference) at test site "Bornheim, summer"

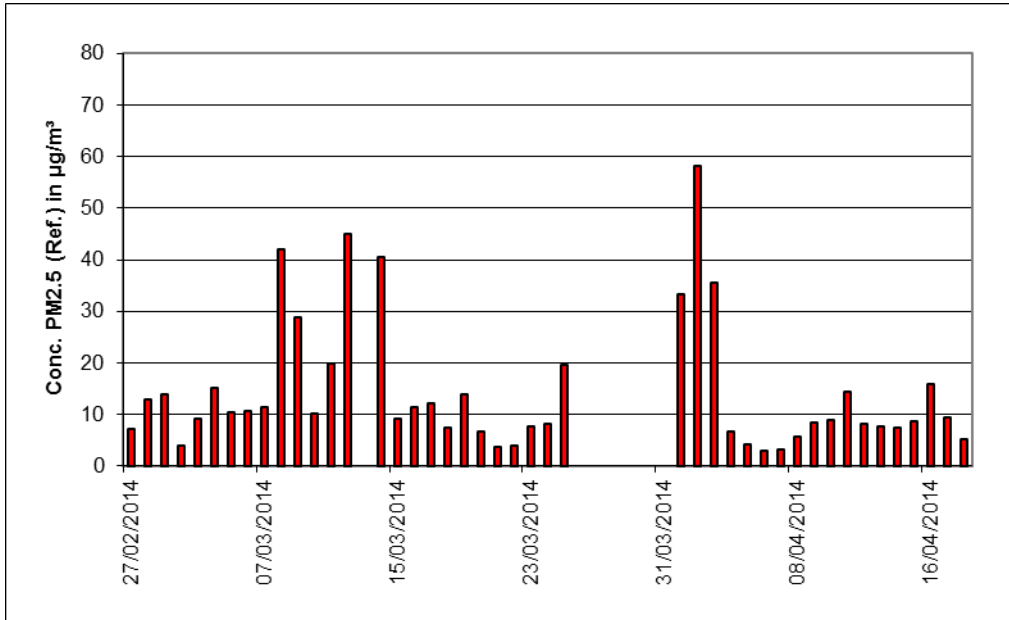


Figure 24: Course of PM_{2.5} concentrations (reference) at test site "Teddington, winter"

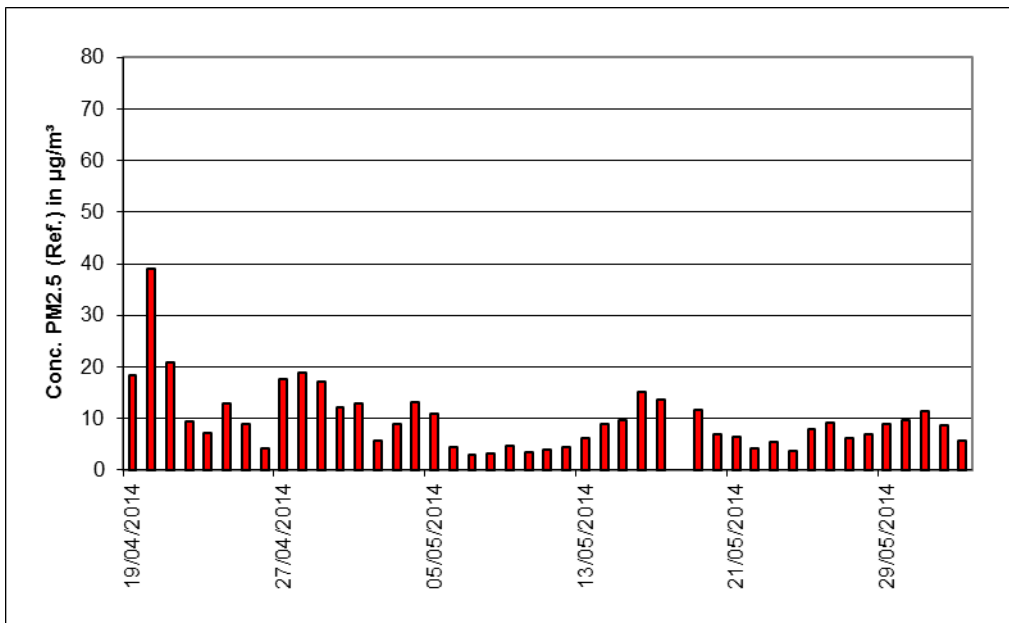


Figure 25: Course of PM_{2.5} concentrations (reference) at test site "Teddington, summer"

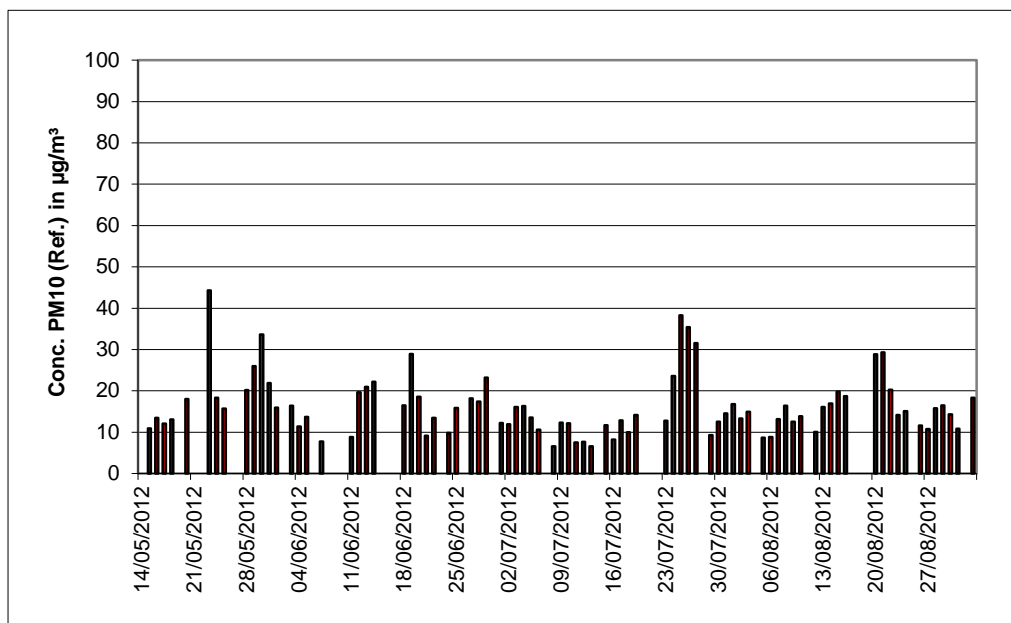


Figure 26: Course of PM₁₀ concentrations (reference) at test site "Cologne, summer"

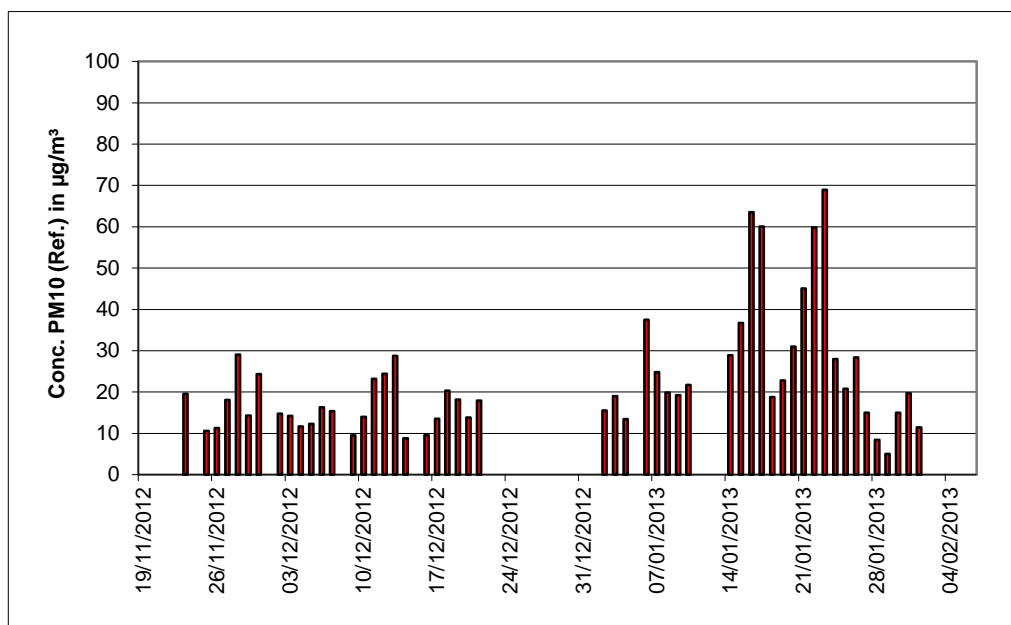


Figure 27: Course of PM₁₀ concentrations (reference) at test site "Cologne, winter"

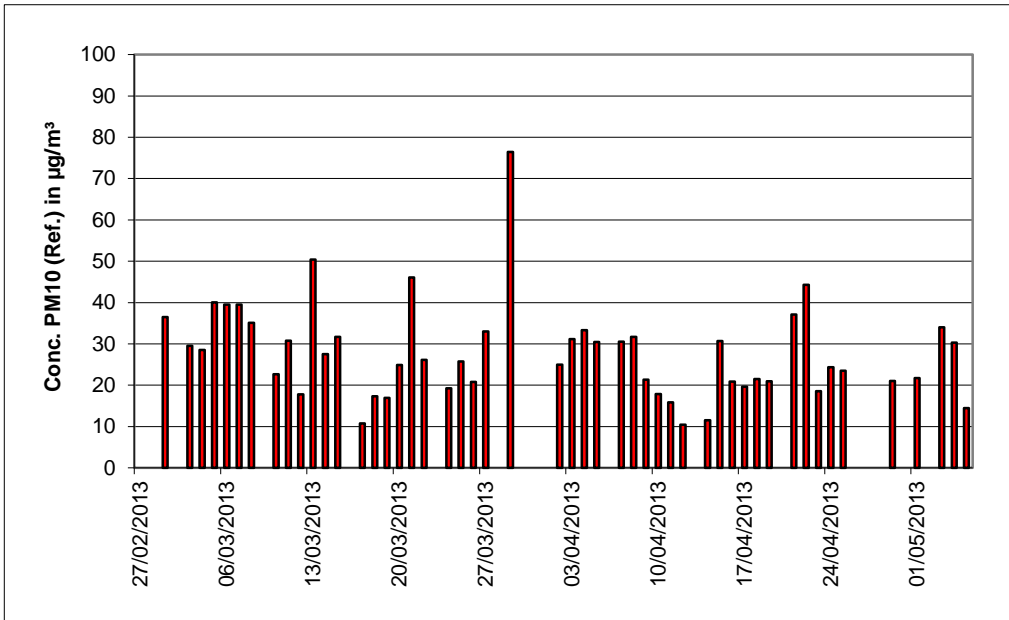


Figure 28: Course of PM₁₀ concentrations (reference) at test site "Bonn, winter"

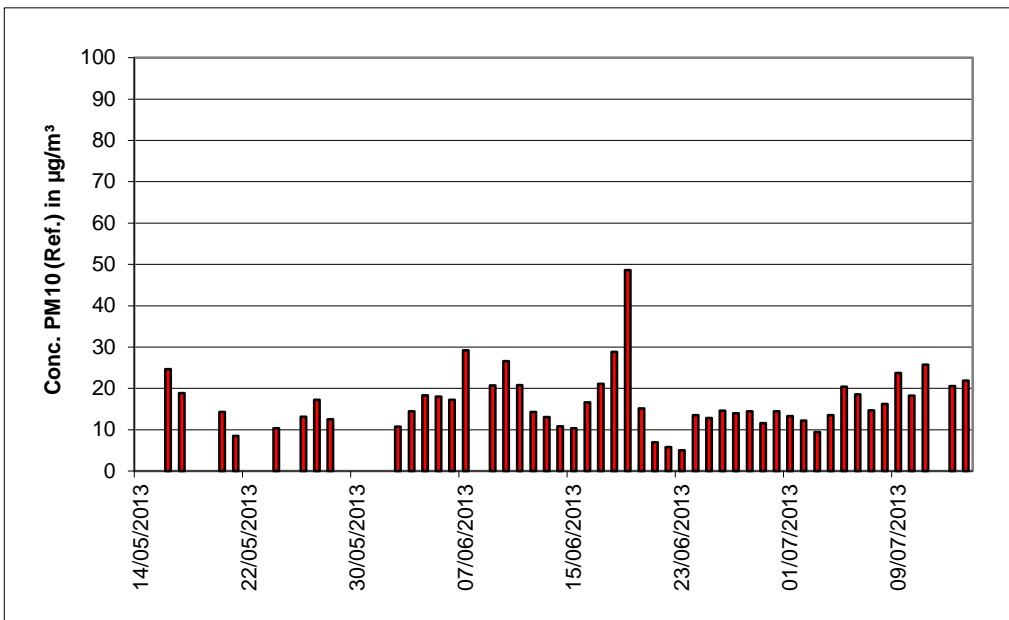


Figure 29: Course of PM₁₀ concentrations (reference) at test site "Bornheim, summer"

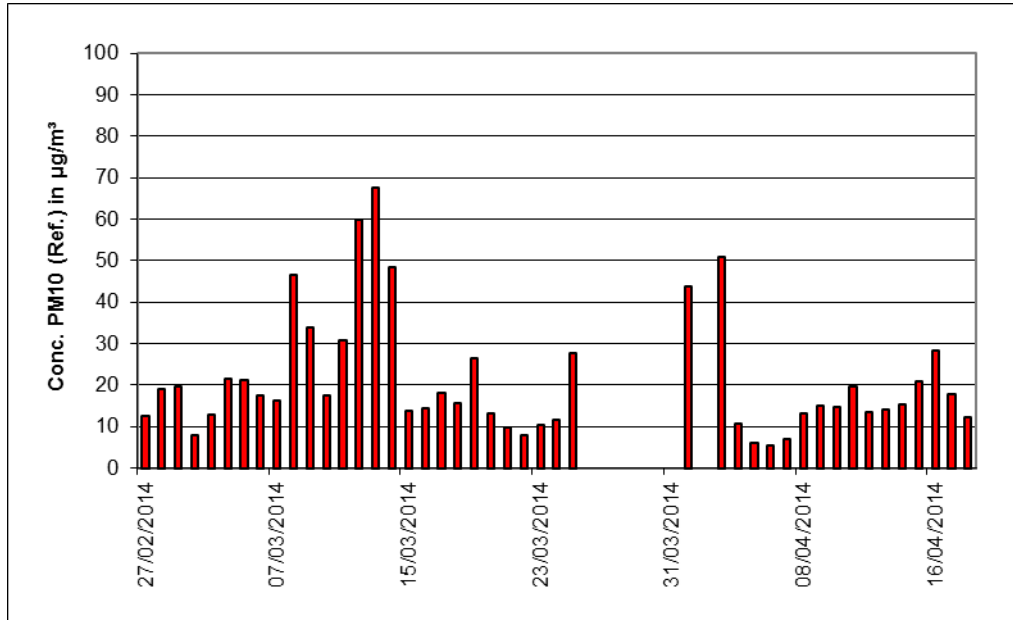


Figure 30: Course of PM₁₀ concentrations (reference) at test site "Teddington, winter"

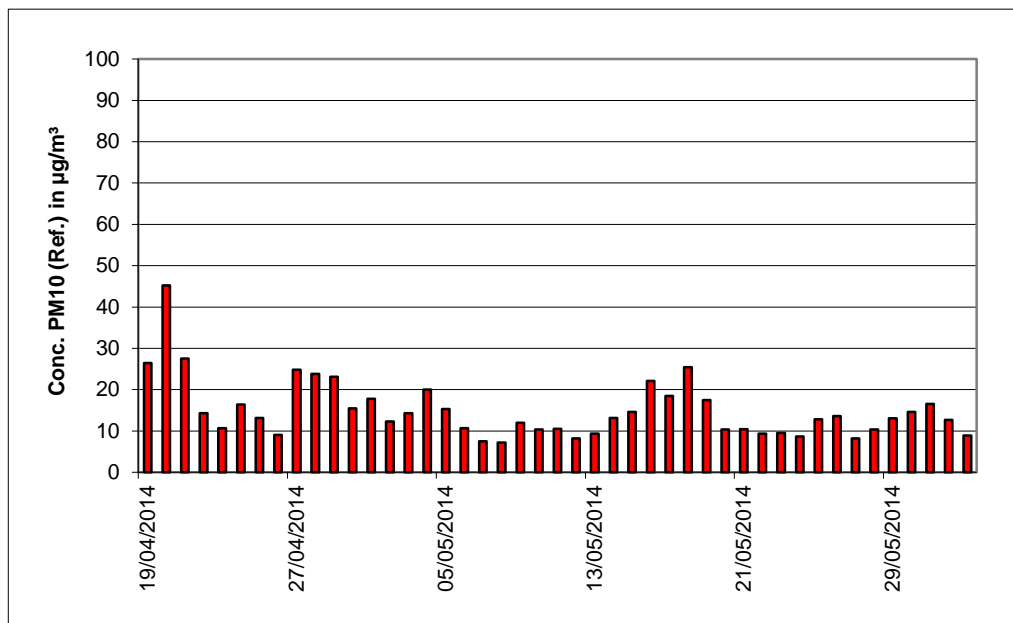


Figure 31: Course of PM₁₀ concentrations (reference) at test site "Teddington, summer"

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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

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Figure 34: *Field test site Bornheim, summer*



Figure 35: *Field test site Teddington, UK*

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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 English 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 PM₁₀ [%]				
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

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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 PM₁₀ [%]		
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 outliers and therefore removed at each site (reference).

Table 10: Results of the Grubbs' outlier test – reference PM₁₀

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' outlier 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 PM₁₀ value pairs according to Grubbs

Test site	Date	Reference 1 [µg/m ³]	Reference 2 [µg/m ³]
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/m ³]	Reference 2 [µg/m ³]
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™, Ø 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.

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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 PM₁₀: Small Filter Device Low Volume Sampler LVS3
Manufacturer: Ingenieurbüro Sven Leckel,
Leberstraße 63, Berlin, Germany
Date of construction: 2007
PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ and PM_{2.5} fractions, the “data” submenu also shows the measurements of the PM₁, PM₄, and PM_{total} fractions as well as particle number, ambient temperature, humidity, and ambient pressure (sliding 30-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.

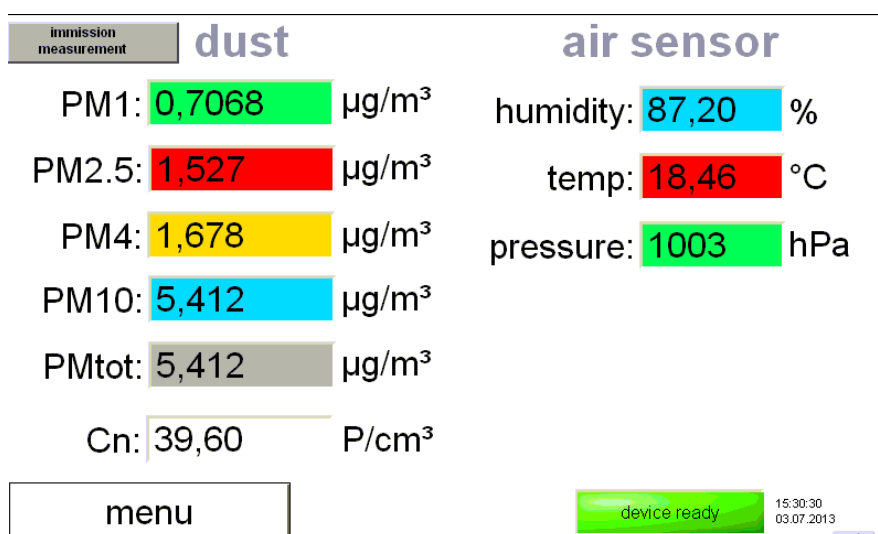


Figure 36: Display of measured concentrations

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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 sensor 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 PM₁₀ 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

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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.

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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.

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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.

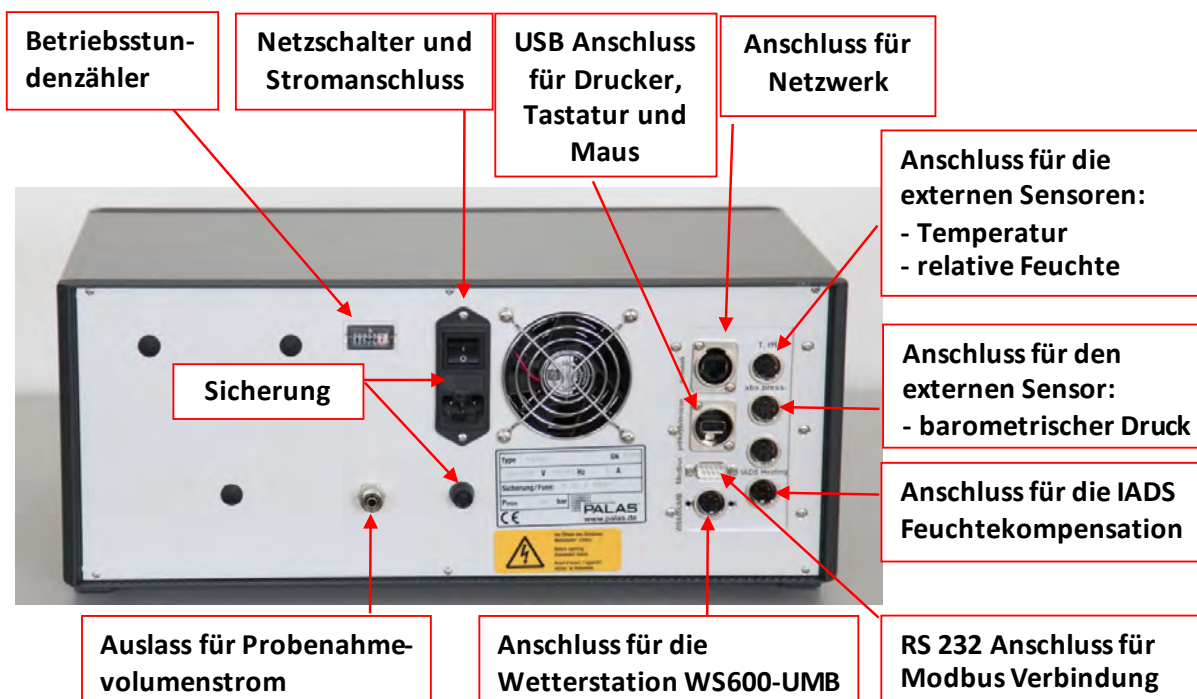


Figure 37: Rear side of the Fidas® 200 S control unit

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 for the weather station WS600-UMB
 Auslass für Probenahmevolumenstrom: Exhaust for sample flow

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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/m ³	in µg/m ³	in µg/m ³	
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:

PM₁₀: 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.

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 PM_{2.5}, Report no.: 936/21227195/A

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: PM₁₀: 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 suppressed (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.

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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.

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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.

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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

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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

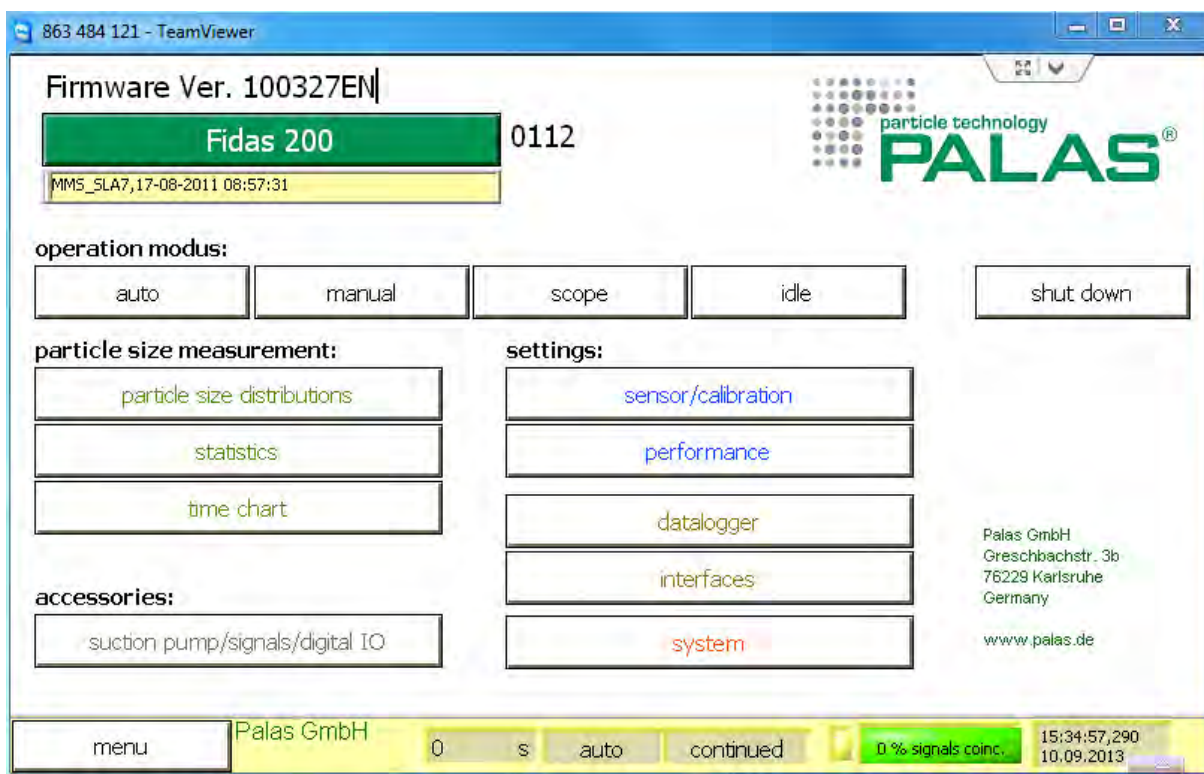


Figure 38: Display of software version – here 100327EN – the label “EN” was only used by Palas in order to mark the firmware used in the type approval test and will not appear in the future

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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 B₀, B₁, and B₂).

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 B₀, B₁, and B₂). 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.

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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_{x_0} 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_{x_0} of the measured values x_{0i} for each candidate multiplied by the Student's factor:

$$X = t_{n-1;0.95} \cdot s_{x_0} \quad \text{with} \cdot s_{x_0} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1,n} (x_{0i} - \bar{x}_0)^2}$$

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

6.5 Assessment

The tests resulted in detection limits of $8.7 \times 10^{-4} \mu\text{g}/\text{m}^3$ (PM₁₀) and $8.7 \times 10^{-4} \mu\text{g}/\text{m}^3$ (PM_{2,5}) for System 1 (SN 0111), and $6.6 \times 10^{-7} \mu\text{g}/\text{m}^3$ (PM₁₀) and $6.6 \times 10^{-7} \mu\text{g}/\text{m}^3$ (PM_{2,5}) for System 2 (SN 0112).

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 18: *Detection limit PM₁₀*

		Device SN 0111	Device SN 0112
Number of values n		15	15
Average of the zero values \bar{x}_0	$\mu\text{g}/\text{m}^3$	0,0001924	0,0000002
Standard deviation of the values s_{x0}	$\mu\text{g}/\text{m}^3$	0,0004064	0,0000003
Student-Factor $t_{n-1;0,95}$		2,14	2,14
Detection limit x	$\mu\text{g}/\text{m}^3$	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 \bar{x}_0	$\mu\text{g}/\text{m}^3$	0,0001638	0,0000002
Standard deviation of the values s_{x0}	$\mu\text{g}/\text{m}^3$	0,0004036	0,0000003
Student-Factor $t_{n-1;0,95}$		2,14	2,14
Detection limit x	$\mu\text{g}/\text{m}^3$	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.

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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 PM₁₀ 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. (PM₁₀) and 5.4.10 (PM_{2.5})

6.3 Method

Particulate measuring systems for PM₁₀ 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. (PM₁₀) and 5.4.10 (PM_{2.5})

6.5 Assessment

Particulate measuring systems for PM₁₀ 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 (PM₁₀) and 5.4.10 (PM_{2.5})

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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_i 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.

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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 PM₁₀ 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: $B_0 = 2 \mu\text{g}/\text{m}^3$

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 $-1.1 \times 10^{-5} \mu\text{g}/\text{m}^3$ for PM_{2.5} and $-1.1 \times 10^{-5} \mu\text{g}/\text{m}^3$ for PM₁₀.

At reference point, no deviations > 5.0 % for PM_{2.5} and > 4.6 % for PM₁₀ in relation to the default temperature of 20 °C were observed.

Performance criterion met? yes

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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, PM₁₀, SN 0111 & SN 0112*

Ambient temperature		Deviation	
Start temperature	End temperature	SN 0111	SN 0112
°C	°C	µg/m ³	µg/m ³
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/m ³	µg/m ³
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, PM₁₀, 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.

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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_i 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 $\mu\text{g}/\text{m}^3$ for PM_{2.5} and 40 $\mu\text{g}/\text{m}^3$ for PM₁₀ 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 PM₁₀ 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 %, PM₁₀, 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 0112

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

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

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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.

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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:

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

- R = Reproducibility at B_1
- U = Uncertainty
- B_1 = 40 $\mu\text{g}/\text{m}^3$ for PM₁₀ and 25 $\mu\text{g}/\text{m}^3$ 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 PM₁₀.
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 PM₁₀ 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 B₁ for each site:

Table 26: Concentration mean values, standard deviation, uncertainty range, and reproducibility in the field, measured component PM₁₀

Test site	Number	\bar{c} (SN 0111)	\bar{c} (SN 0112)	\bar{c}_{ges}	s _D	t	U	R
		µg/m ³	µg/m ³	µg/m ³	µg/m ³		µg/m ³	
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/m ³	µg/m ³	µg/m ³	µg/m ³		µg/m ³	
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.

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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_i 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 PM₁₀ 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 B₀ = 2 µg/m³.

For PM₁₀, 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 B₀ = 2 µg/m³.

The sensitivity drift values that were determined during testing are max. -4.7 % for PM_{2.5} and -8.1 % for PM₁₀ in relation to the respective start value. Therefore, they exceed the permissible deviation of ± 5 % of B₁.

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 PM₁₀). 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).

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Table 28: Zero point drift SN 0111 & SN 0112, PM₁₀, 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/m ³	µg/m ³	µg/m ³		µg/m ³	µg/m ³	µg/m ³
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

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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/m ³	µg/m ³	µg/m ³		µg/m ³	µg/m ³	µg/m ³
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

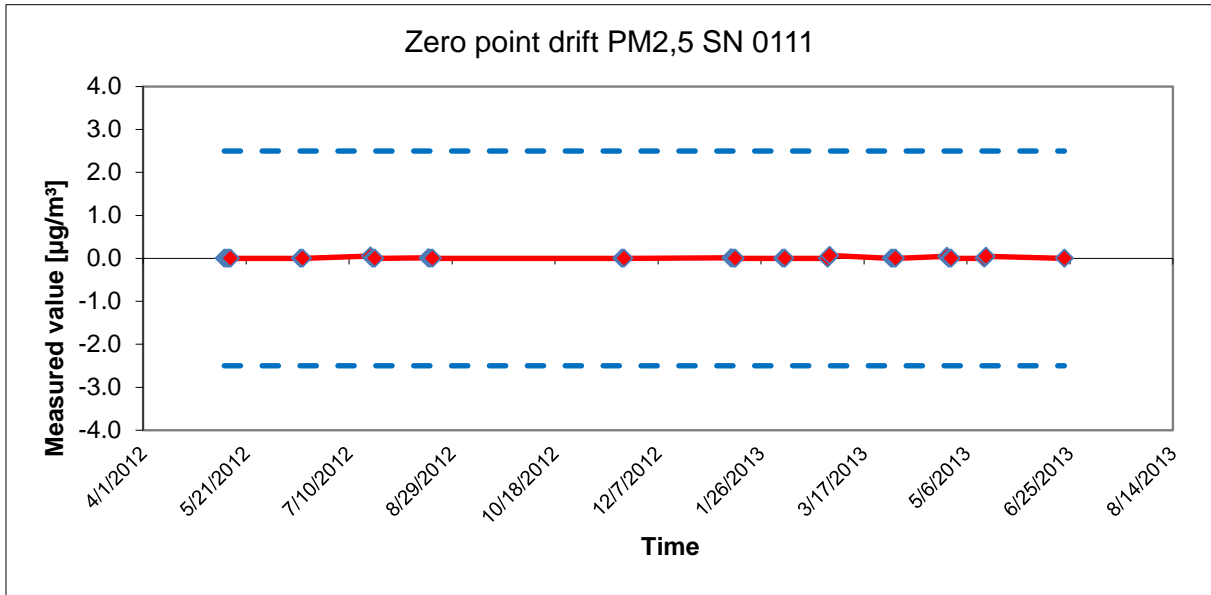


Figure 39: Zero point drift SN 0111, measured component PM_{2.5}

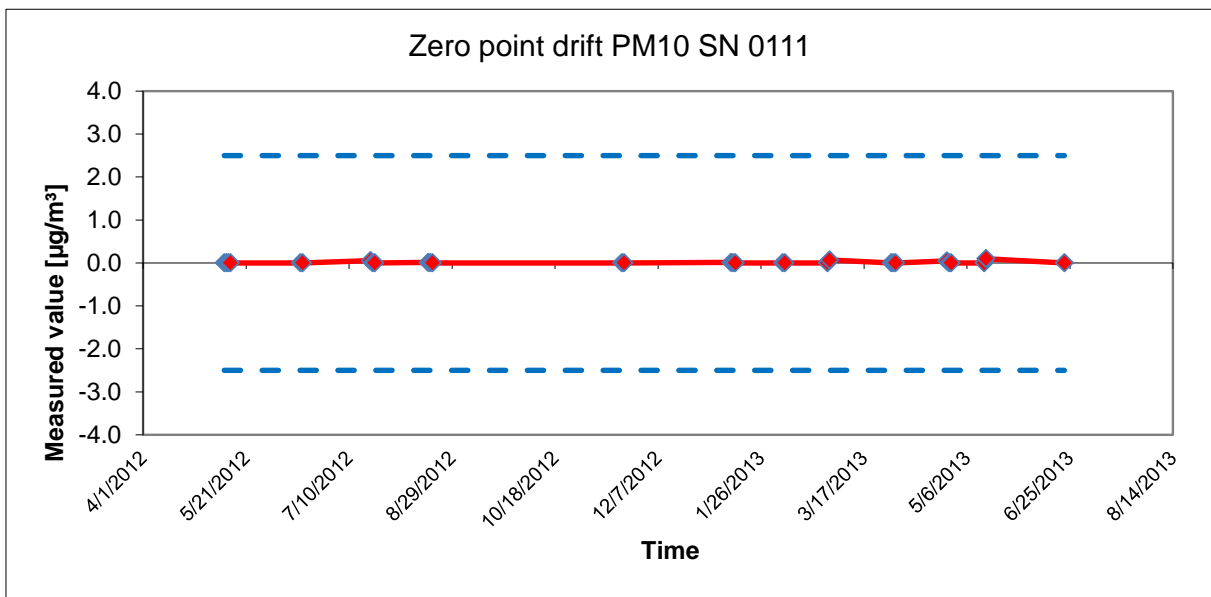


Figure 40: Zero point drift SN 0111, measured component PM₁₀

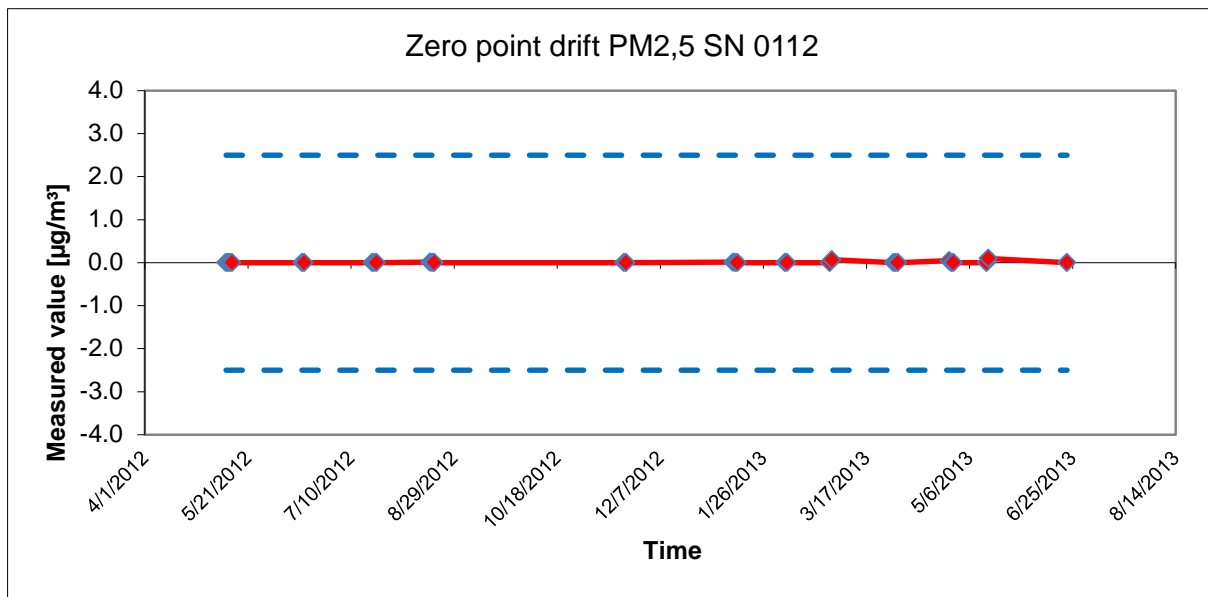


Figure 41: Zero point drift SN 0112, measured component PM_{2,5}

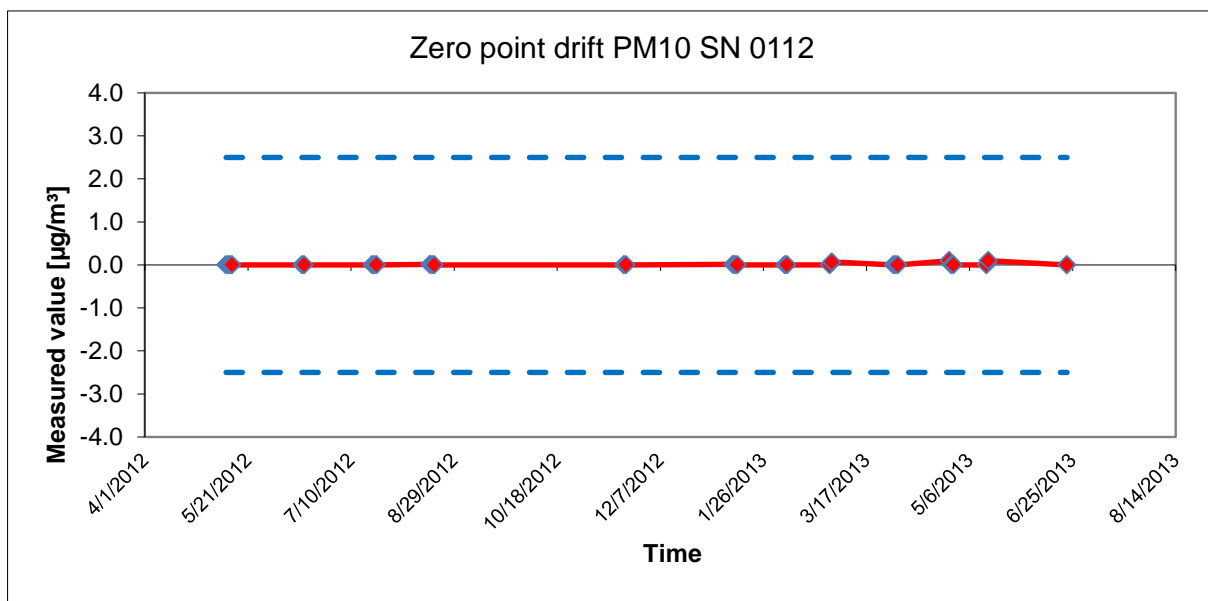


Figure 42: Zero point drift SN 0112, measured component PM₁₀

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Table 30: Sensitivity drift SN 0111 & SN 0112, PM₁₀

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

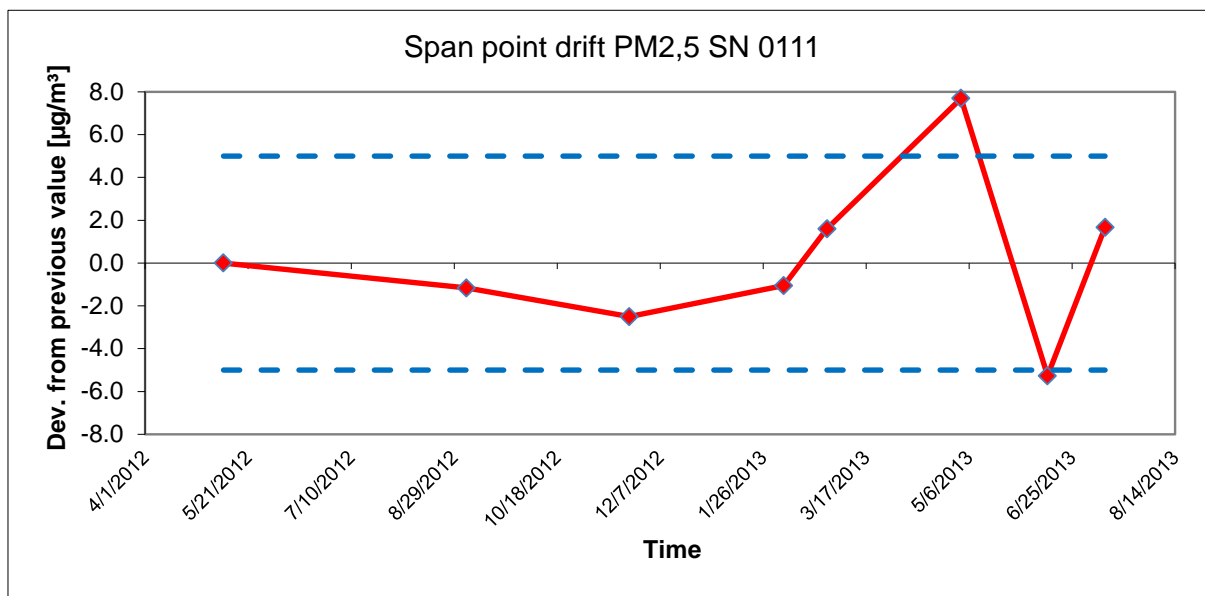


Figure 43: Drift of the measured value SN 0111, measured component PM_{2,5}

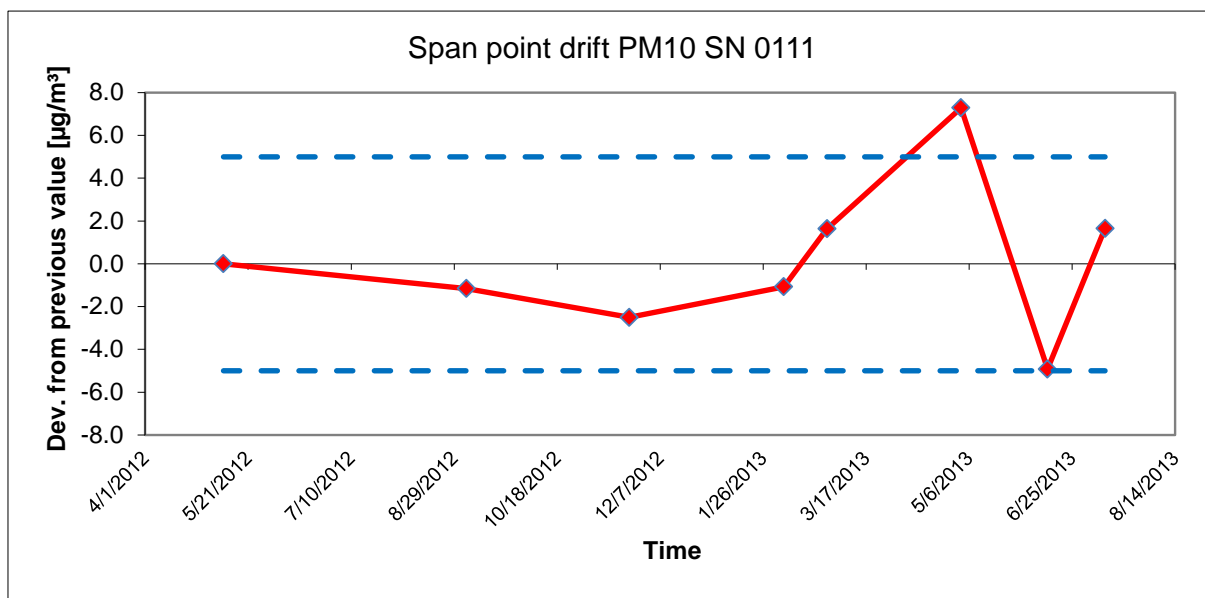


Figure 44: Drift of the measured value SN 0111, measured component PM₁₀

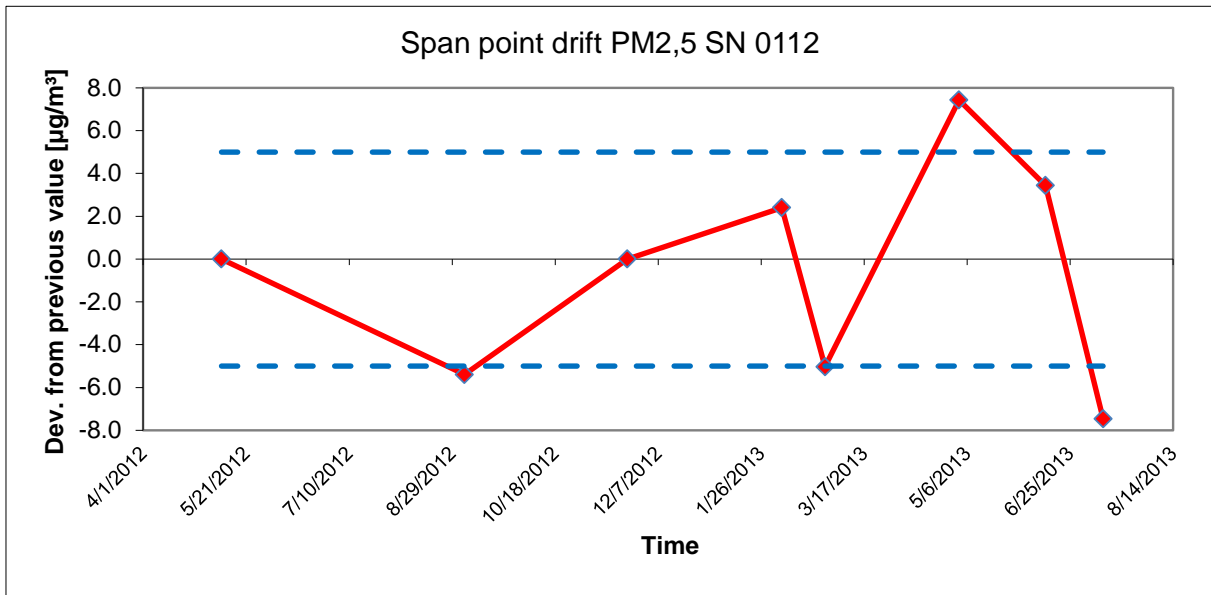


Figure 45: Drift of the measured value SN 0112, measured component PM_{2.5}

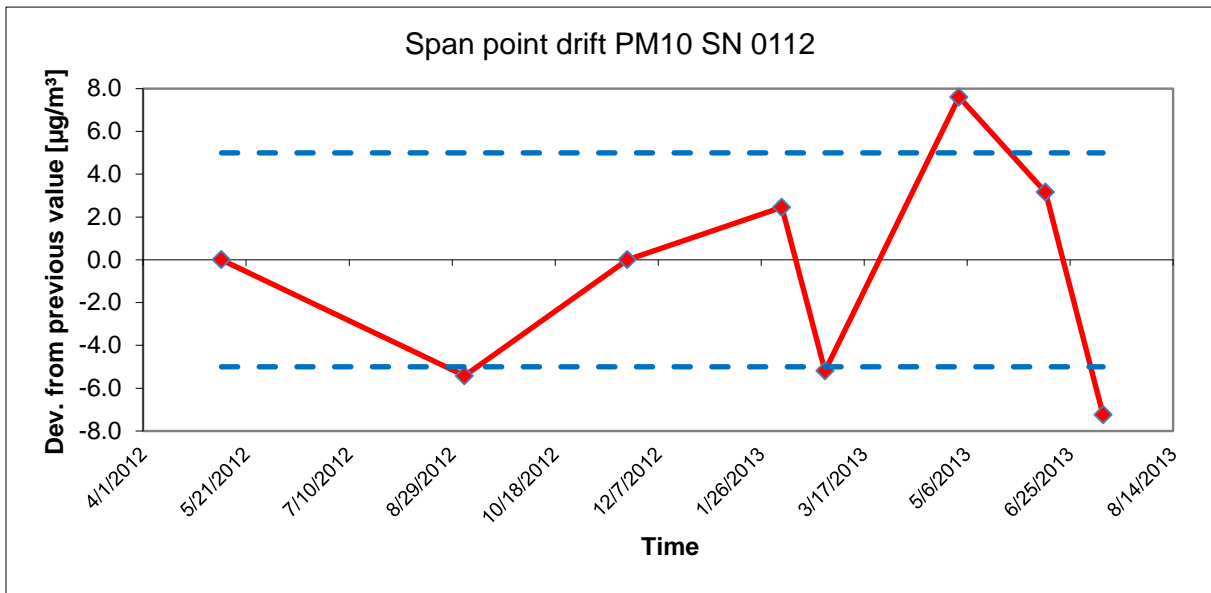


Figure 46: Drift of the measured value SN 0112, measured component PM₁₀

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_i 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.

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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_i 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.

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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 NO₂ concentration due to residence in the AMS

In case of NO_x measuring systems the increase of NO₂ 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.

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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.

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6.1 5.4.2 Equivalency of the sampling system

The equivalency between the PM₁₀ 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 PM₁₀ 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:

$$y = (x \pm 10) \mu\text{g}/\text{m}^3 \text{ for concentration mean values } \leq 100 \mu\text{g}/\text{m}^3 \text{ and}$$

$$y = 0.9x \mu\text{g}/\text{m}^3 \text{ or } 1.1x \mu\text{g}/\text{m}^3 \text{ for concentration mean values } > 100 \mu\text{g}/\text{m}^3$$

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 $\mu\text{g}/\text{m}^3$).

$$y_i = m \cdot x + b$$

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 $\geq 0,95$ 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.

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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				
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

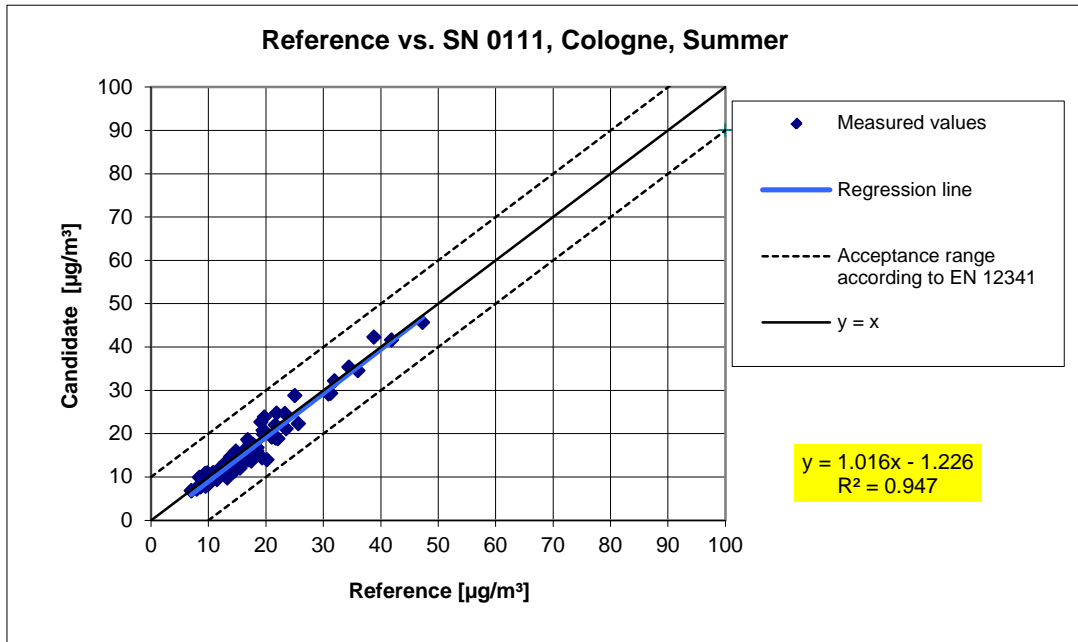


Figure 47: Reference equivalence function SN 0111, test site Cologne, summer

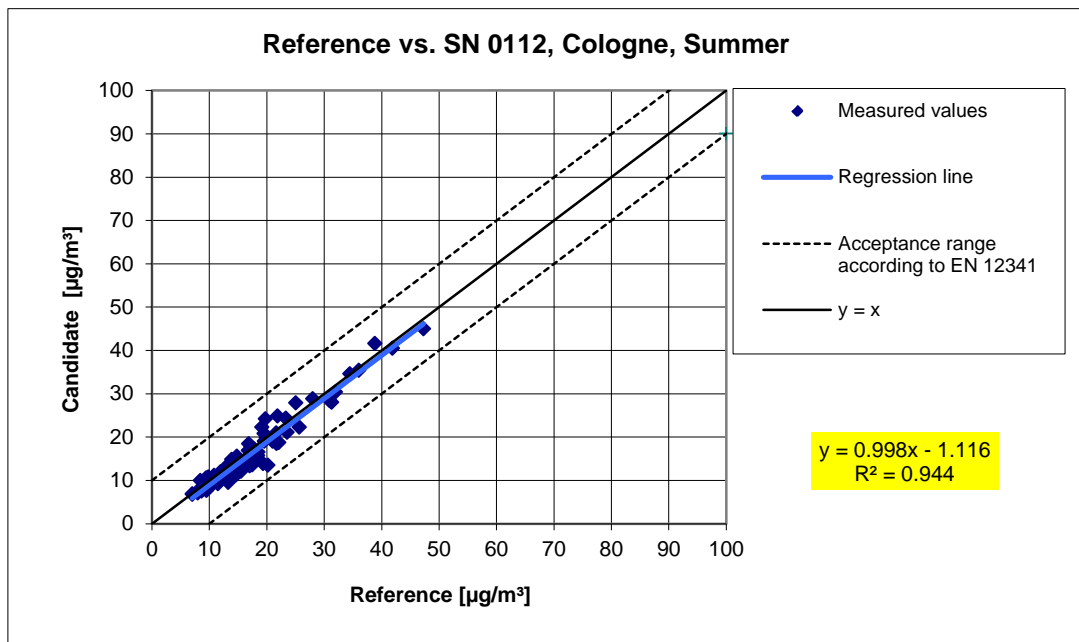


Figure 48: Reference equivalence function SN 0112, test site Cologne, summer

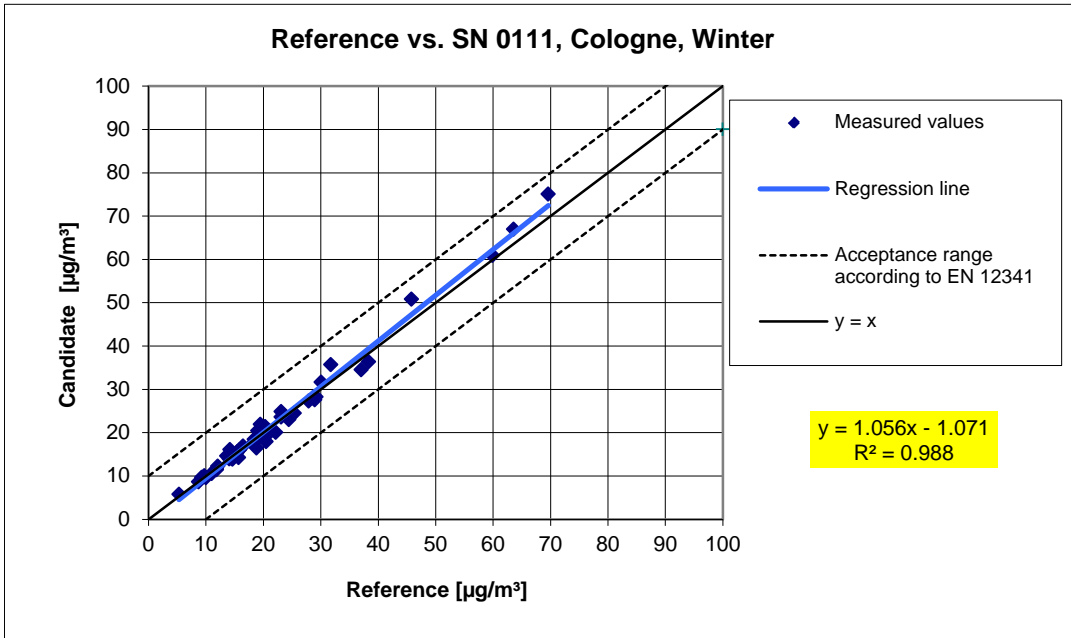


Figure 49: Reference equivalence function SN 0111, test site Cologne, winter

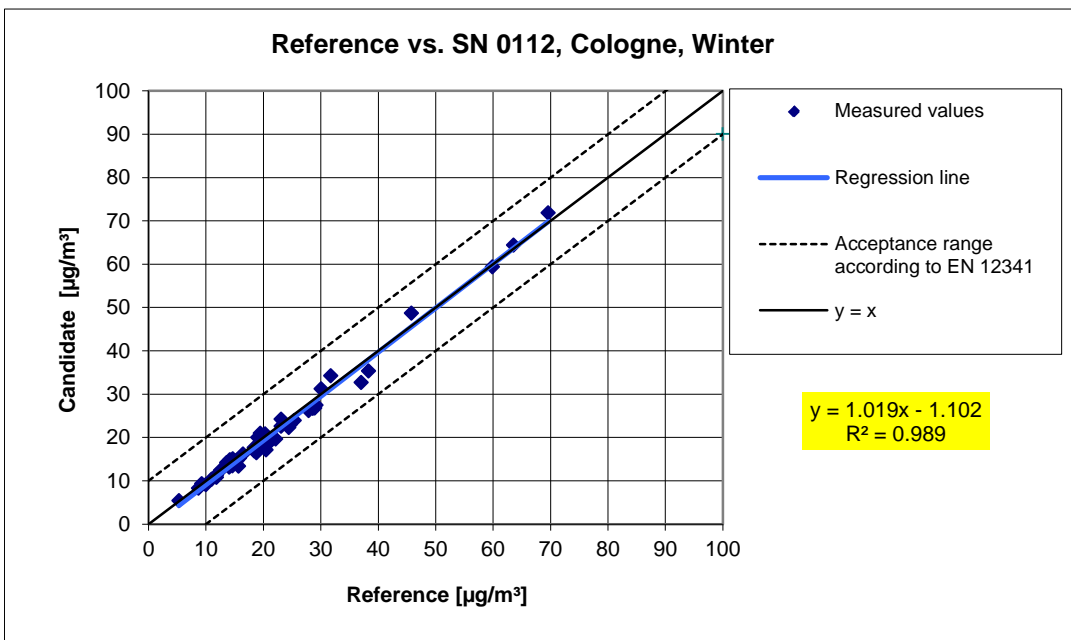


Figure 50: Reference equivalence function SN 0112, test site Cologne, winter

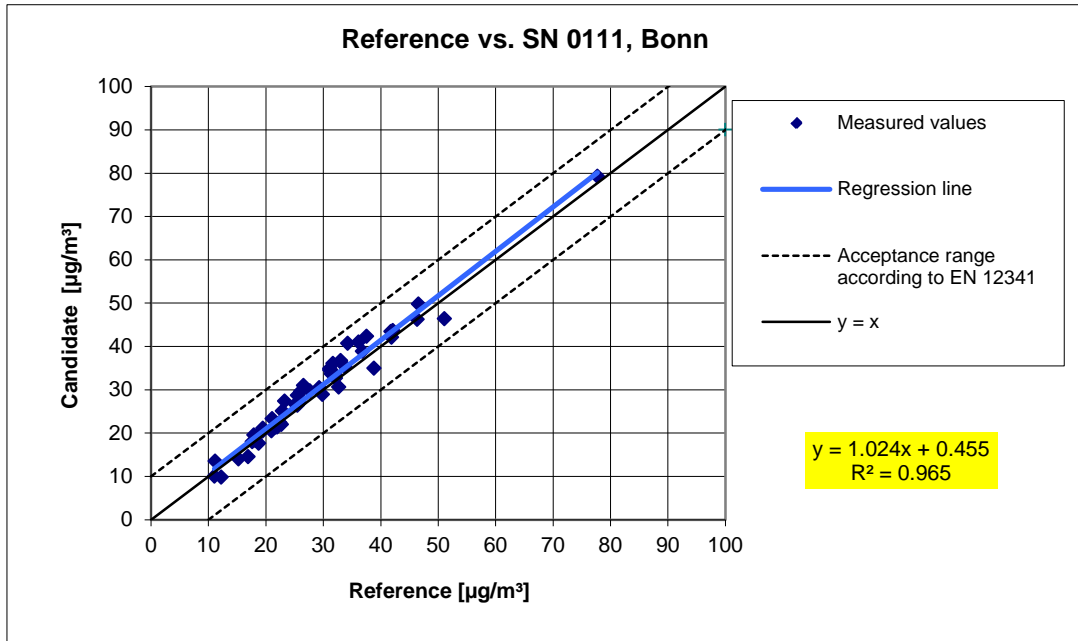


Figure 51: Reference equivalence function SN 0111, test site Bonn, winter

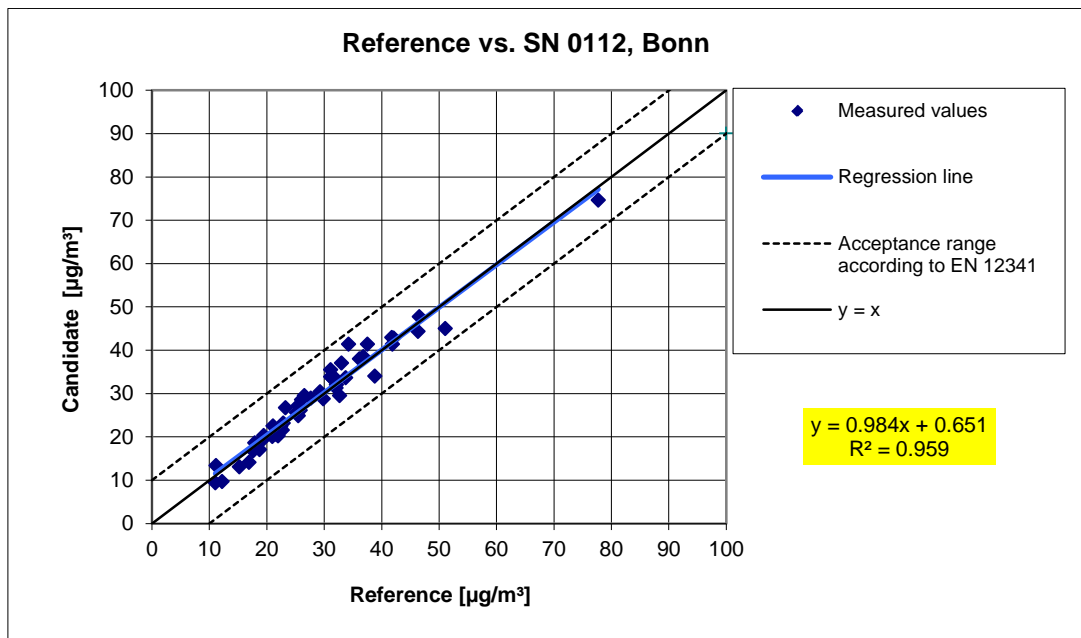


Figure 52: Reference equivalence function SN 0112, test site Bonn, winter

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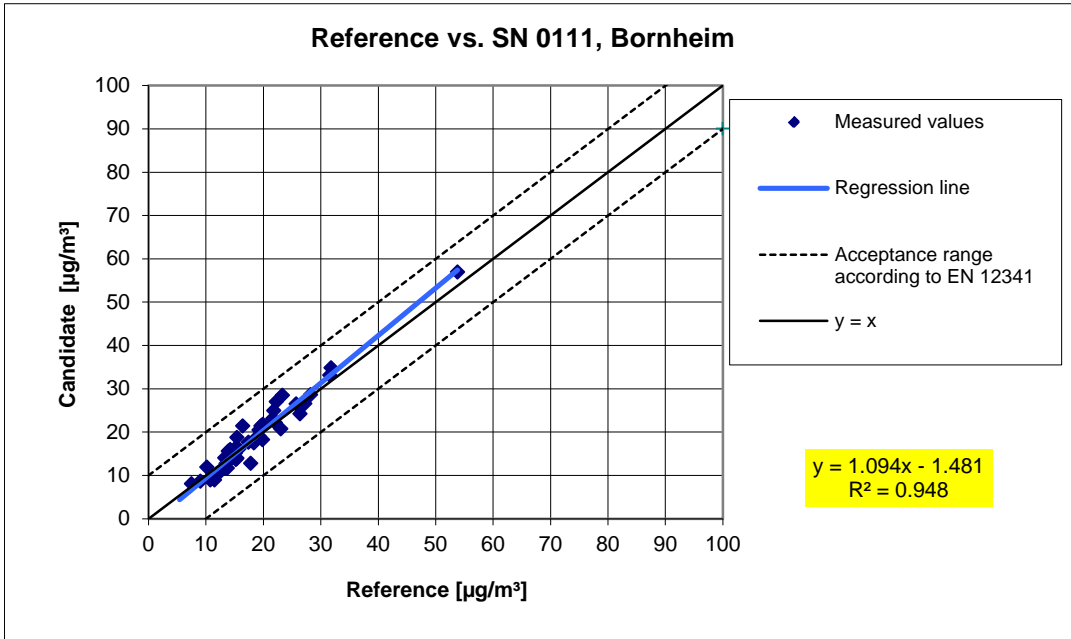


Figure 53: Reference equivalence function SN 0111, test site Bornheim, summer

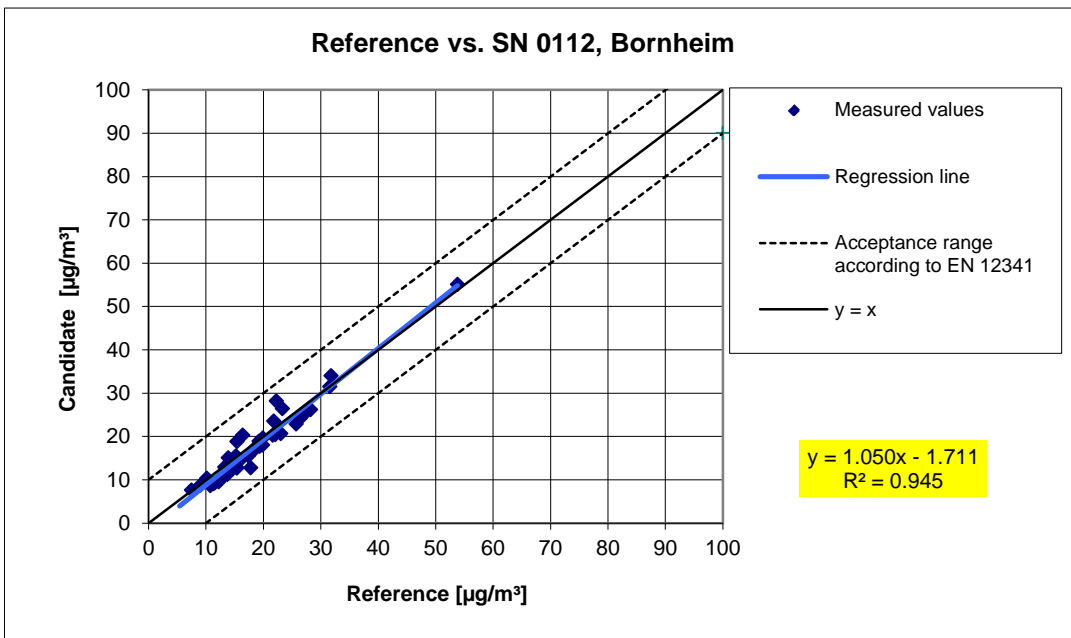


Figure 54: Reference equivalence function SN 0112, test site Bornheim, summer

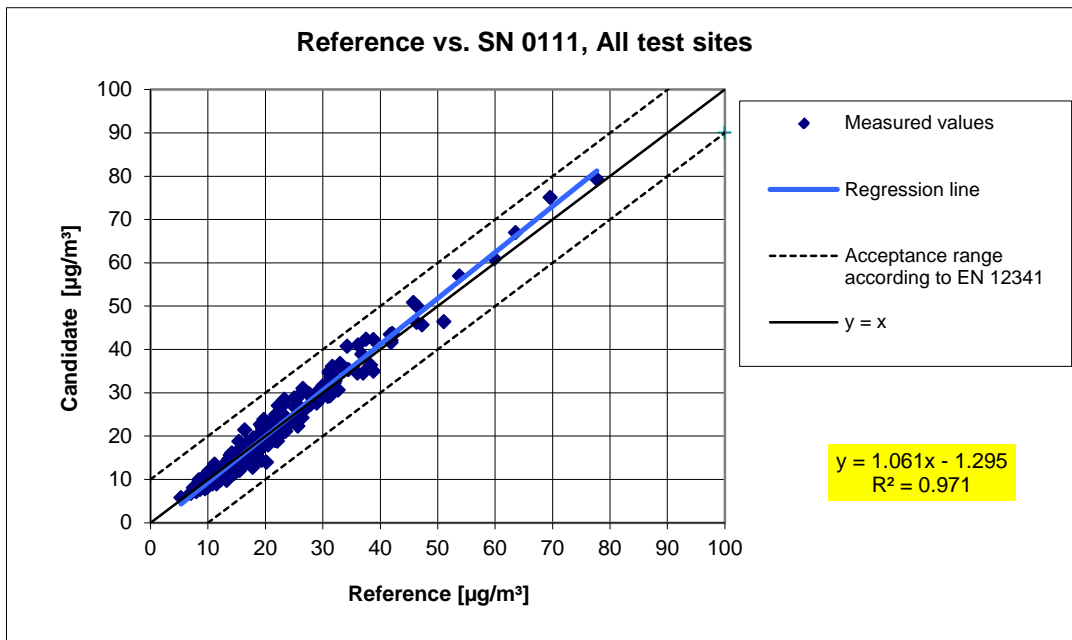


Figure 55: Reference equivalence function SN 0111, all sites

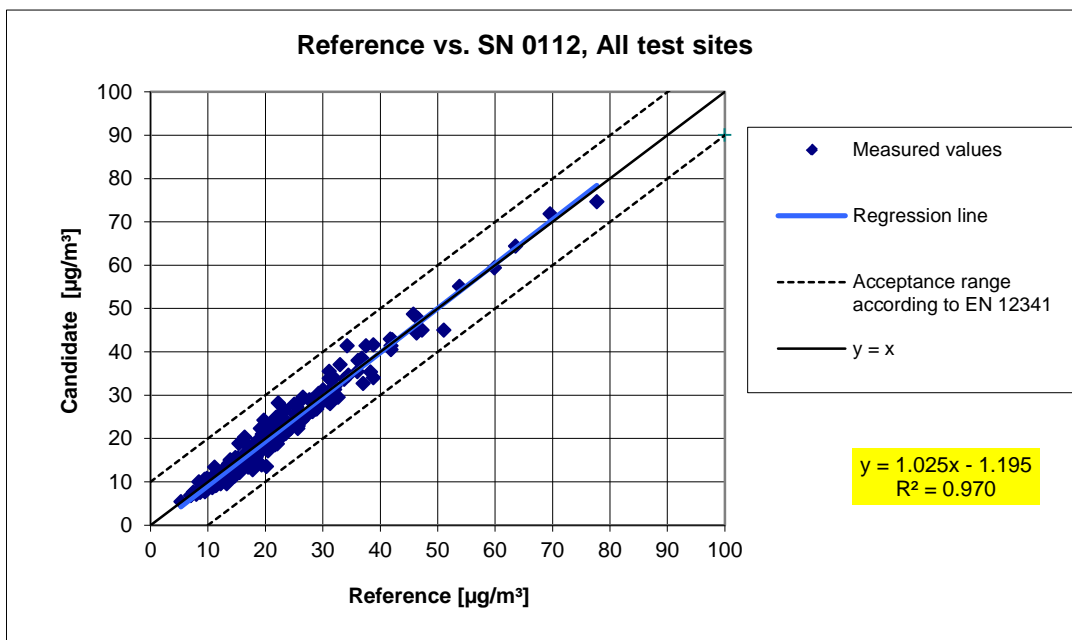


Figure 56: Reference equivalence function SN 0112, all sites

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6.1 5.4.3 Reproducibility of the sampling systems

The PM₁₀ 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 PM₁₀ 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 $Y_i \leq 100 \mu\text{g}/\text{m}^3$ with number of data pairs n_{\leq} and
- b) Dataset with $Y_i > 100 \mu\text{g}/\text{m}^3$ with number of data pairs $n_{>}$

With respect to a):

The data pairs of the dataset with $Y_i \leq 100 \mu\text{g}/\text{m}^3$ are used to calculate the absolute standard deviation s_a :

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

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 $\leq 100 \mu\text{g}/\text{m}^3$ 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 $Y_i > 100 \mu\text{g}/\text{m}^3$:

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

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 $> 100 \mu\text{g}/\text{m}^3$ is calculated as follows:

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

During the field tests, no concentration values $> 100 \mu\text{g}/\text{m}^3$ 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. $1.88 \mu\text{g}/\text{m}^3$ is far below the permissible limit of $5 \mu\text{g}/\text{m}^3$.

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.

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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			$\mu\text{g}/\text{m}^3$		$\mu\text{g}/\text{m}^3$
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

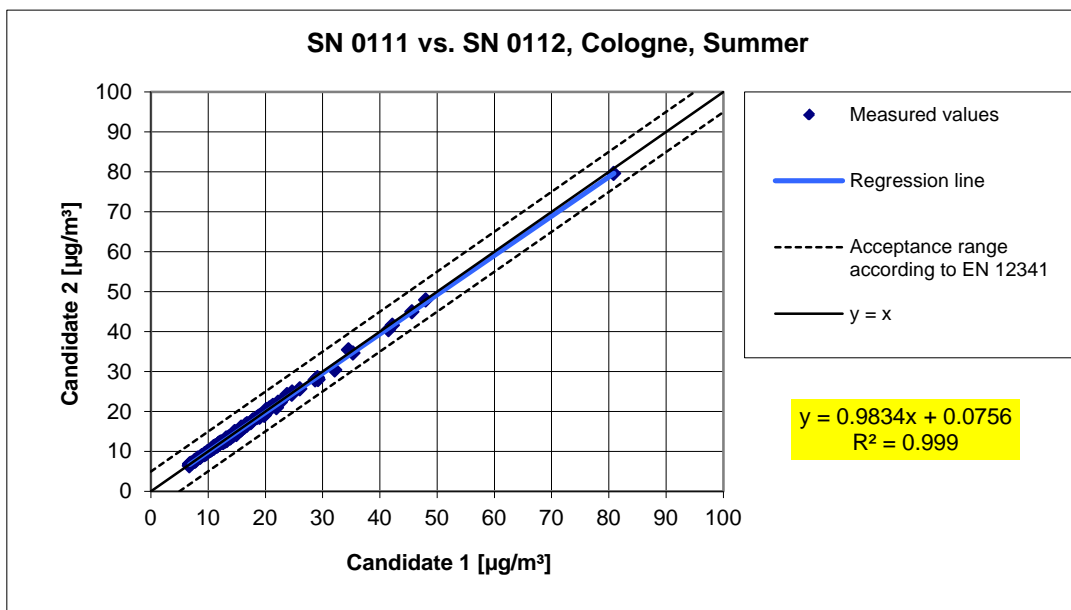


Figure 57: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Cologne, summer

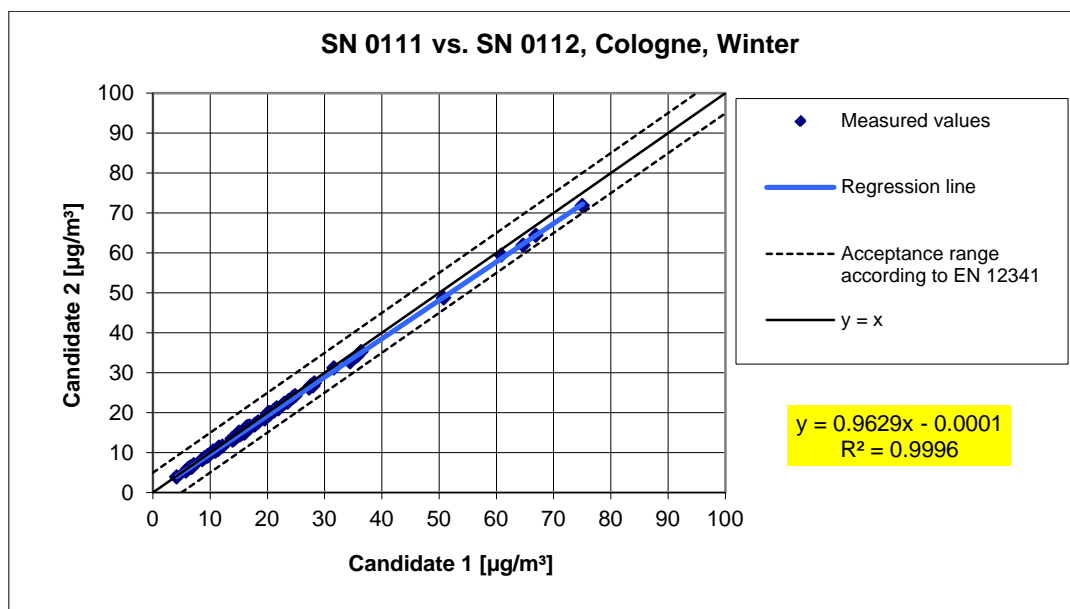


Figure 58: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Cologne, winter

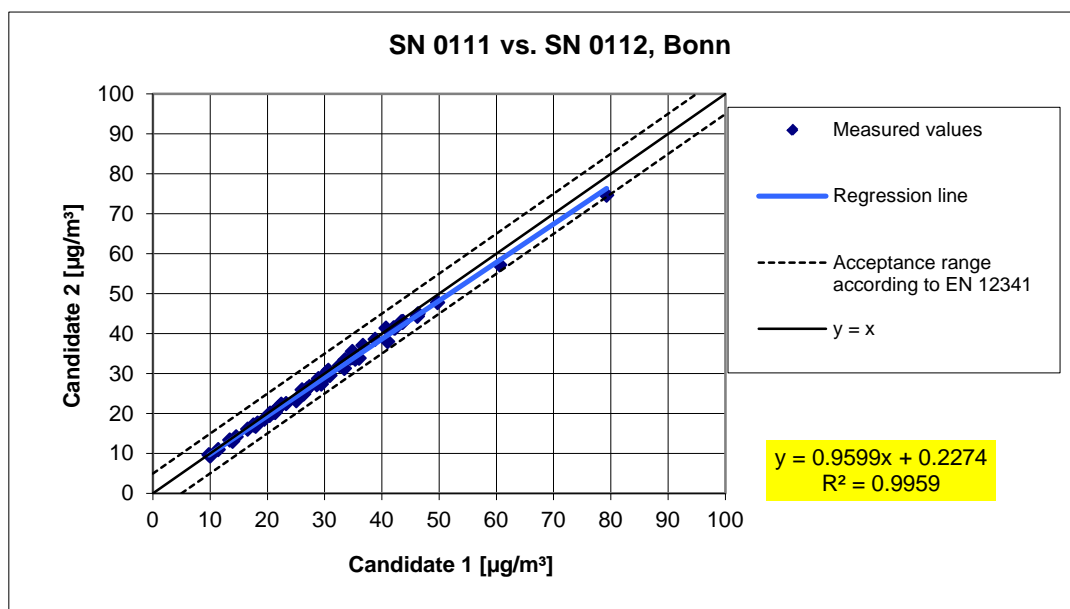


Figure 59: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Bonn, winter

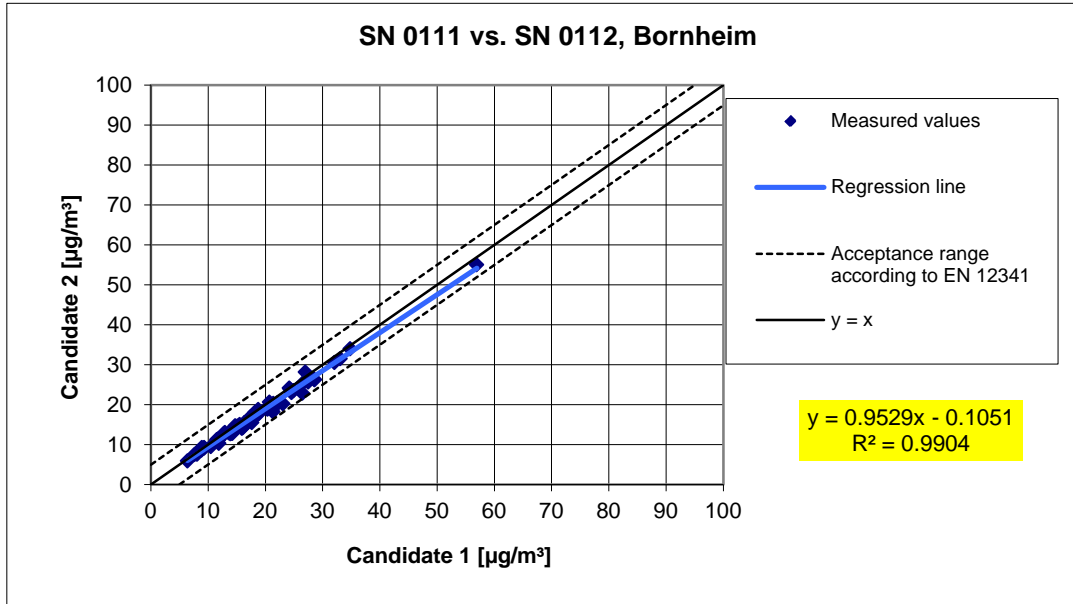


Figure 60: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Bornheim, summer

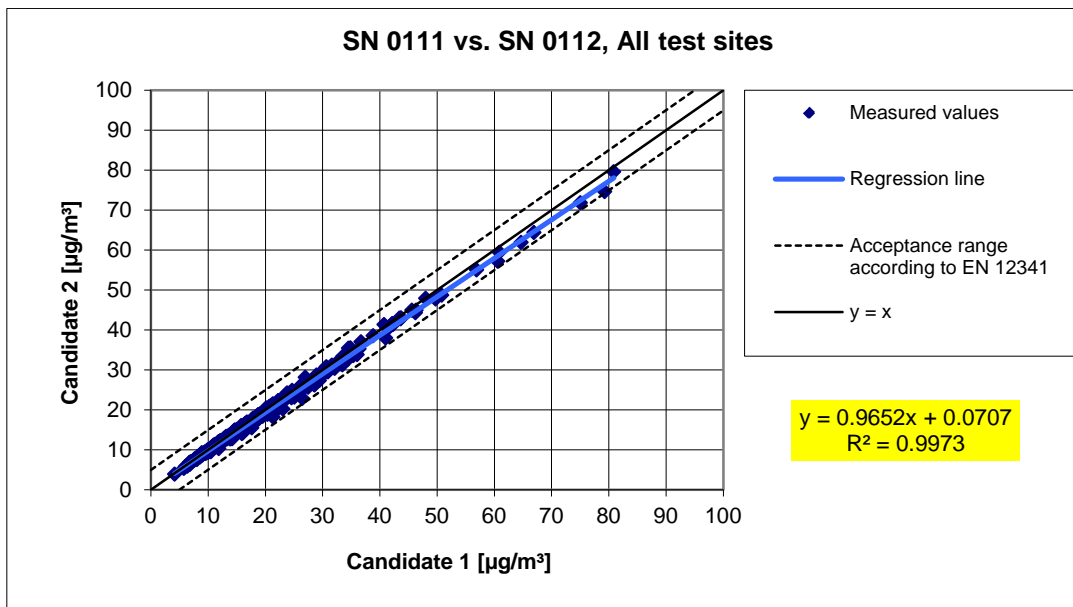


Figure 61: Results of parallel measurements with the tested devices SN 0111 / SN 0112, all test sites

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 PM₁₀:

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.

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Table 35: Results of the calibration function and analytical function, measured component PM₁₀

Device no.	Calibration function		Analytical function	
	Y = m * x + b		x = 1/m * y - b/m	
	m	b	1/m	b/m
	µg/m ³ / µg/m ³	µg/m ³	µg/m ³ / µg/m ³	µg/m ³
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/m ³ / µg/m ³	µg/m ³	µg/m ³ / µg/m ³	µg/m ³
System 1 (SN 0111)	1.096	-0.408	0.912	-0.372
System 2 (SN 0112)	1.056	-0.234	0.947	-0.222

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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.

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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 PM₁₀ = 40 µg/m³

10 % of the annual limit value = 4 µg/m³

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 $> 0.5 \mu\text{g}/\text{m}^3$ caused by interference due to moisture in the sample could be observed for PM_{2.5}. For PM₁₀, no deviation of the measured signal from the nominal value $> -1.1 \mu\text{g}/\text{m}^3$ 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	$\mu\text{g}/\text{m}^3$	13.8	14.3	14.0
Dev. to mean value of referenve in $\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	-	0.5	0.2
Dev. in % of mean value reference	%	-	3.9	1.2
Deviation in % of annual LV	%	-	2.2	0.7

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Table 38: Deviation between reference measurement and candidate on days with a relative humidity of > 70 %, measured component PM₁₀

Field test, days with rel. humidity >70 %				
		Reference	SN 0111	SN 0112
Mean value	µg/m ³	20.2	19.7	19.1
Dev. to mean value of referenve in µg/m ³	µg/m ³	-	-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 present 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	
Status of measured values	Raw data	Limit value	30	µg/m ³
		Allowed uncertainty	25	%
All test sites, rH>70%				
Uncertainty between Reference	0.58	µg/m ³		
Uncertainty between Candidates	0.52	µg/m ³		
	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	%

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Table 40: Comparison of the candidates 0111 / 0112 with the reference device, rel. humidity > 70 %, all test sites, measured component PM₁₀

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	
Status of measured values	Raw data	Limit value	50	µg/m ³
		Allowed uncertainty	25	%
All test sites, rH>70%				
Uncertainty between Reference	0.60			µg/m ³
Uncertainty between Candidates	0.67			µg/m ³
	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	%

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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 $\pm 3\%$ of the rated value. All instantaneous values of the sample volumetric flow shall be within a range of $\pm 5\%$ 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.

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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	SN 0111		SN 0112	
	[l/min]	Deviation from nominal value [%]	[l/min]	Deviation from nominal value [%]
Test site:				
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

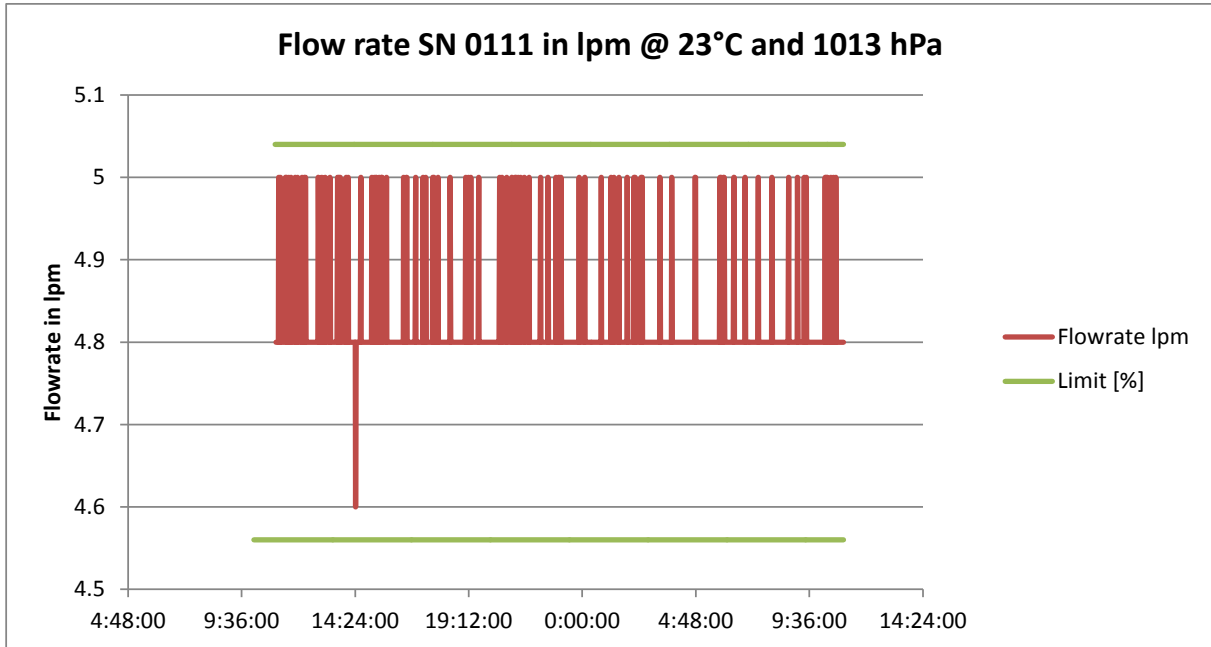


Figure 62: Flow rate of device SN 0111

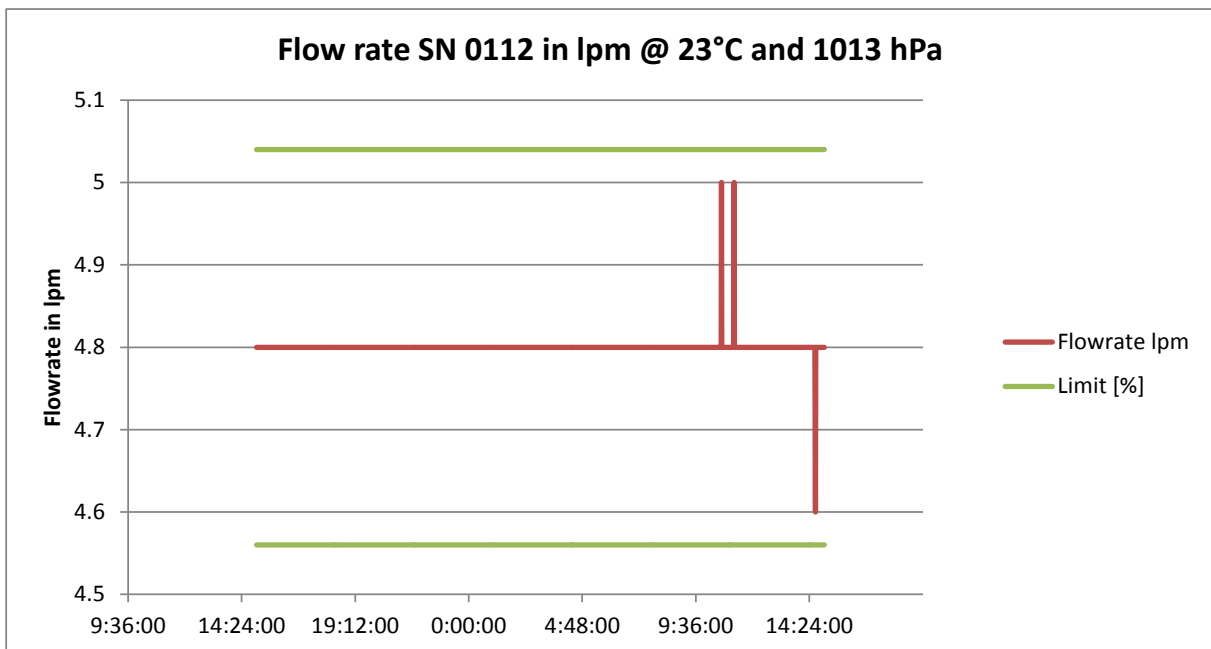


Figure 63: Flow rate of device SN 0112

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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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀.

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 PM₁₀ 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 PM₁₀.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (4 test sites, PM₁₀: 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/m³ for PM_{2.5} and a total of 20.3 % of the measured values exceed the upper assessment threshold of 28 µg/m³ for PM₁₀. 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 PM₁₀ (basis: mean values of reference measurement)

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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 PM₁₀ (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 PM₁₀ 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			$\mu\text{g}/\text{m}^3$
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 $\geq 18 \mu\text{g}/\text{m}^3$	54	0.84
0111 / 0112	Values $< 18 \mu\text{g}/\text{m}^3$	171	0.33

Table 45: Uncertainty between candidates u_{bs} for the devices SN 0111 and SN 0112, measured component PM₁₀

Device	Test site	No. of values	Uncertainty u_{bs}
SN			$\mu\text{g}/\text{m}^3$
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 $\geq 30 \mu\text{g}/\text{m}^3$	54	1.17
0111 / 0112	Values $< 30 \mu\text{g}/\text{m}^3$	171	0.58

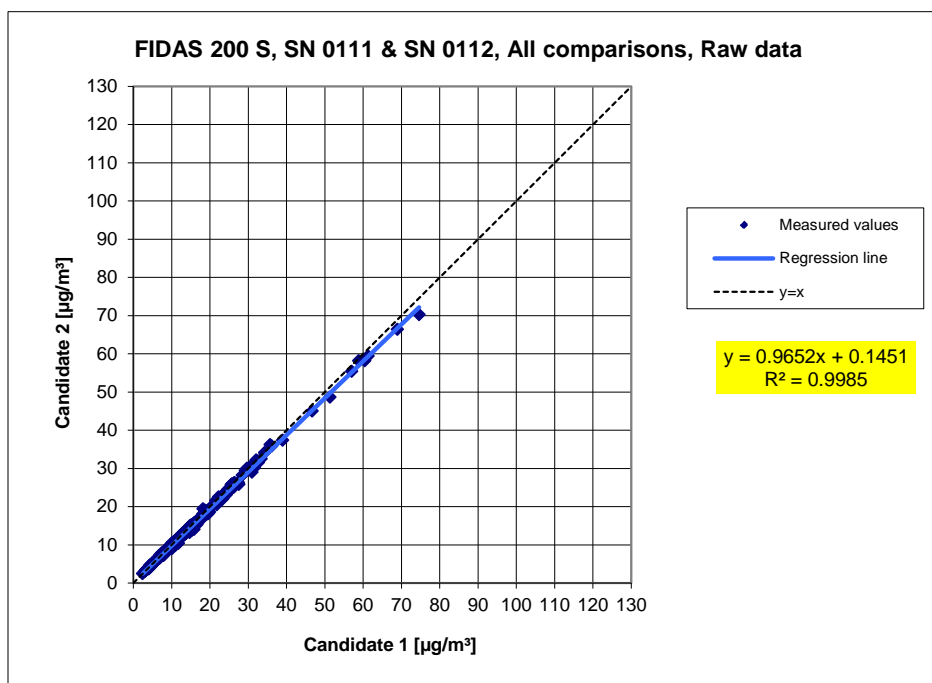


Figure 64: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, all test sites

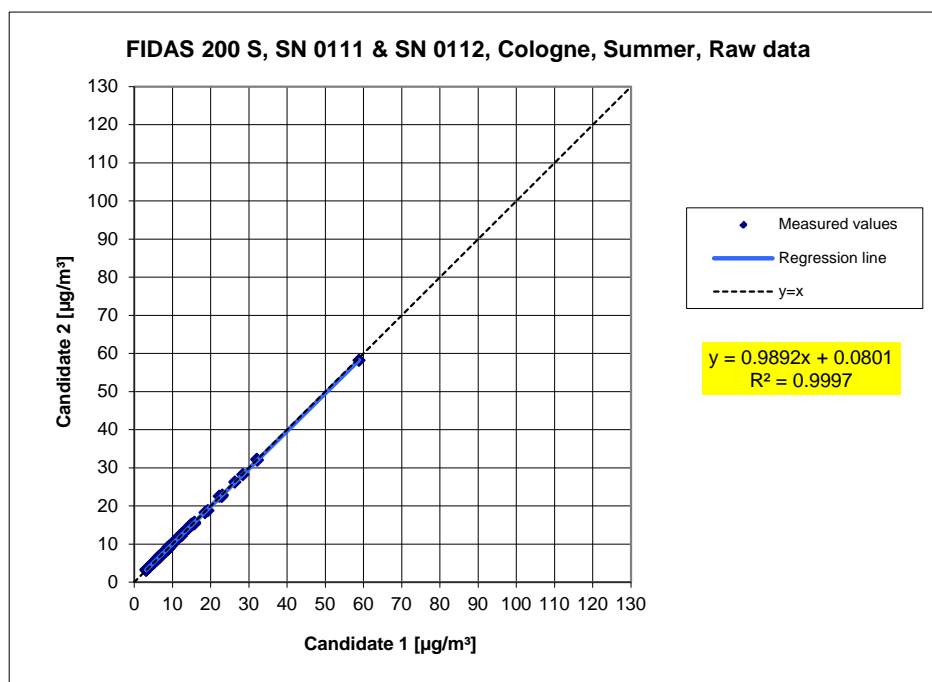


Figure 65: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, test site Cologne, summer

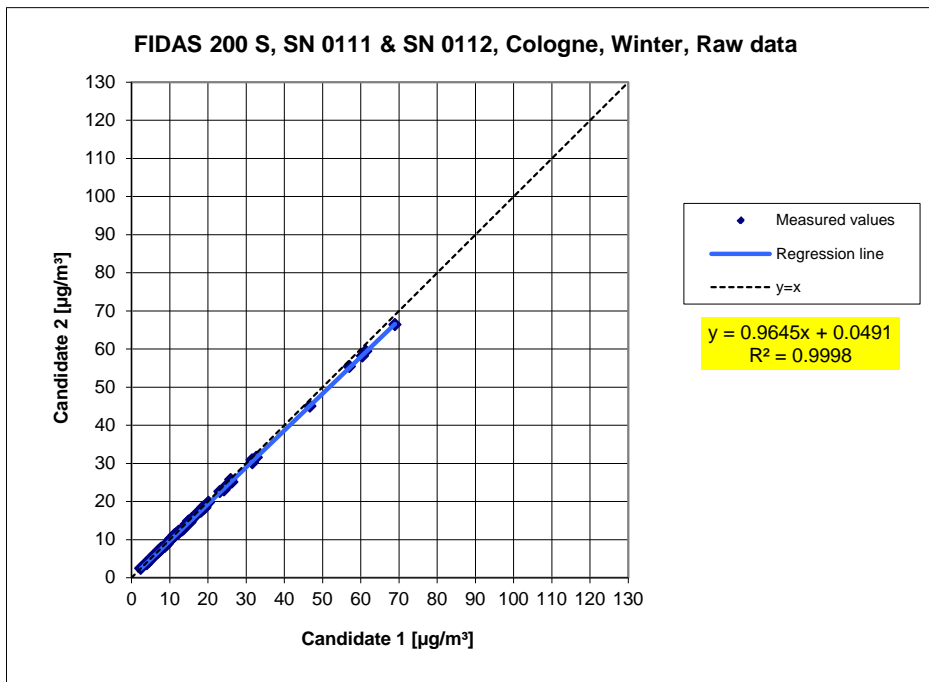


Figure 66: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, test site Cologne, winter

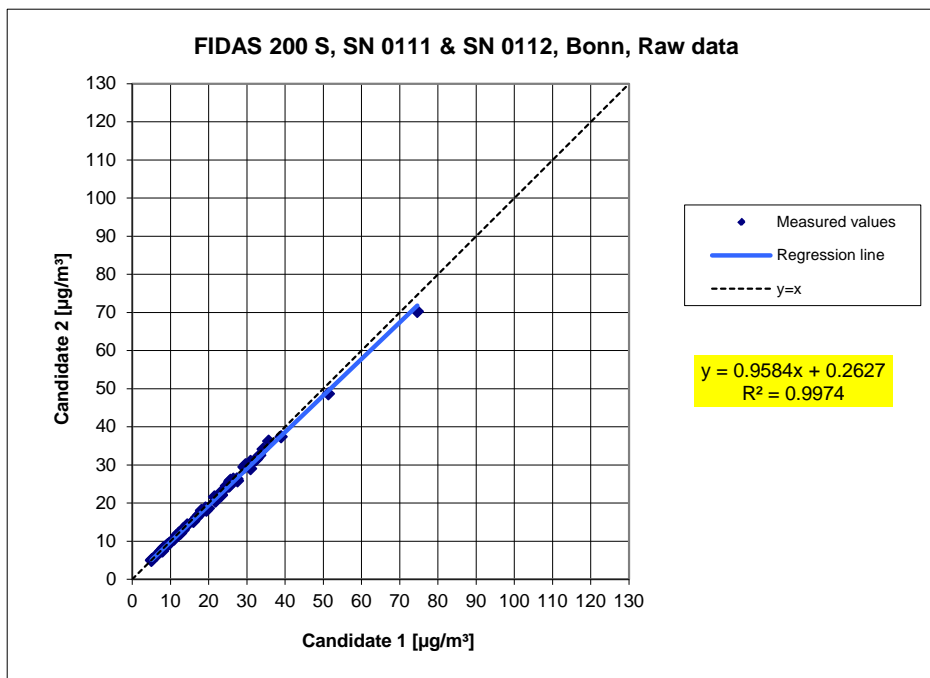


Figure 67: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, test site Bonn, winter

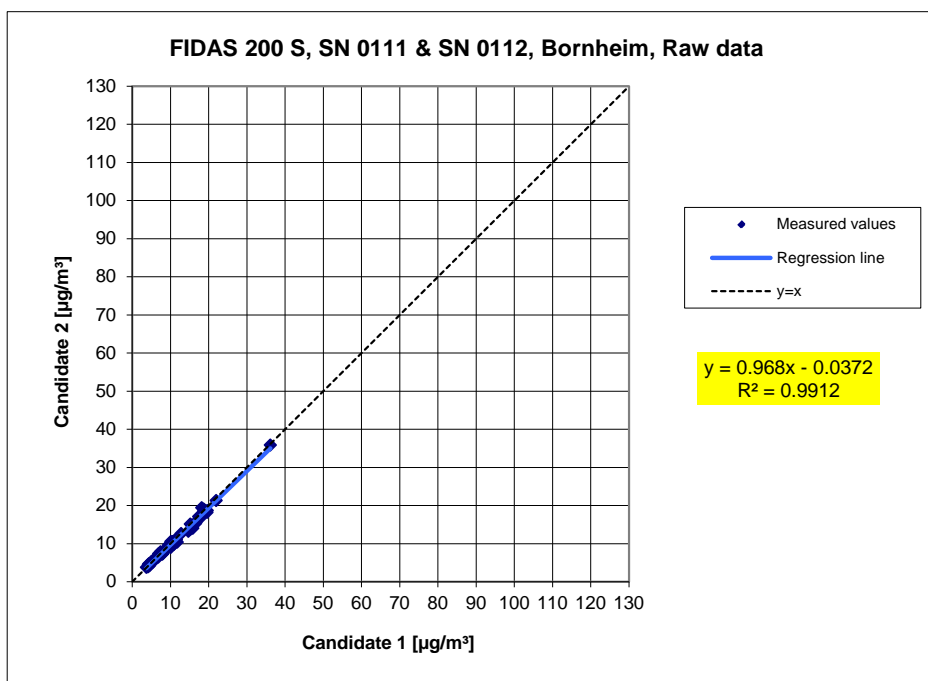


Figure 68: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, test site Bornheim, summer

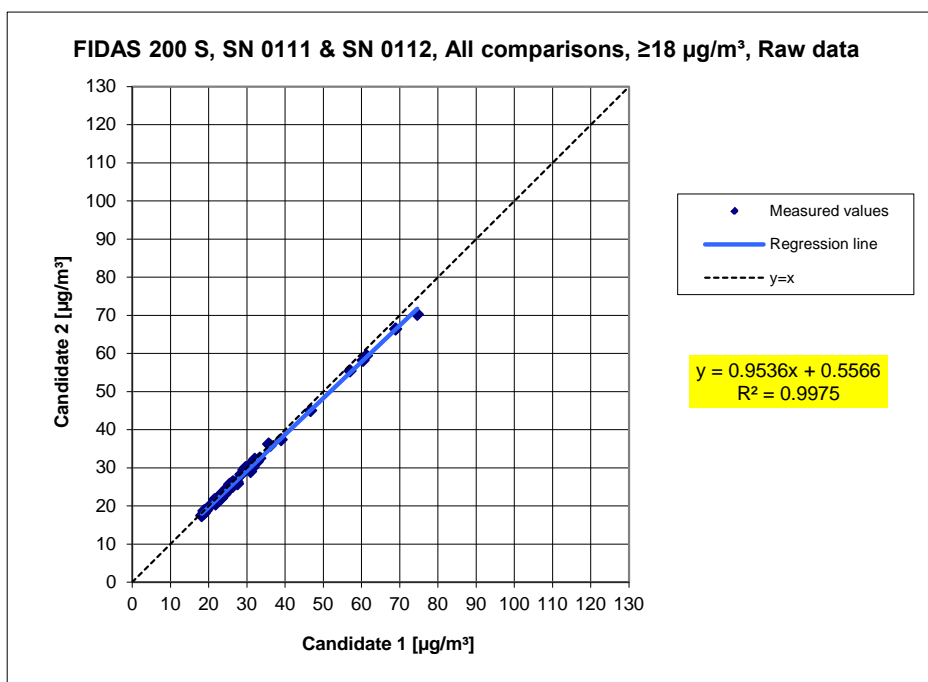


Figure 69: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, all test sites, values ≥ 18 µg/m³

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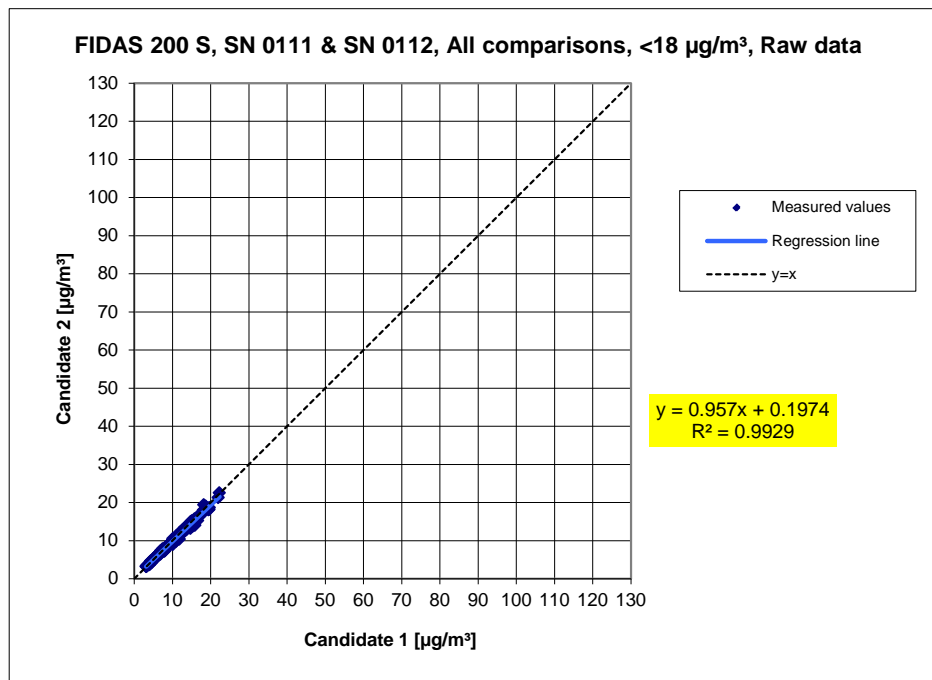


Figure 70: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, all test sites, values < 18 µg/m³

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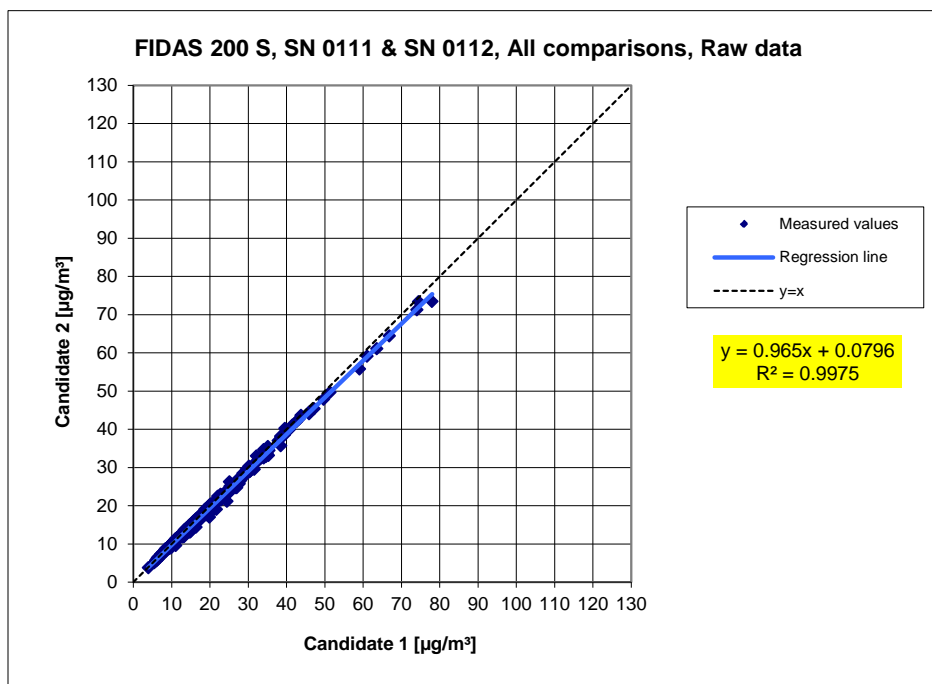


Figure 71: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, all test sites

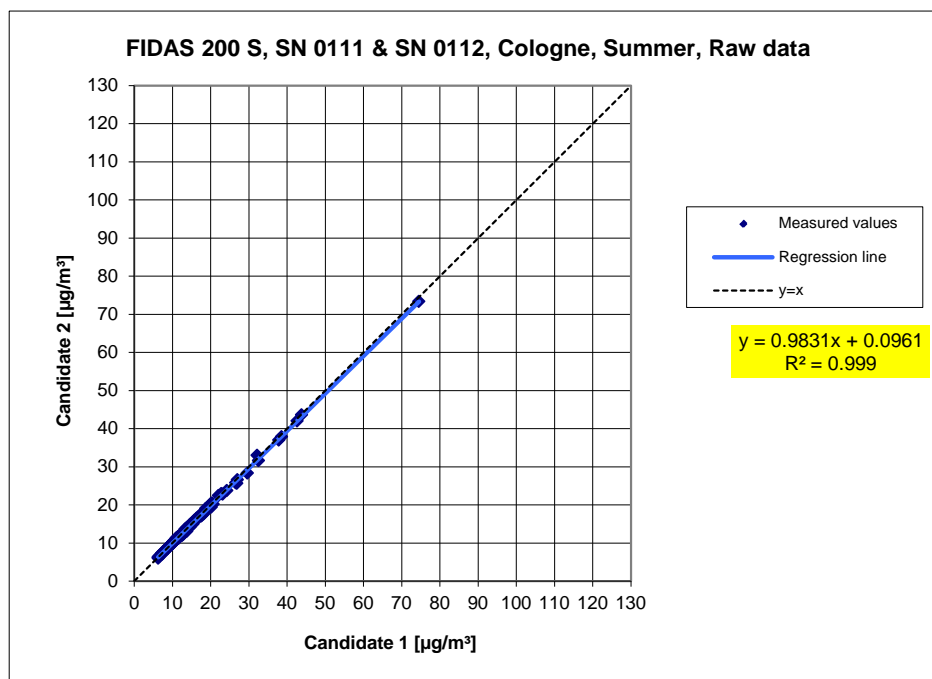


Figure 72: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, test site Cologne, summer

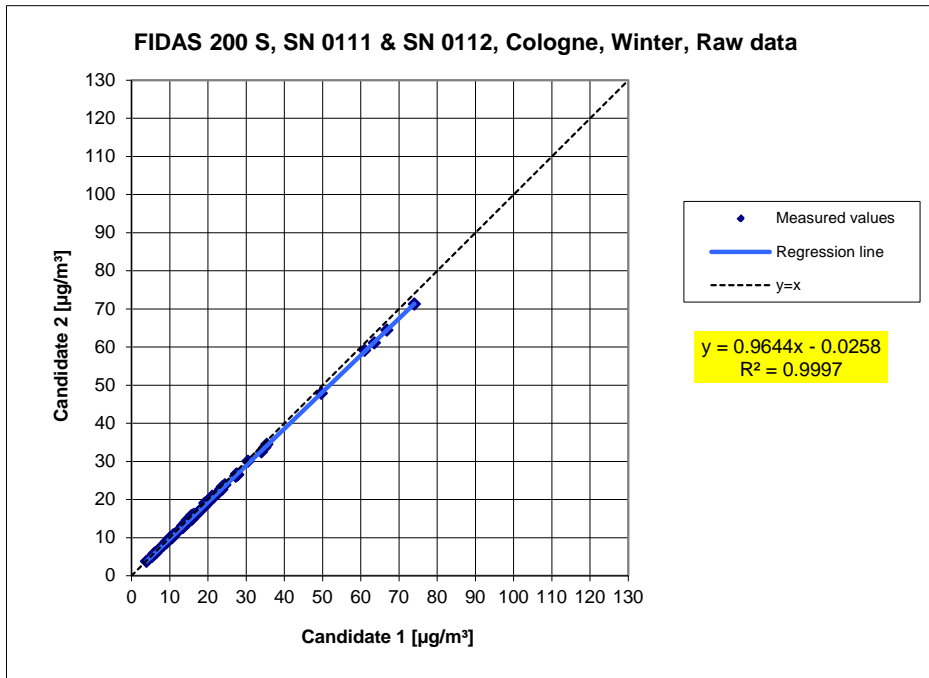


Figure 73: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, test site Cologne, winter

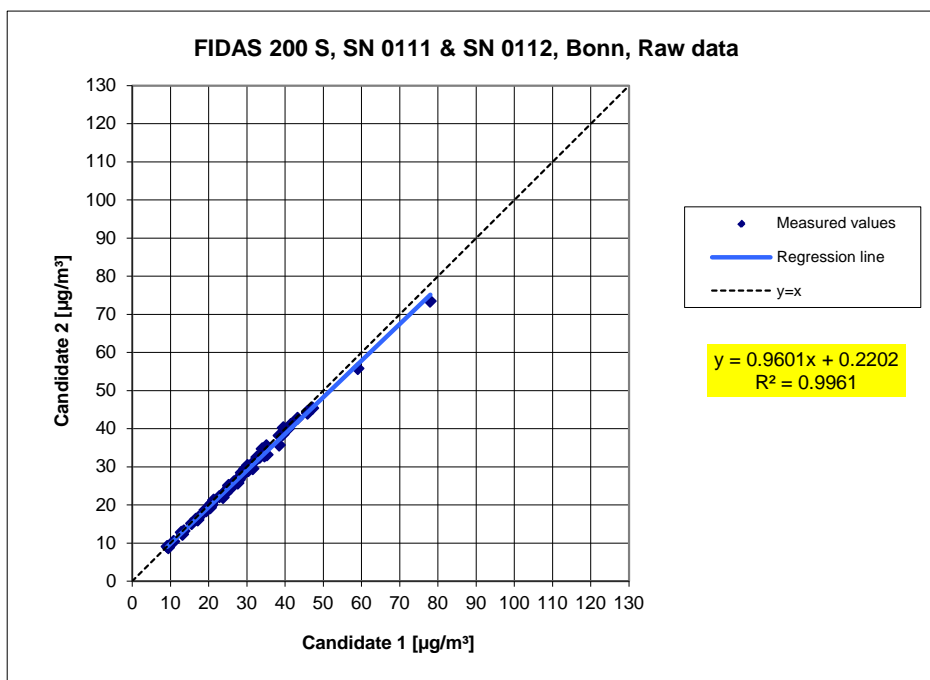


Figure 74: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, test site Bonn, winter

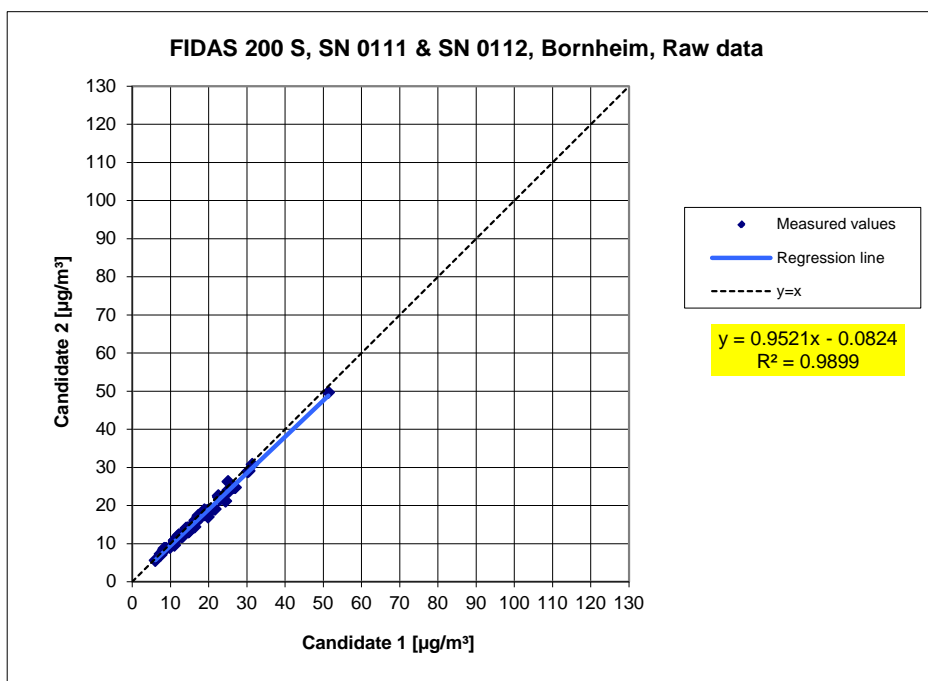


Figure 75: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, test site Bornheim, summer

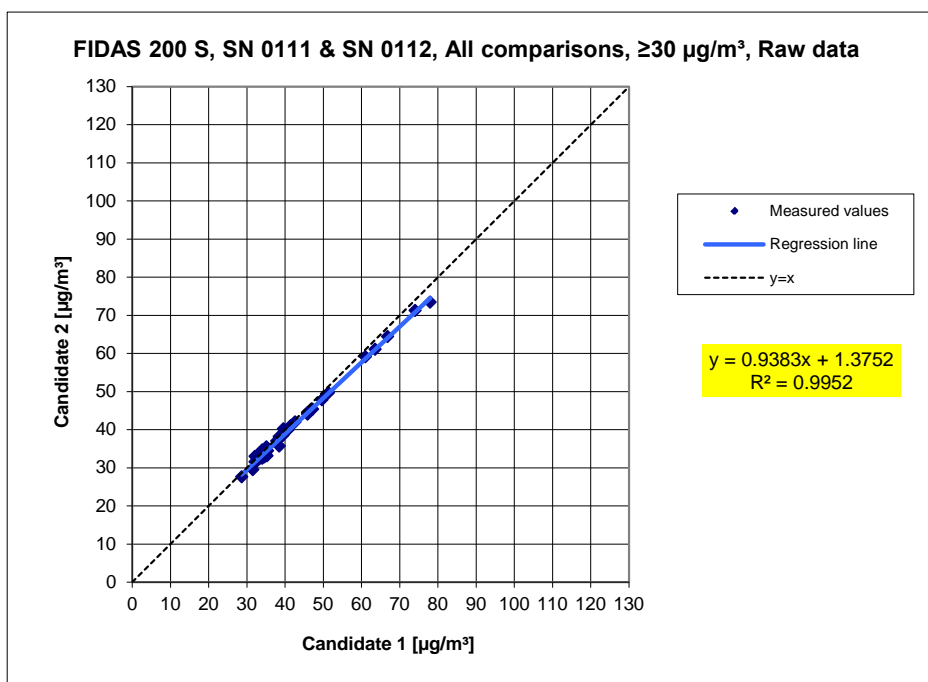


Figure 76: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, all test sites, values ≥ 30 µg/m³

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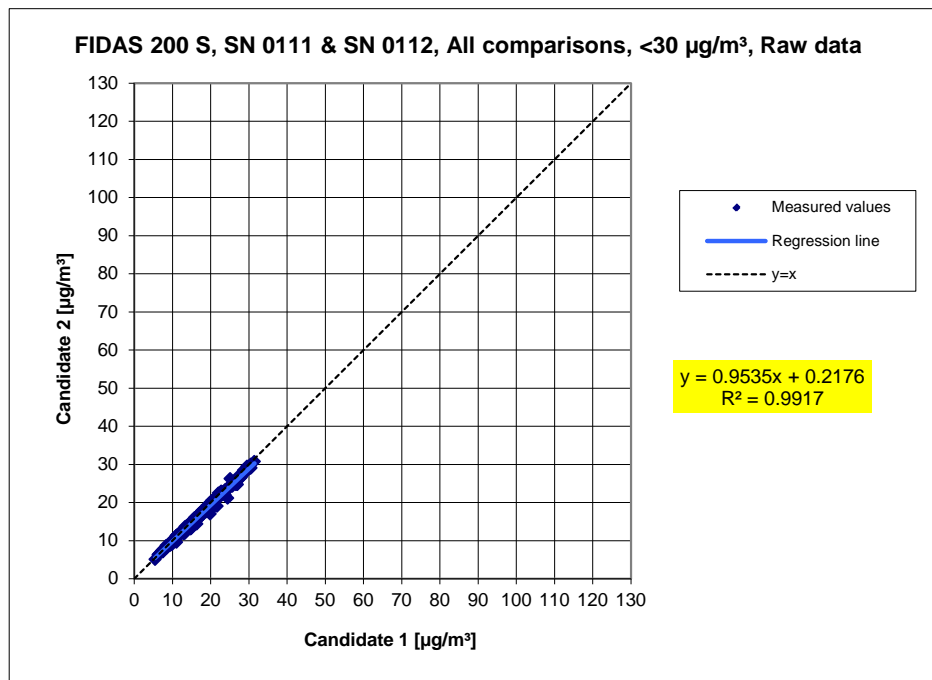


Figure 77: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, all test sites, values < 30 µg/m³

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 PM₁₀.

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 PM₁₀ 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 PM₁₀.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (4 test sites, PM₁₀: 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/m³ for PM_{2.5} and a total of 20.3 % of the measured values exceed the upper assessment threshold of 28 µg/m³ for PM₁₀. 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 $\leq 2 \mu\text{g}/\text{m}^3$.

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.

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Regression is calculated for:

- All test sites/comparisons together
- Each test site/comparison separately
- 1 dataset with measured values $\geq 18 \mu\text{g}/\text{m}^3$ for PM_{2.5} (basis: mean values of reference measurement)
- 1 dataset with measured values $\geq 30 \mu\text{g}/\text{m}^3$ for PM₁₀ (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 u_{bs})

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 $\geq 18 \mu\text{g}/\text{m}^3$ for PM_{2.5} (basis: mean values of reference measurement)
- 1 dataset with measured values $\geq 30 \mu\text{g}/\text{m}^3$ for PM₁₀ (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 $y_i = 30 \mu\text{g}/\text{m}^3$ for PM_{2.5} and at the level of $y_i = 50 \mu\text{g}/\text{m}^3$ for PM₁₀.

[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. $W_{CM} \leq W_{dqo}$ → Candidate method is considered equivalent to the reference method
2. $W_{CM} > W_{dqo}$ → 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 PM₁₀ 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

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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 PM₁₀. 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	
Status of measured values	Raw data	Limit value	30	µg/m ³
		Allowed uncertainty	25	%
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	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/m ³
Uncertainty between Candidates	0.84			µg/m ³
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/m ³
Uncertainty between Candidates	0.33			µg/m ³
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			%

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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
Status of measured values	Raw data		Limit value	30 $\mu\text{g}/\text{m}^3$
			Allowed uncertainty	25 %
Cologne, Summer				
Uncertainty between Reference	0.66	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.12	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.55	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.70	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.50	$\mu\text{g}/\text{m}^3$		
	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, $\geq 18 \mu\text{g}/\text{m}^3$				
Uncertainty between Reference	0.63	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.84	$\mu\text{g}/\text{m}^3$		
	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, $< 18 \mu\text{g}/\text{m}^3$				
Uncertainty between Reference	0.57	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.33	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.48	$\mu\text{g}/\text{m}^3$		
	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	%

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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.

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Table 47: Overview of equivalence test of Fidas[®] 200 S for PM₁₀

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	
Status of measured values	Raw data	Limit value	50	µg/m ³
		Allowed uncertainty	25	%
All comparisons				
Uncertainty between Reference	0.62			µg/m ³
Uncertainty between Candidates	0.67			µg/m ³
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/m ³
Uncertainty between Candidates	1.17			µg/m ³
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/m ³
Uncertainty between Candidates	0.58			µg/m ³
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			%

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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
Status of measured values	Raw data		Limit value	50 $\mu\text{g}/\text{m}^3$
			Allowed uncertainty	25 %
Cologne, Summer				
Uncertainty between Reference	0.80	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.27	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.67	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.90	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.87	$\mu\text{g}/\text{m}^3$		
	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, $\geq 30 \mu\text{g}/\text{m}^3$				
Uncertainty between Reference	0.67	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	1.17	$\mu\text{g}/\text{m}^3$		
	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, $< 30 \mu\text{g}/\text{m}^3$				
Uncertainty between Reference	0.61	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.58	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.67	$\mu\text{g}/\text{m}^3$		
	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 PM₁₀ 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 PM₁₀ 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 PM₁₀ lie below the specified expanded relative uncertainty W_{dqo} of 25 % for particulate matter for all datasets considered.

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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 PM₁₀:

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 PM₁₀, 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.			$\mu\text{g}/\text{m}^3$
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 PM₁₀*

Reference devices	Test site	No. of values	Uncertainty u_{bs}
Nr.			$\mu\text{g}/\text{m}^3$
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 $< 2 \mu\text{g}/\text{m}^3$ for all test sites.

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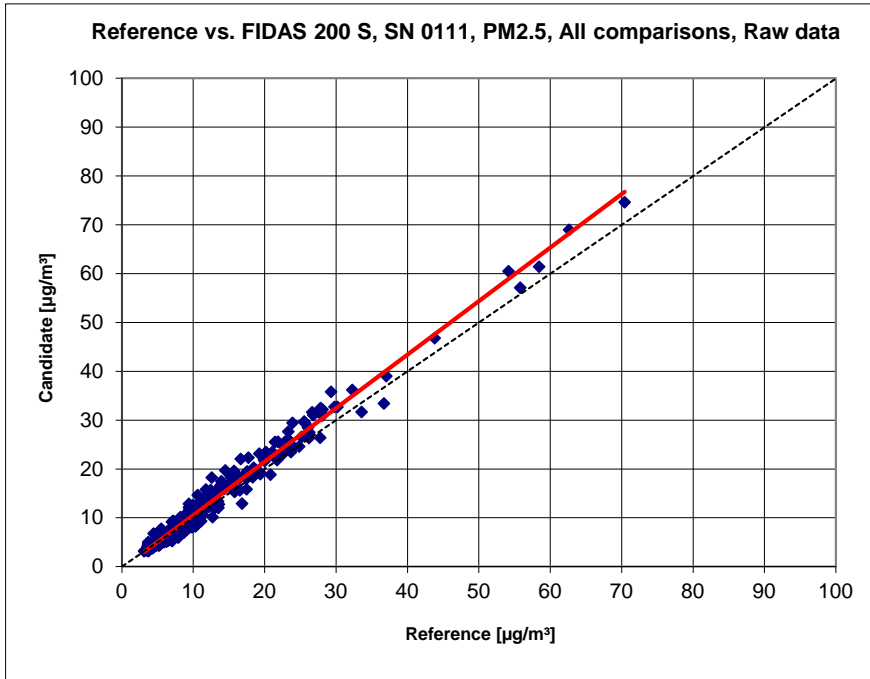


Figure 78: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, all test sites

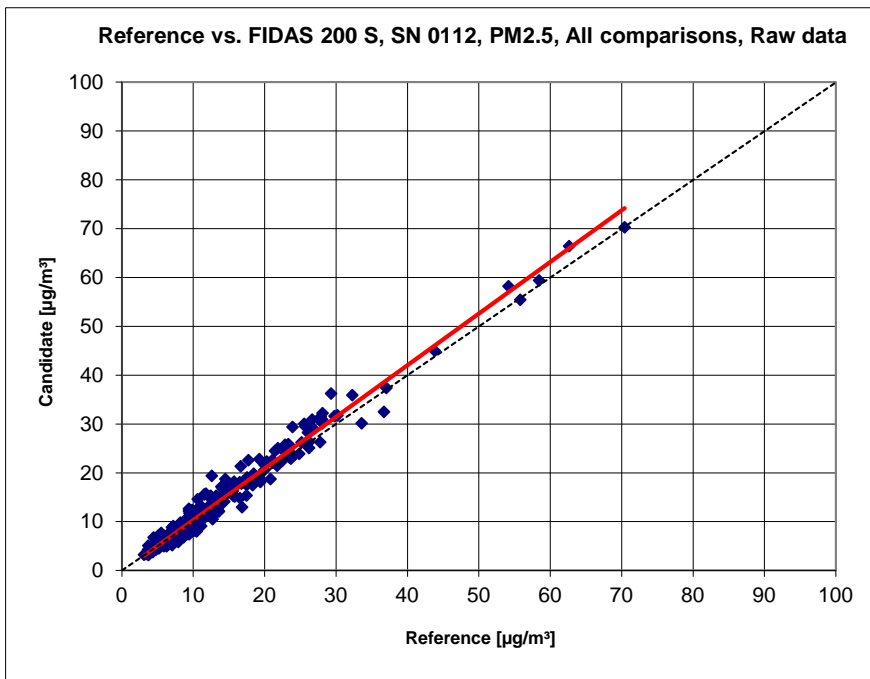


Figure 79: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, all test sites

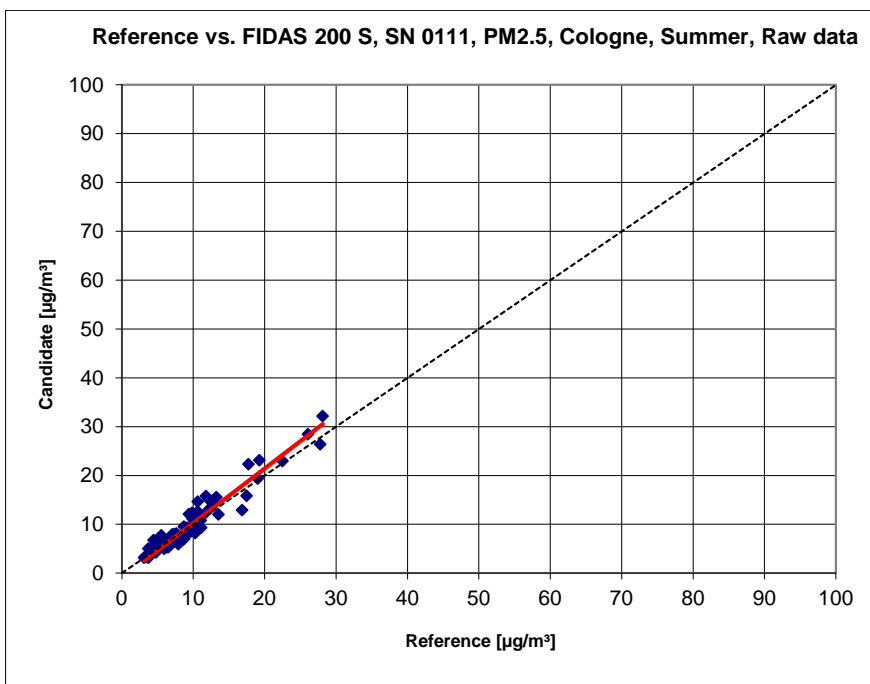


Figure 80: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, Cologne, summer

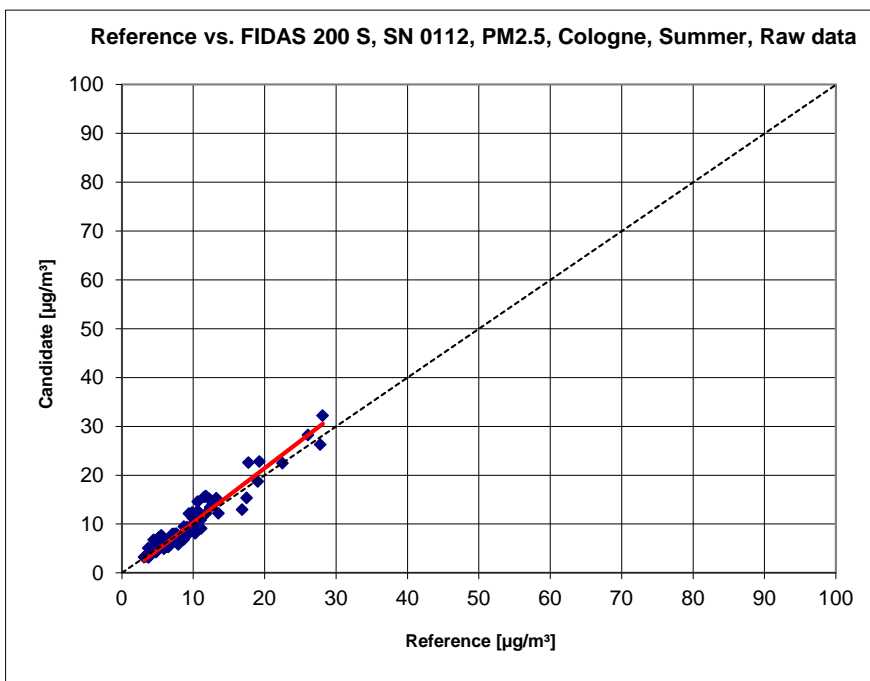


Figure 81: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, Cologne, summer

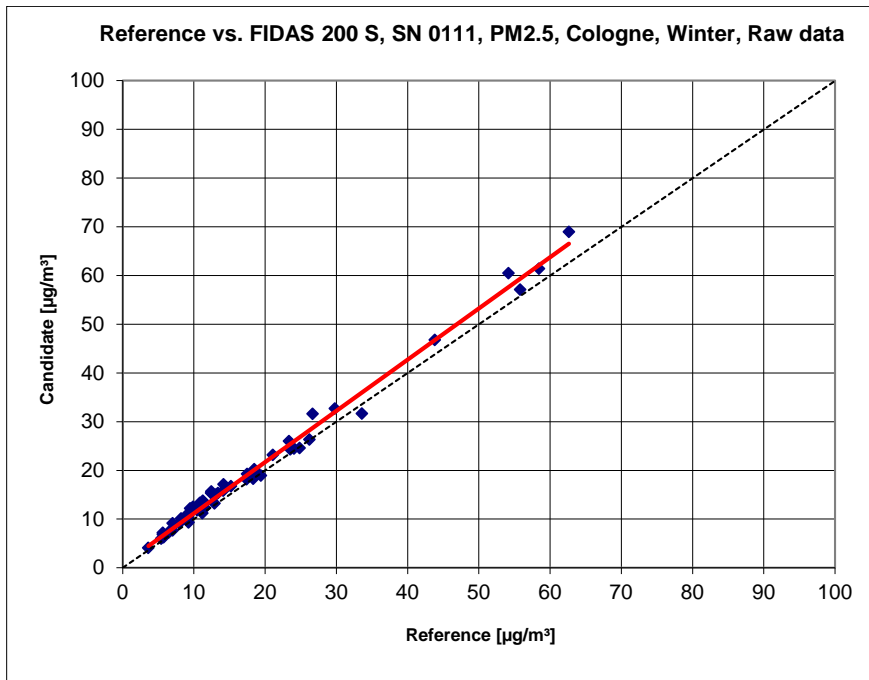


Figure 82: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, Cologne, winter

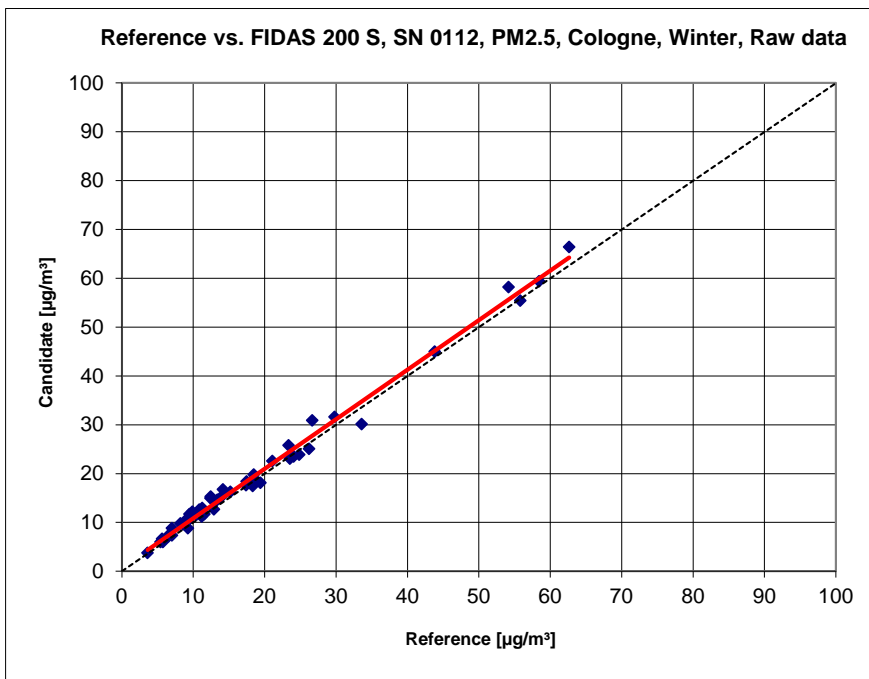


Figure 83: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, Cologne, winter

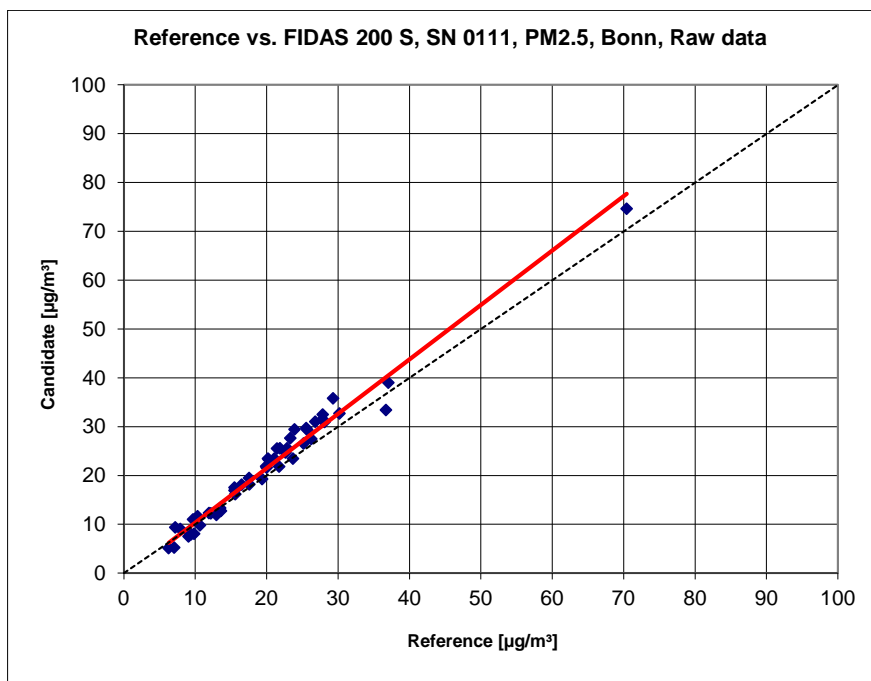


Figure 84: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, Bonn, winter

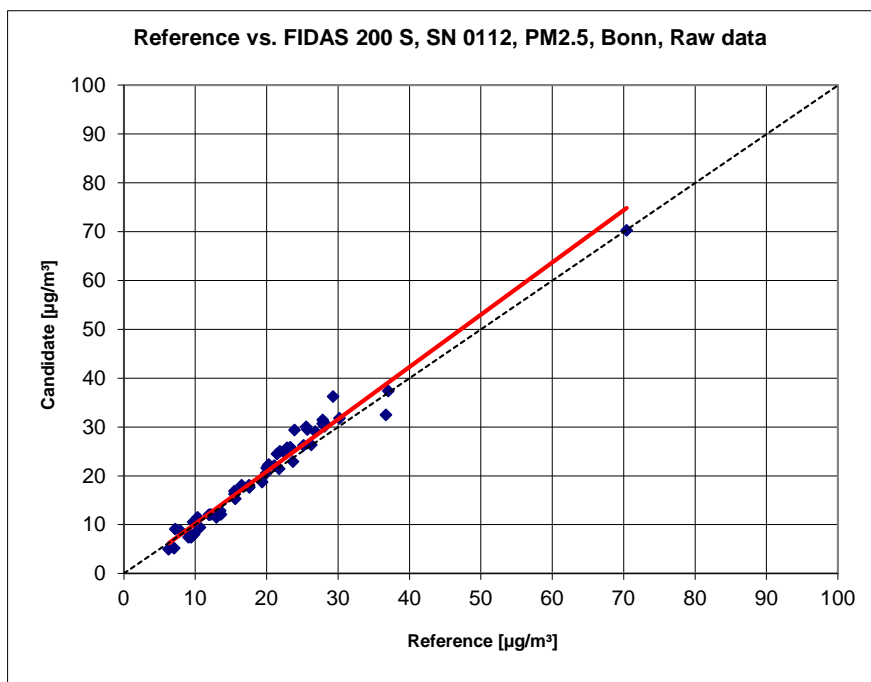


Figure 85: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, Bonn, winter

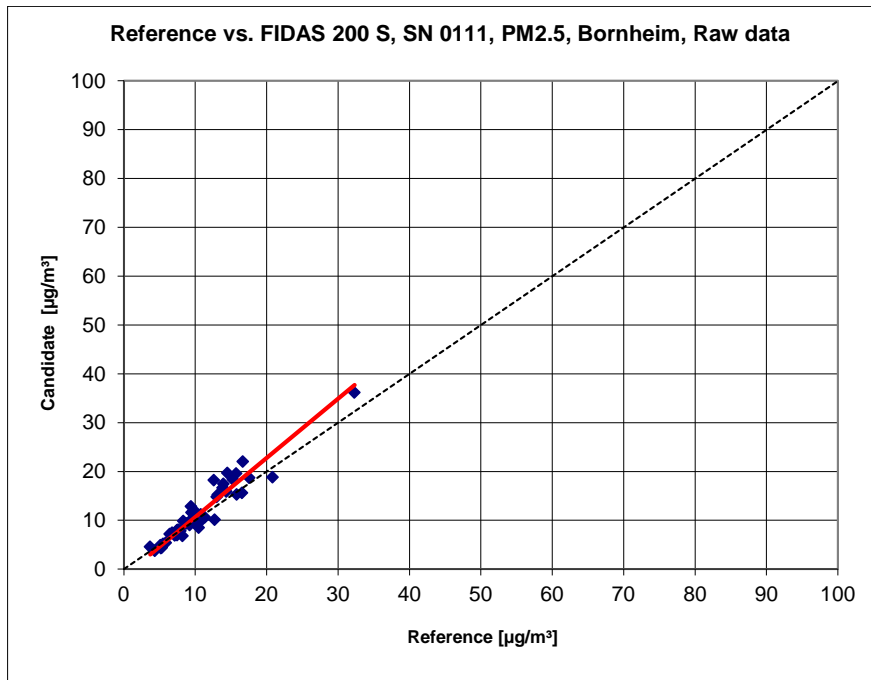


Figure 86: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, Bornheim, summer

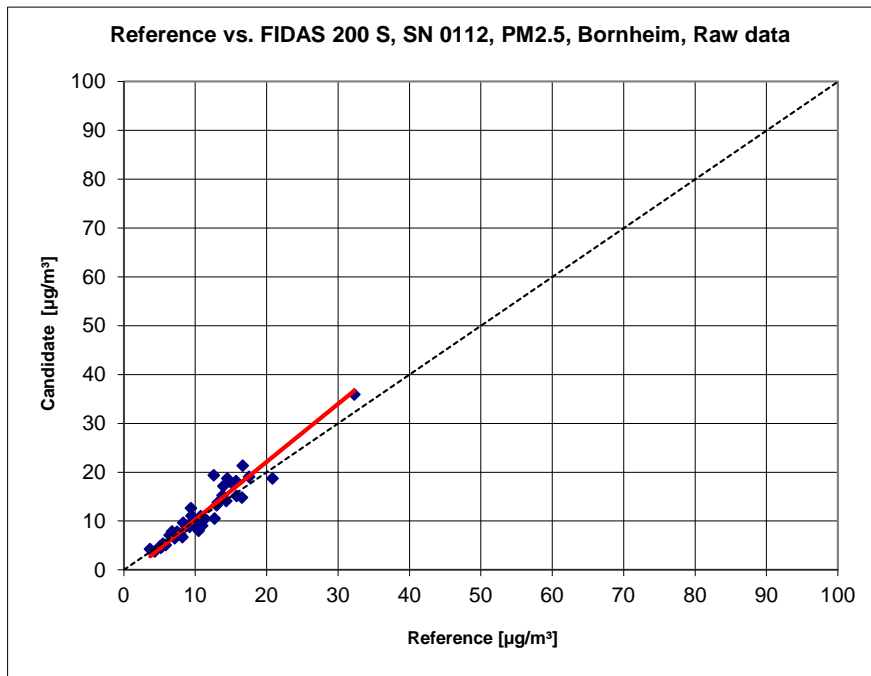


Figure 87: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, Bornheim, summer

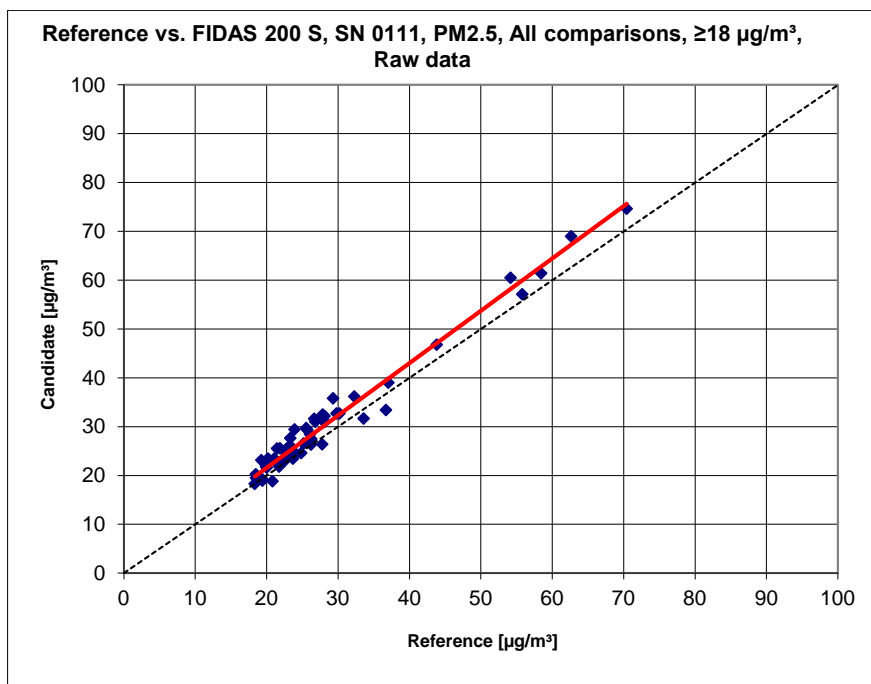


Figure 88: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, values $\geq 18 \mu\text{g}/\text{m}^3$

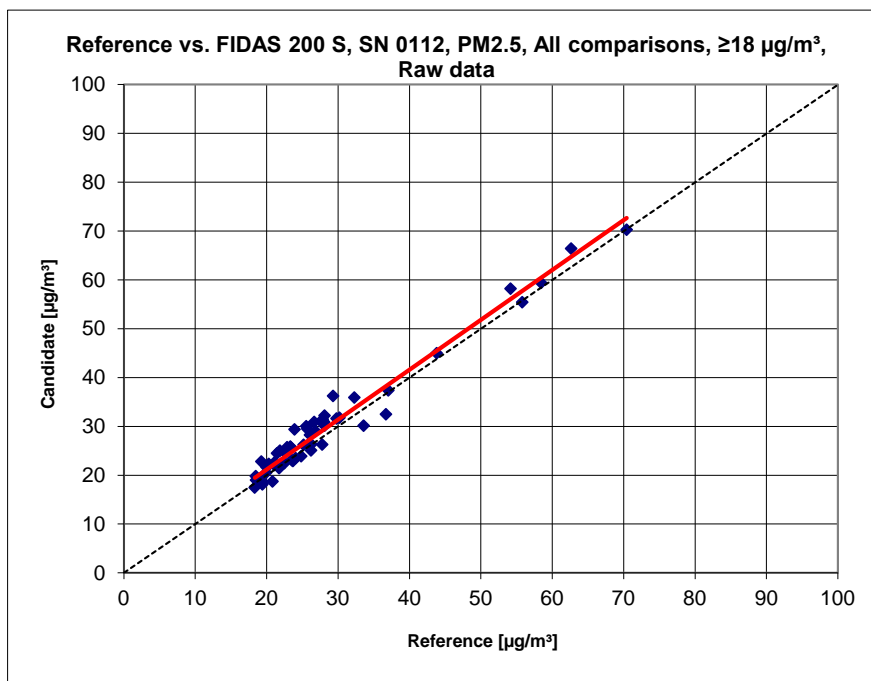


Figure 89: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, values $\geq 18 \mu\text{g}/\text{m}^3$

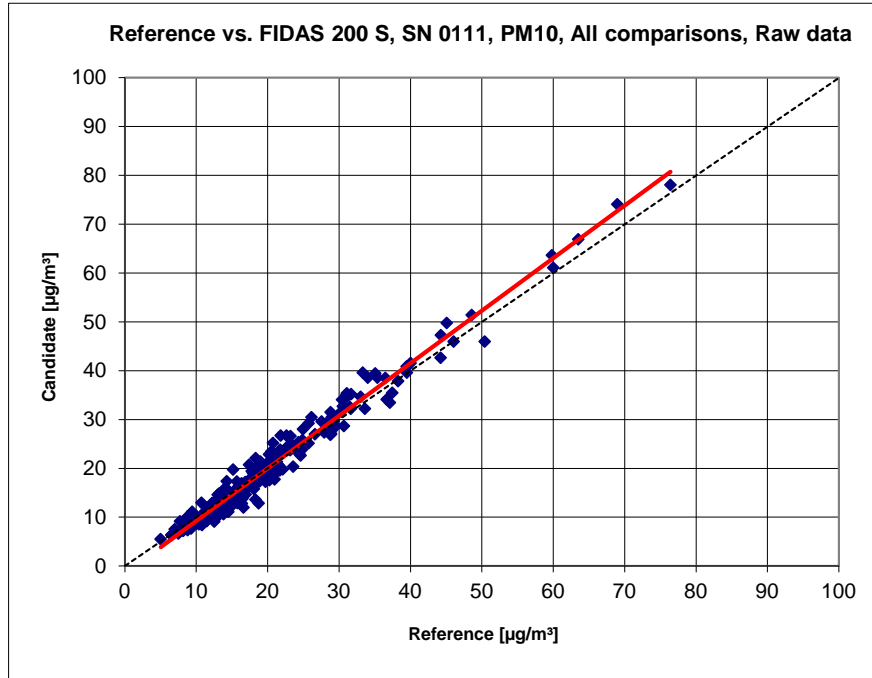


Figure 90: Reference device vs. candidate, SN 0111, measured component PM₁₀, all test sites

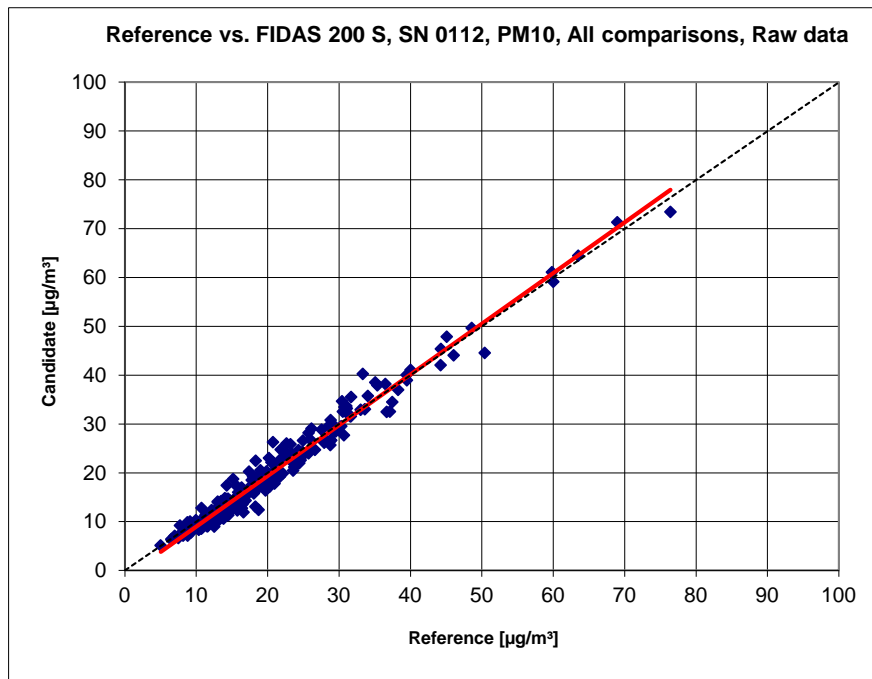


Figure 91: Reference device vs. candidate, SN 0112, measured component PM₁₀, all test sites

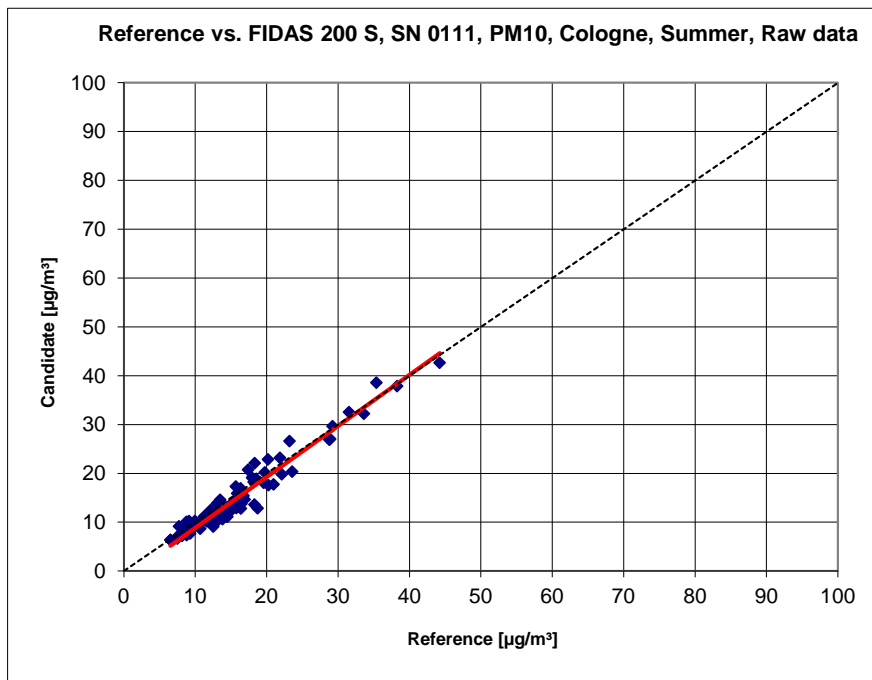


Figure 92: Reference device vs. candidate, SN 0111, measured component PM₁₀, Cologne, summer

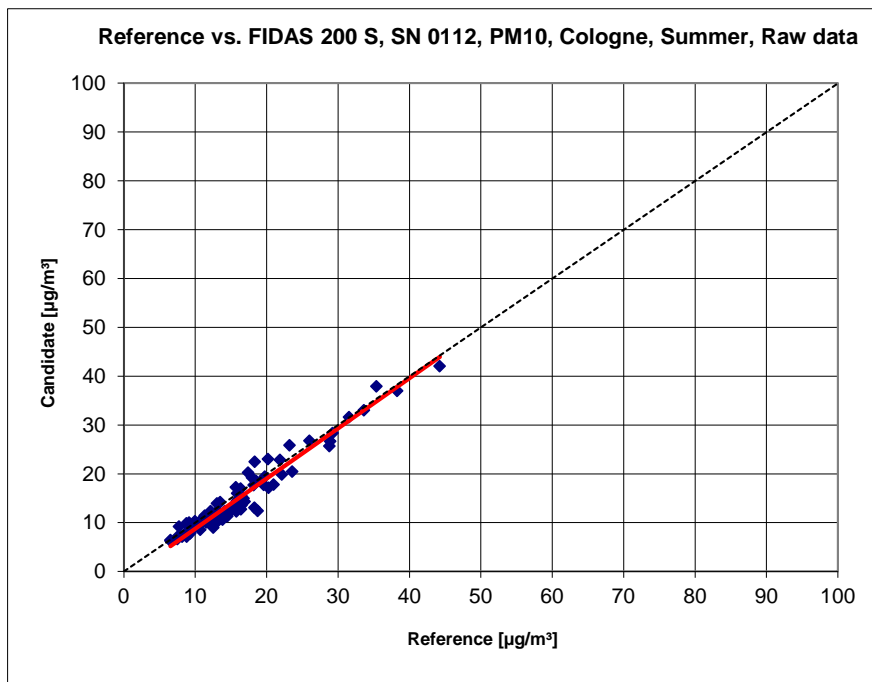


Figure 93: Reference device vs. candidate, SN 0112, measured component PM₁₀, Cologne, summer

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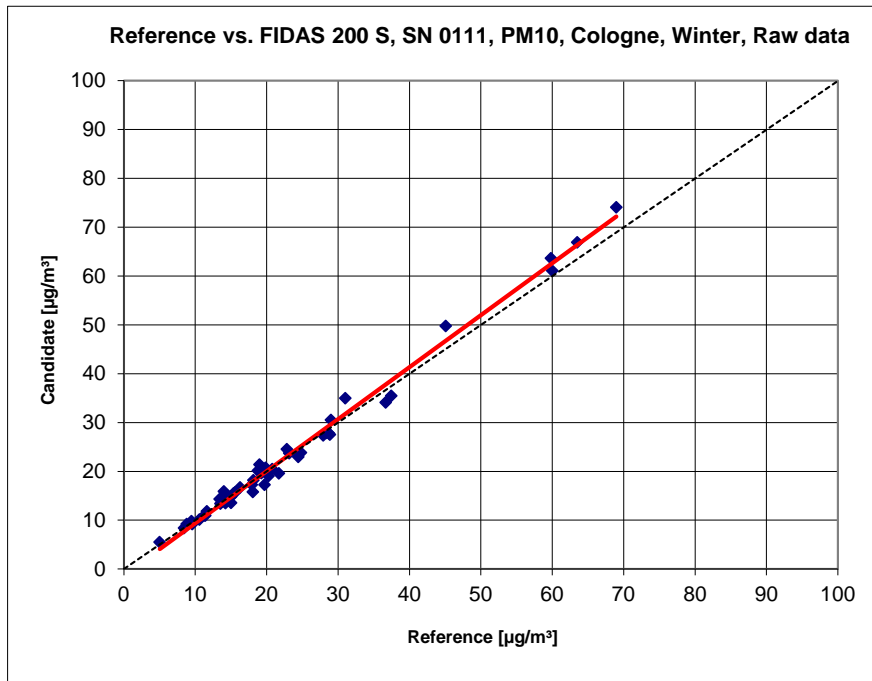


Figure 94: Reference device vs. candidate, SN 0111, measured component PM₁₀, Cologne, winter

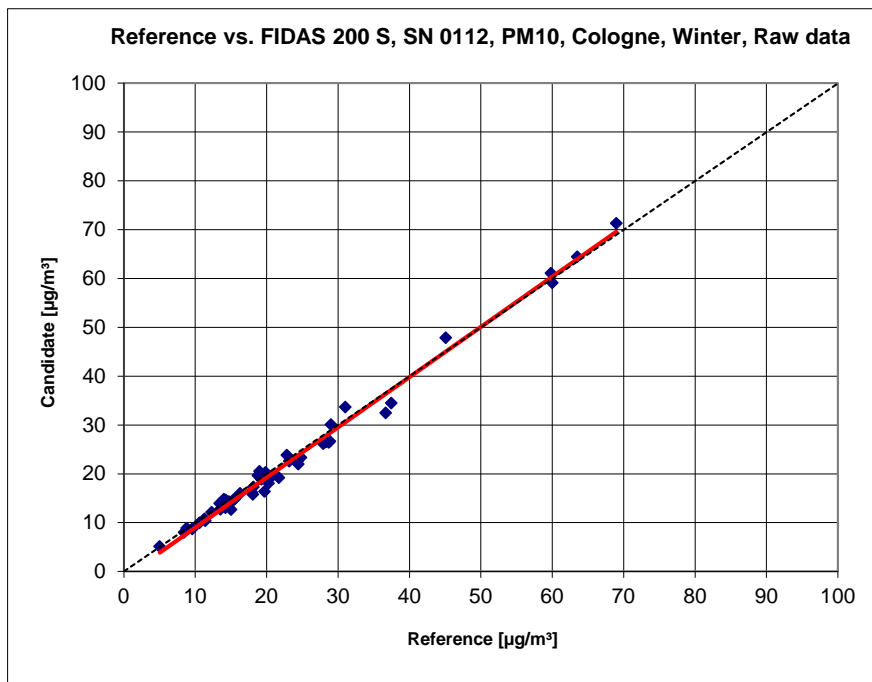


Figure 95: Reference device vs. candidate, SN 0112, measured component PM₁₀, Cologne, winter

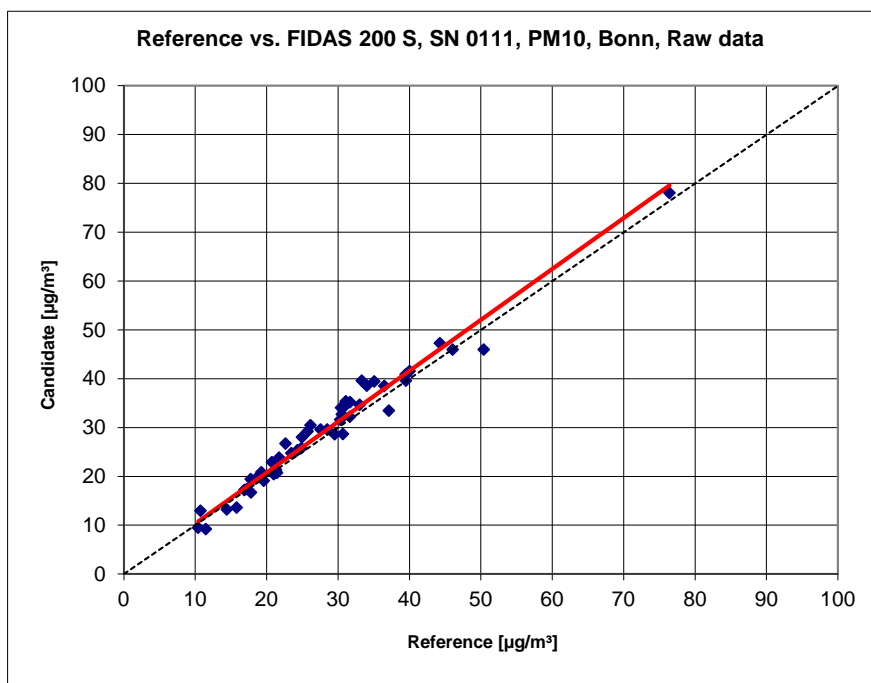


Figure 96: Reference device vs. candidate, SN 0111, measured component PM₁₀, Bonn, winter

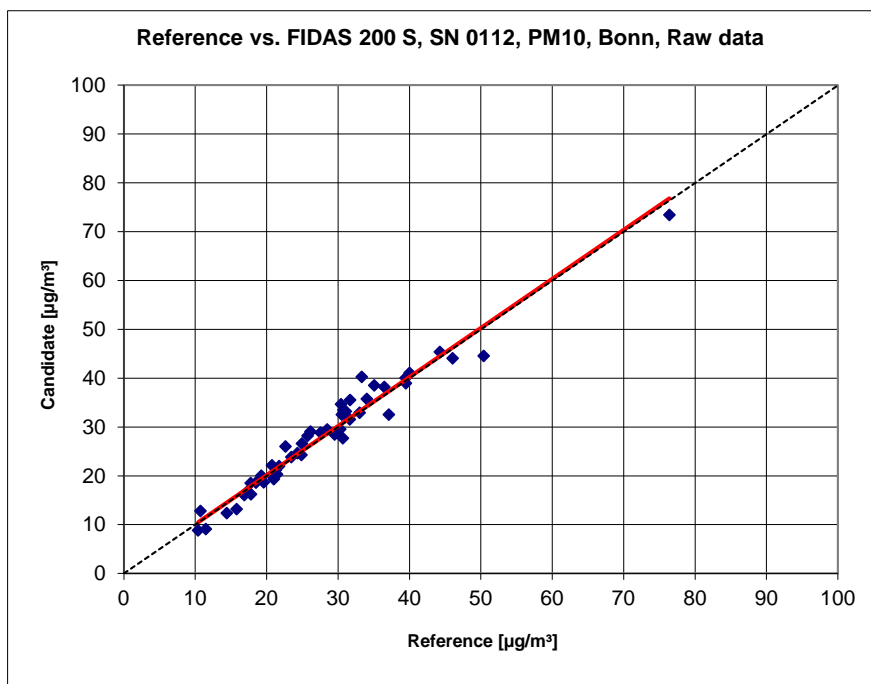


Figure 97: Reference device vs. candidate, SN 0112, measured component PM₁₀, Bonn, winter

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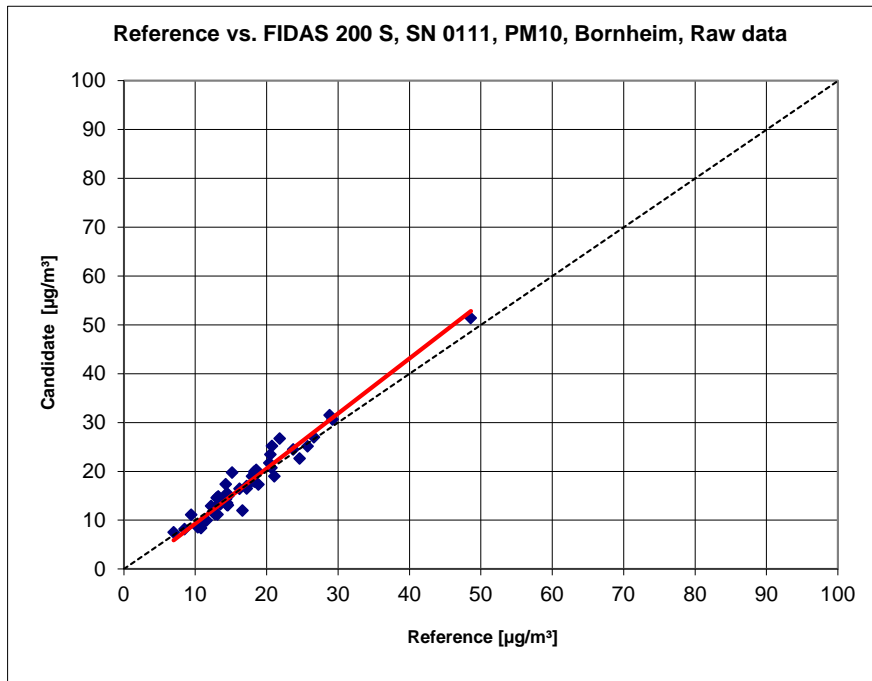


Figure 98: Reference device vs. candidate, SN 0111, measured component PM₁₀, Bornheim, summer

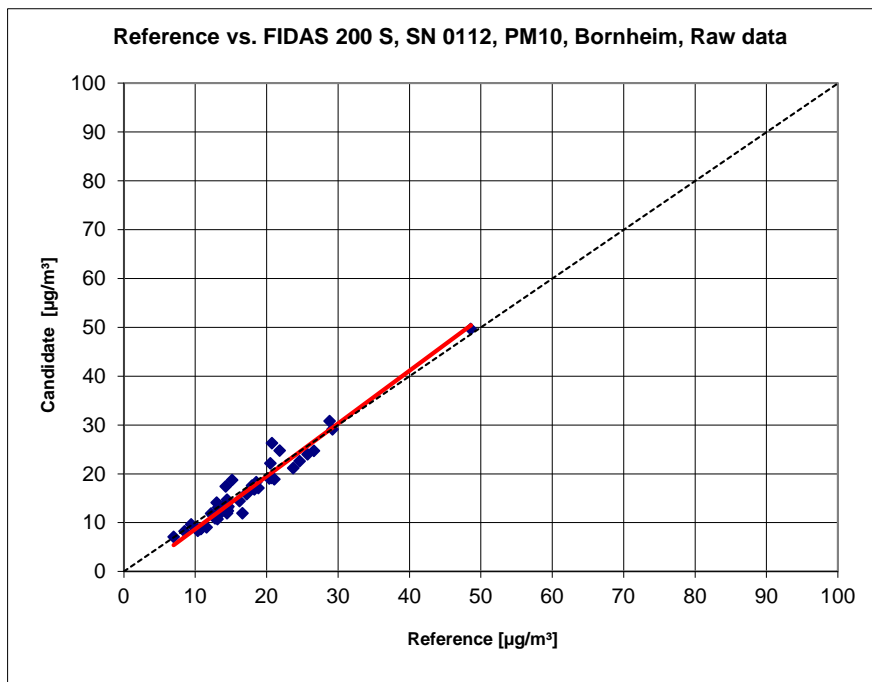


Figure 99: Reference device vs. candidate, SN 0112, measured component PM₁₀, Bornheim, summer

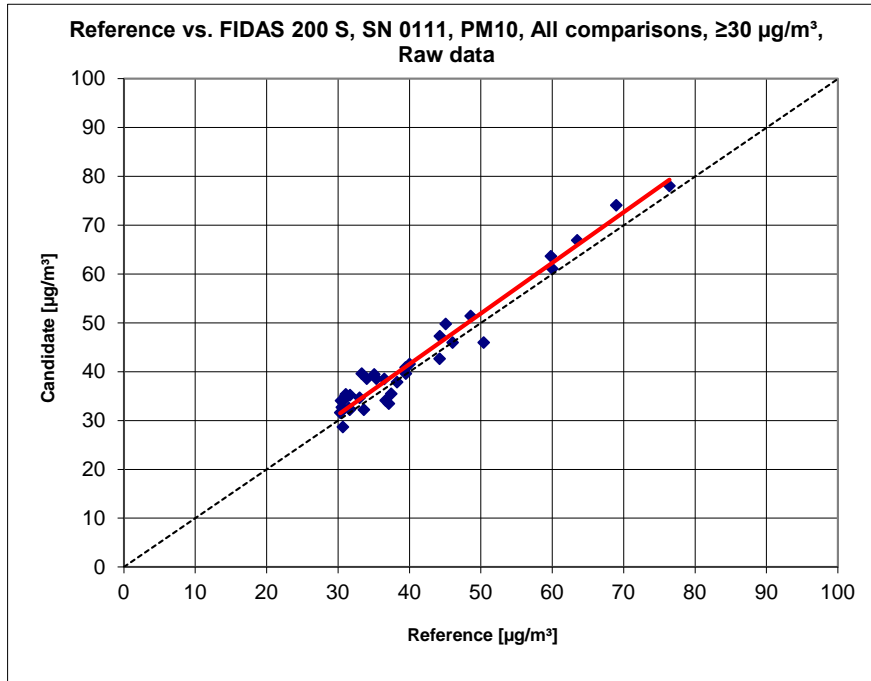


Figure 100: Reference device vs. candidate, SN 0111, measured component PM₁₀, values $\geq 30 \mu\text{g}/\text{m}^3$

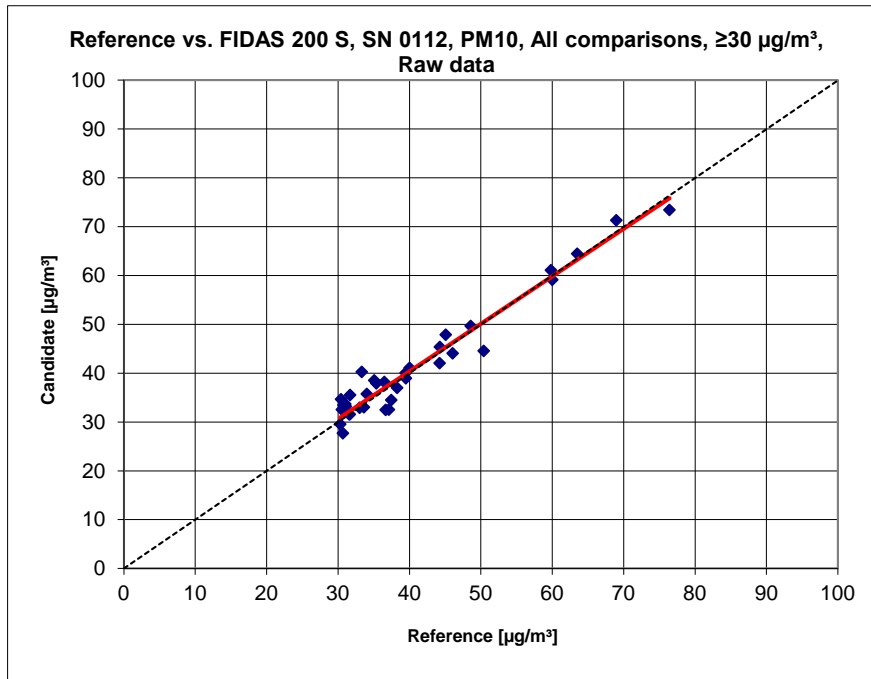


Figure 101: Reference device vs. candidate, SN 0112, measured component PM₁₀, values $\geq 30 \mu\text{g}/\text{m}^3$

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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 PM₁₀.

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:

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

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and

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

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:

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

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 PM₁₀. For PM₁₀, 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 PM₁₀.

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 PM₁₀:

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 PM₁₀, 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 PM₁₀: 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).

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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	
Status of measured values	Slope & offset corrected	Limit value	30	µg/m ³
		Allowed uncertainty	25	%
All comparisons				
Uncertainty between Reference	0.58			µg/m ³
Uncertainty between Candidates	0.44			µg/m ³
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/m ³
Uncertainty between Candidates	0.78			µg/m ³
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/m ³
Uncertainty between Candidates	0.31			µg/m ³
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			%

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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
Status of measured values	Slope & offset corrected		Limit value	30 $\mu\text{g}/\text{m}^3$
			Allowed uncertainty	25 %
Cologne, Summer				
Uncertainty between Reference	0.66	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.11	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.51	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.65	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.46	$\mu\text{g}/\text{m}^3$		
	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, $\geq 18 \mu\text{g}/\text{m}^3$				
Uncertainty between Reference	0.63	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.78	$\mu\text{g}/\text{m}^3$		
	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, $< 18 \mu\text{g}/\text{m}^3$				
Uncertainty between Reference	0.57	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.31	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.44	$\mu\text{g}/\text{m}^3$		
	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	%

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Table 51: Summary of the results of the equivalence test, SN 0111 & SN 0112, measured component PM₁₀ 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
Status of measured values	Slope and offset corrected	Limit value	50 $\mu\text{g}/\text{m}^3$
		Allowed uncertainty	25 %
All comparisons			
Uncertainty between Reference	0.62		$\mu\text{g}/\text{m}^3$
Uncertainty between Candidates	0.64		$\mu\text{g}/\text{m}^3$
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, $\geq 30 \mu\text{g}/\text{m}^3$			
Uncertainty between Reference	0.67		$\mu\text{g}/\text{m}^3$
Uncertainty between Candidates	1.10		$\mu\text{g}/\text{m}^3$
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, $< 30 \mu\text{g}/\text{m}^3$			
Uncertainty between Reference	0.61		$\mu\text{g}/\text{m}^3$
Uncertainty between Candidates	0.55		$\mu\text{g}/\text{m}^3$
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		%

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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
Status of measured values	Slope and offset corrected		Limit value	50 $\mu\text{g}/\text{m}^3$
			Allowed uncertainty	25 %
Cologne, Summer				
Uncertainty between Reference	0.80	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.26	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.63	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.85	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.82	$\mu\text{g}/\text{m}^3$		
	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, $\geq 30 \mu\text{g}/\text{m}^3$				
Uncertainty between Reference	0.67	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	1.10	$\mu\text{g}/\text{m}^3$		
	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, $< 30 \mu\text{g}/\text{m}^3$				
Uncertainty between Reference	0.61	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.55	$\mu\text{g}/\text{m}^3$		
	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	$\mu\text{g}/\text{m}^3$		
Uncertainty between Candidates	0.64	$\mu\text{g}/\text{m}^3$		
	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	%

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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 campaigns from the UK fit very well to the already existing 4 campaigns from Germany and the equivalence for both PM₁₀ and PM_{2.5} can also be surely demonstrated with in total 6 comparison campaigns.

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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 PM₁₀.

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 PM₁₀ 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 PM₁₀.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (6 test sites, PM₁₀: 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/m³ 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 PM₁₀. 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 $\leq 2.5 \mu\text{g}/\text{m}^3$. If the uncertainty between the candidates exceeds $2.5 \mu\text{g}/\text{m}^3$, 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 $\geq 18 \mu\text{g}/\text{m}^3$ for PM_{2.5} (basis: mean values of reference measurement)
- 1 dataset with measured values $\geq 30 \mu\text{g}/\text{m}^3$ for PM₁₀ (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 PM₁₀ (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 PM₁₀ does not exceed the required value of 2.5 µg/m³.

Performance criterion met? yes

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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			$\mu\text{g}/\text{m}^3$
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 $\geq 18 \mu\text{g}/\text{m}^3$	67	0.85
0111 / 0112	Values $< 18 \mu\text{g}/\text{m}^3$	246	0.32

Table 53: *Uncertainty between candidates u_{bs} for the devices SN 0111 and SN 0112, measured component PM₁₀, PM_ENVIRO_0011*

Device	Test site	No. of values	Uncertainty u_{bs}
SN			$\mu\text{g}/\text{m}^3$
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 $\geq 30 \mu\text{g}/\text{m}^3$	67	1.19
0111 / 0112	Values $< 30 \mu\text{g}/\text{m}^3$	246	0.57

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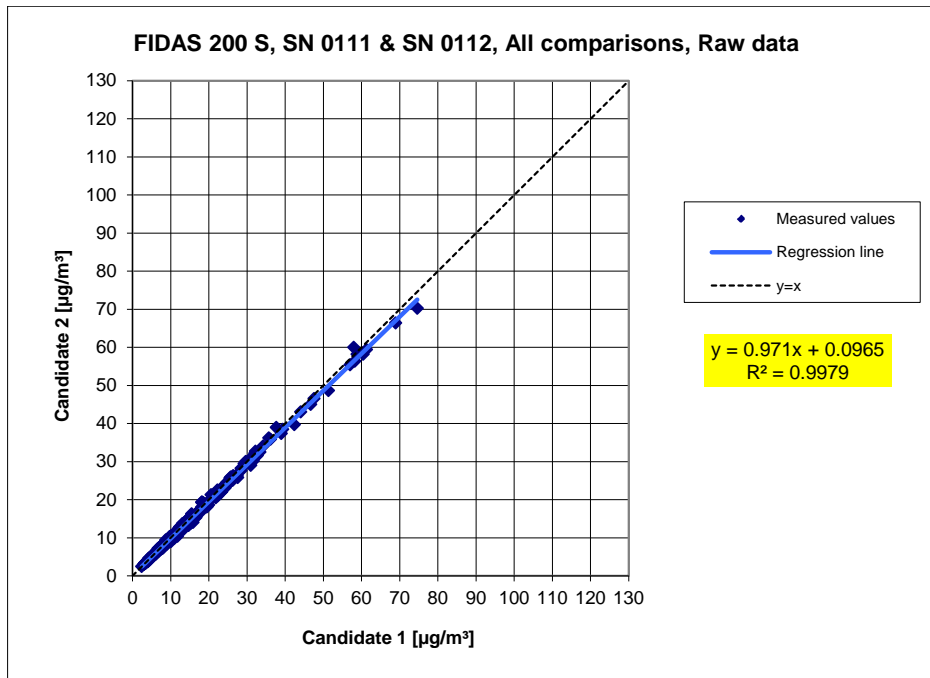


Figure 102: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, all test sites (GER+UK), PM_ENVIRO_0011

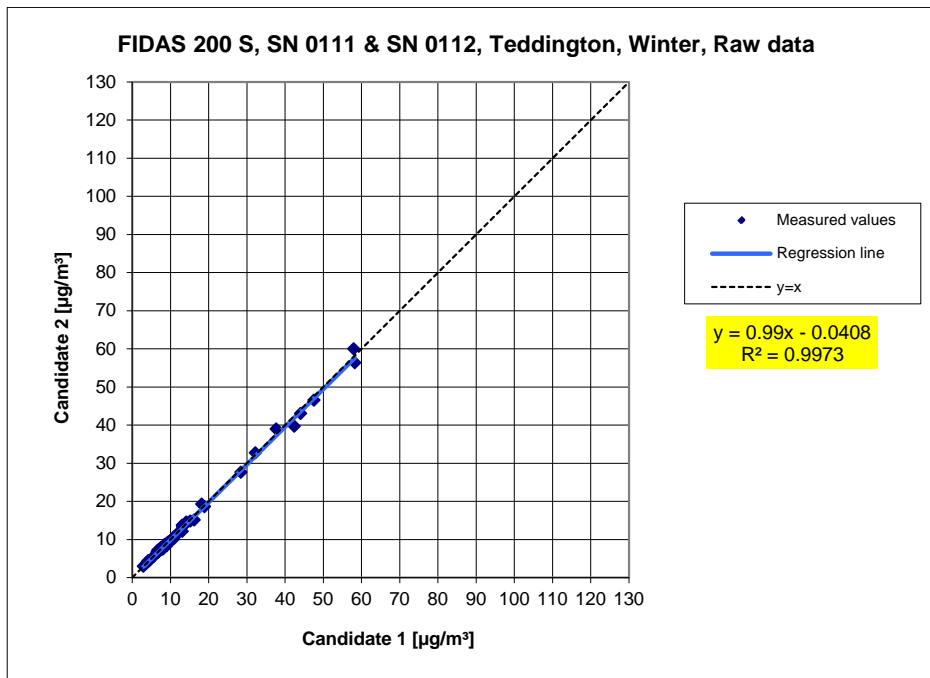


Figure 103: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, test site Teddington, winter, PM_ENVIRO_0011

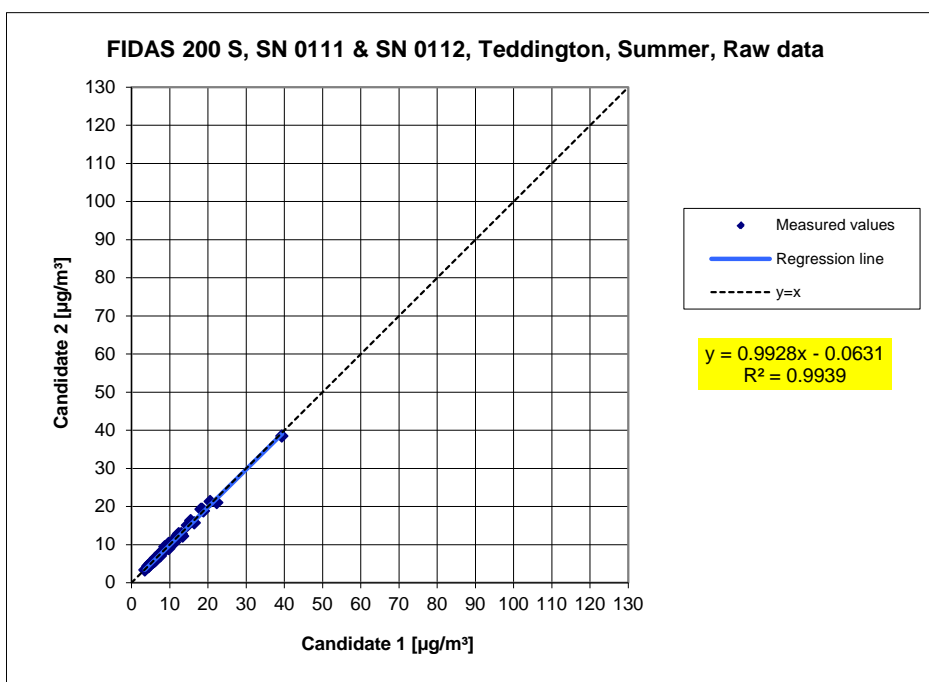


Figure 104: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, test site Teddington, summer, PM_ENVIRO_0011

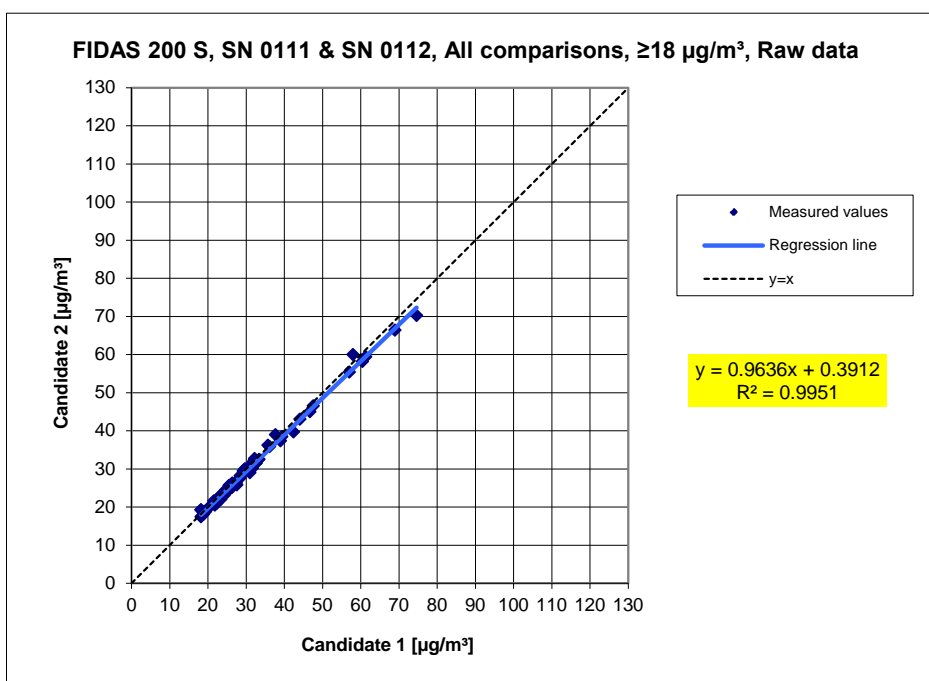


Figure 105: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, all test sites (GER+UK), values ≥ 18 µg/m³, PM_ENVIRO_0011

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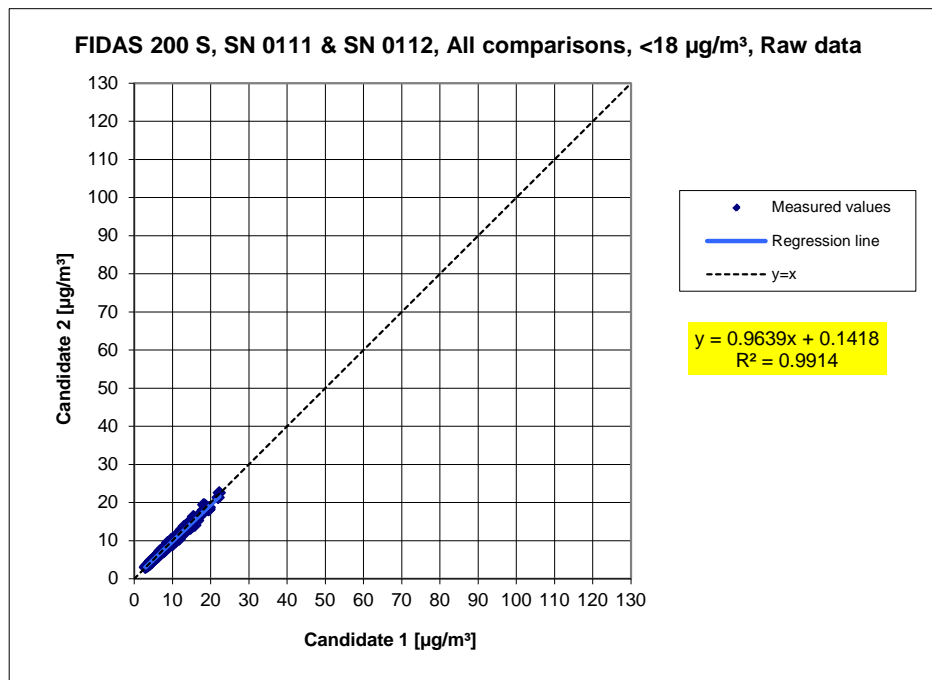


Figure 106: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM_{2.5}, all test sites (GER+UK), values < 18 µg/m³, PM_ENVIRO_0011

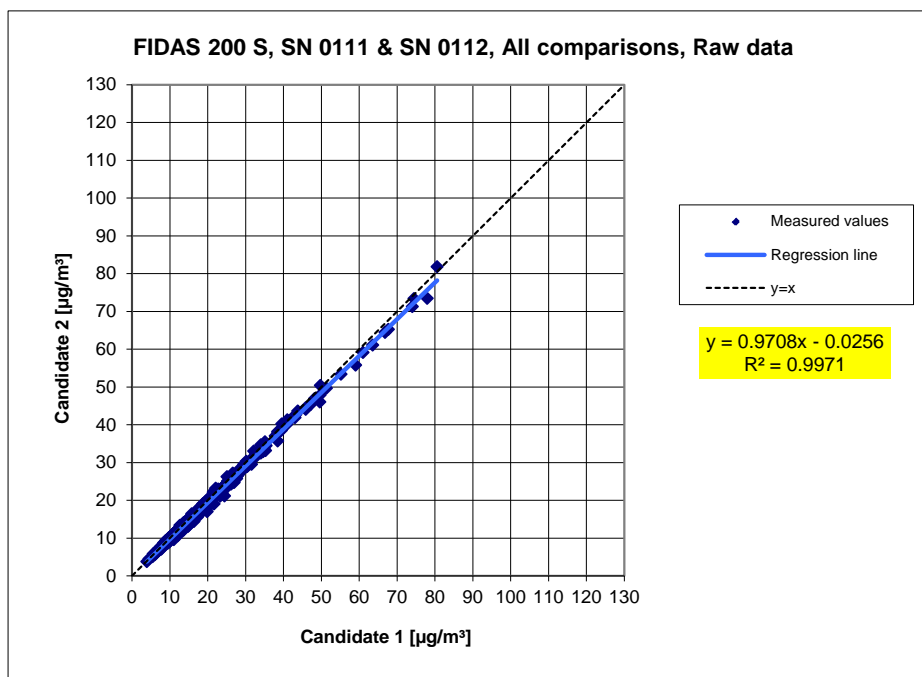


Figure 107: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, all test sites (GER+UK), PM_ENVIRO_0011

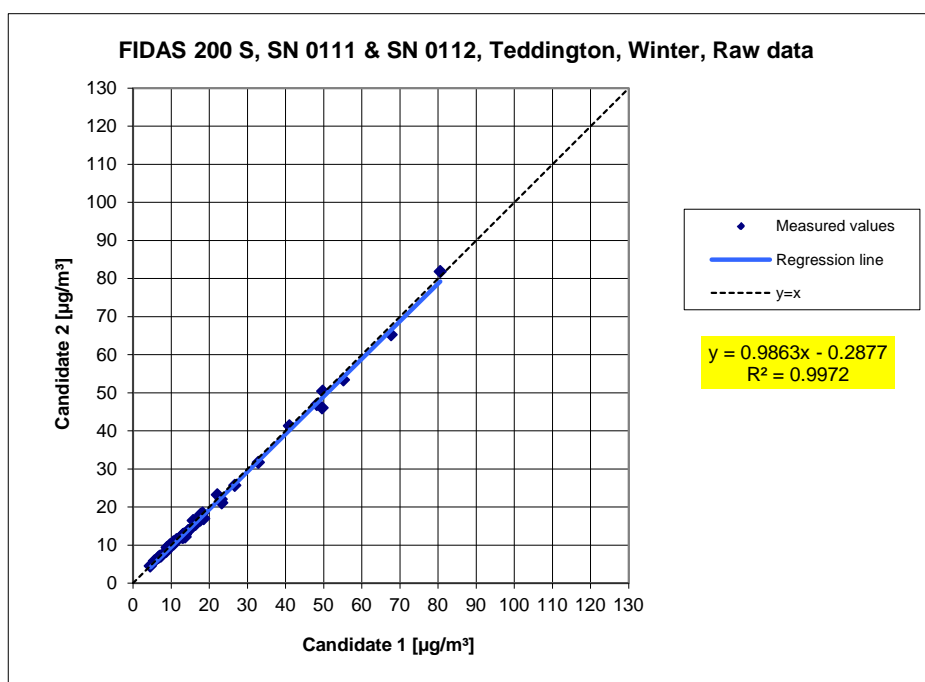


Figure 108: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, test site Teddington, winter, PM_ENVIRO_0011

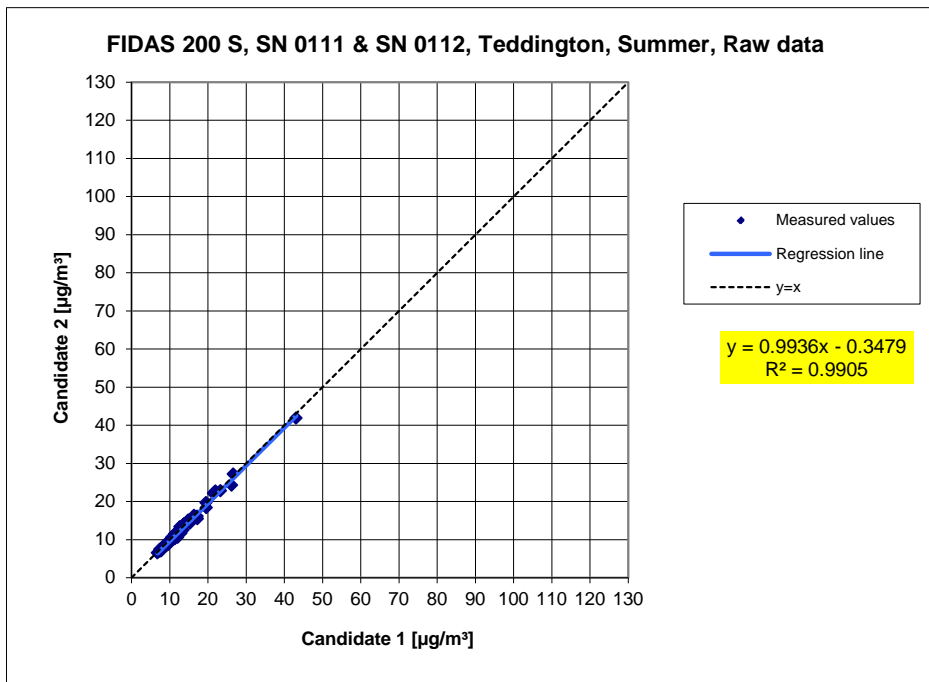


Figure 109: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, test site Teddington, summer, PM_ENVIRO_0011

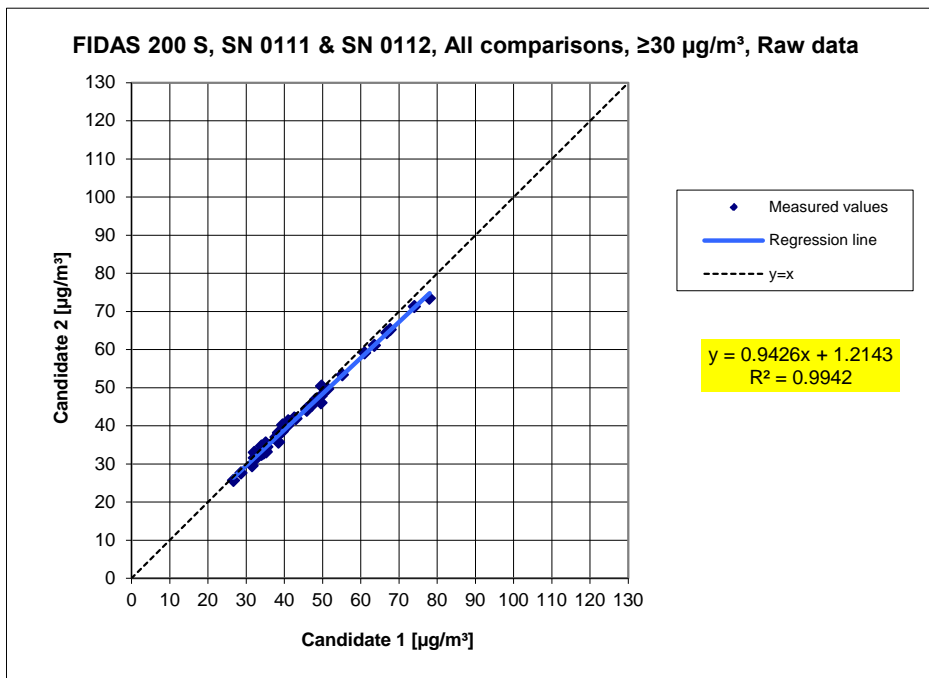


Figure 110: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, all test sites (GER+UK), values ≥ 30 µg/m³, PM_ENVIRO_0011

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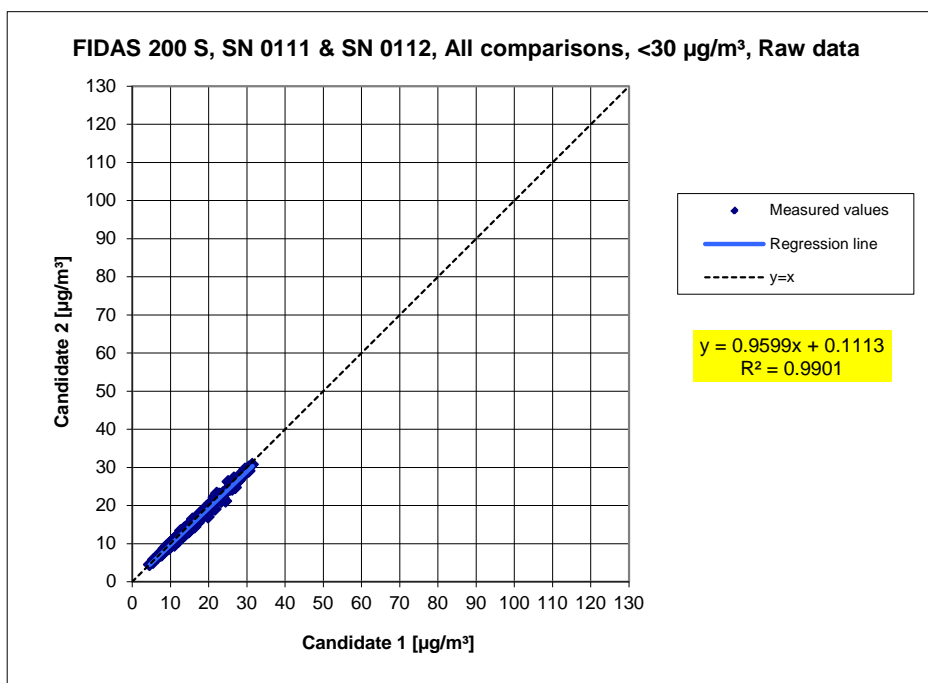


Figure 111: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component PM₁₀, all test sites (GER+UK), values < 30 µg/m³, PM_ENVIRO_0011

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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 PM₁₀.

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 PM₁₀ 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 PM₁₀.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (6 test sites, PM₁₀: 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/m³ 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 PM₁₀. 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 $\leq 2 \mu\text{g}/\text{m}^3$.

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 $\geq 18 \mu\text{g}/\text{m}^3$ for PM_{2.5} (basis: mean values of reference measurement)
- 1 dataset with measured values $\geq 30 \mu\text{g}/\text{m}^3$ for PM₁₀ (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 u_{bs})

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 $\geq 18 \mu\text{g}/\text{m}^3$ for PM_{2.5} (basis: mean values of reference measurement)
- 1 dataset with measured values $\geq 30 \mu\text{g}/\text{m}^3$ for PM₁₀ (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: $|a| \leq 2 \cdot u(a)$

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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 $y_i = 30 \mu\text{g}/\text{m}^3$ for PM_{2.5} and at the level of $y_i = 50 \mu\text{g}/\text{m}^3$ for PM₁₀.

[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. $W_{CM} \leq W_{dqo}$ → Candidate method is considered equivalent to the reference method
2. $W_{CM} > W_{dqo}$ → 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 PM₁₀ 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 PM₁₀, 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 PM₁₀. 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	
Status of measured values	Raw data	Limit value	30	µg/m ³
		Allowed uncertainty	25	%
All comparisons				
Uncertainty between Reference	0.53			µg/m ³
Uncertainty between Candidates	0.48			µg/m ³
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/m ³
Uncertainty between Candidates	0.85			µg/m ³
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/m ³
Uncertainty between Candidates	0.32			µg/m ³
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			%

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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
Status of measured values	Raw data		Limit value	µg/m ³
			Allowed uncertainty	%
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	%
Teddington, Winter				
Uncertainty between Reference	0.42	µg/m ³		
Uncertainty between Candidates	0.55	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.37	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.85	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.32	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.48	µg/m ³		
	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.

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Table 55: Overview of equivalence test of Fidas[®] 200 S for PM₁₀ (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	
Status of measured values	Raw data	Limit value	50	µg/m ³
		Allowed uncertainty	25	%
All comparisons				
Uncertainty between Reference	0.58			µg/m ³
Uncertainty between Candidates	0.67			µg/m ³
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/m ³
Uncertainty between Candidates	1.19			µg/m ³
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/m ³
Uncertainty between Candidates	0.57			µg/m ³
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			%

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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
Status of measured values	Raw data		Limit value	µg/m³
			Allowed uncertainty	%
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	%

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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 PM₁₀ 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 PM₁₀, 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 PM₁₀ 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 PM₁₀:

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 PM₁₀, 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)).

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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.			$\mu\text{g}/\text{m}^3$
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 PM₁₀*

Reference devices	Test site	No. of values	Uncertainty u_{bs}
Nr.			$\mu\text{g}/\text{m}^3$
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 $< 2 \mu\text{g}/\text{m}^3$ for all test sites.

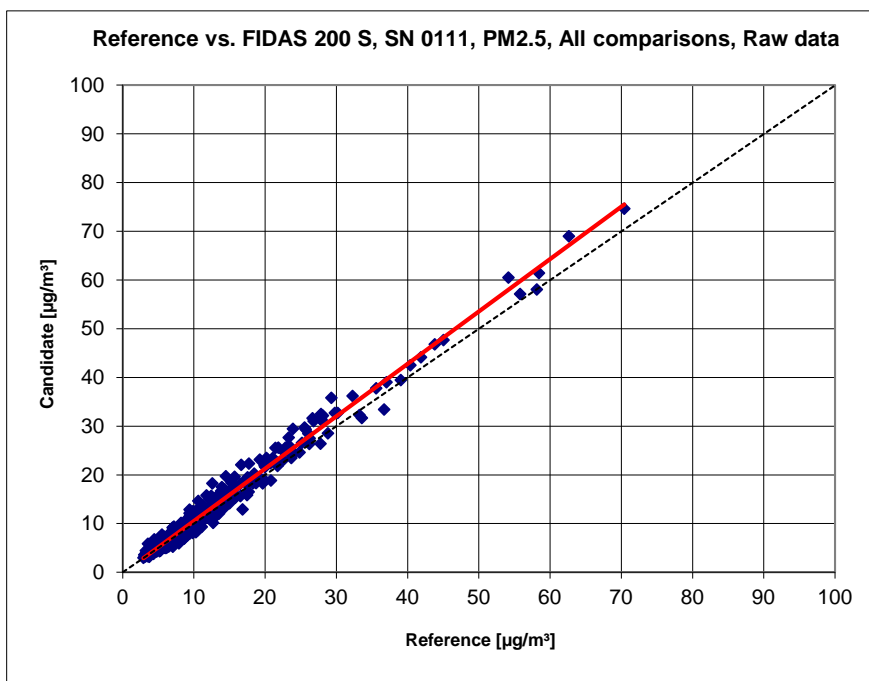


Figure 112: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, all test sites (GER+UK), PM_ENVIRO_0011

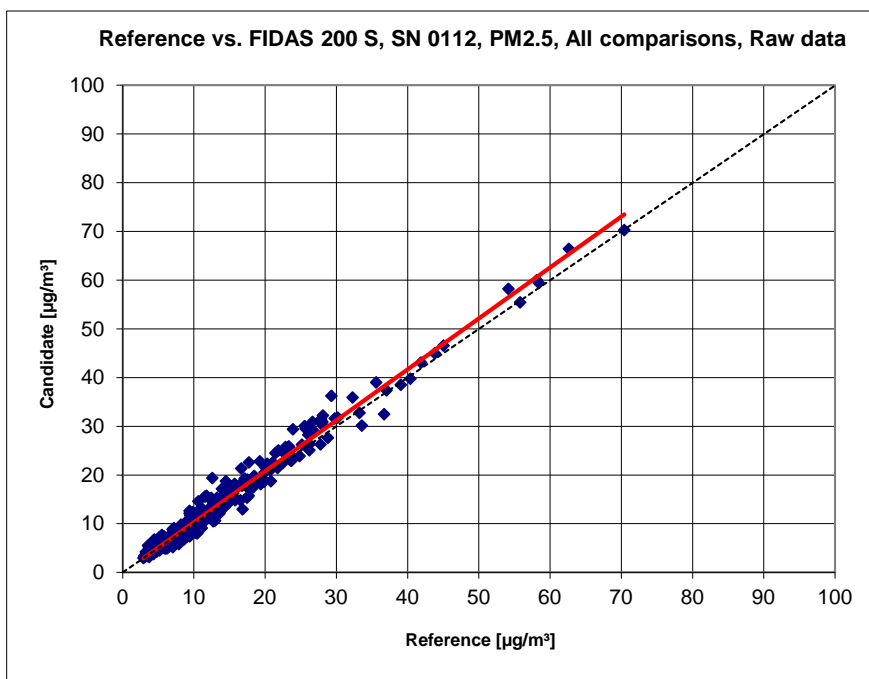


Figure 113: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, all test sites (GER+UK), PM_ENVIRO_0011

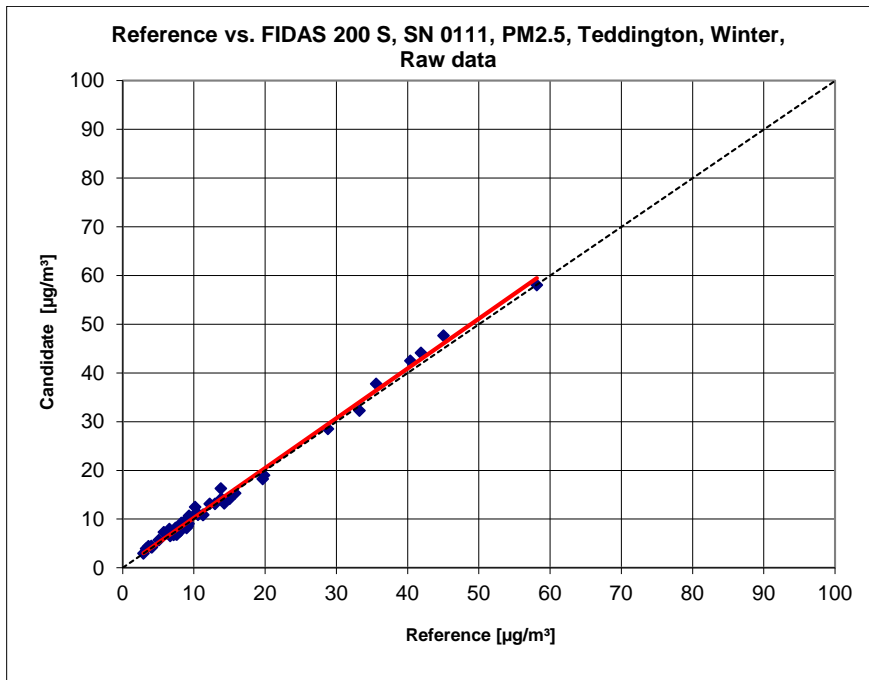


Figure 114: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, Teddington, winter, PM_ENVIRO_0011

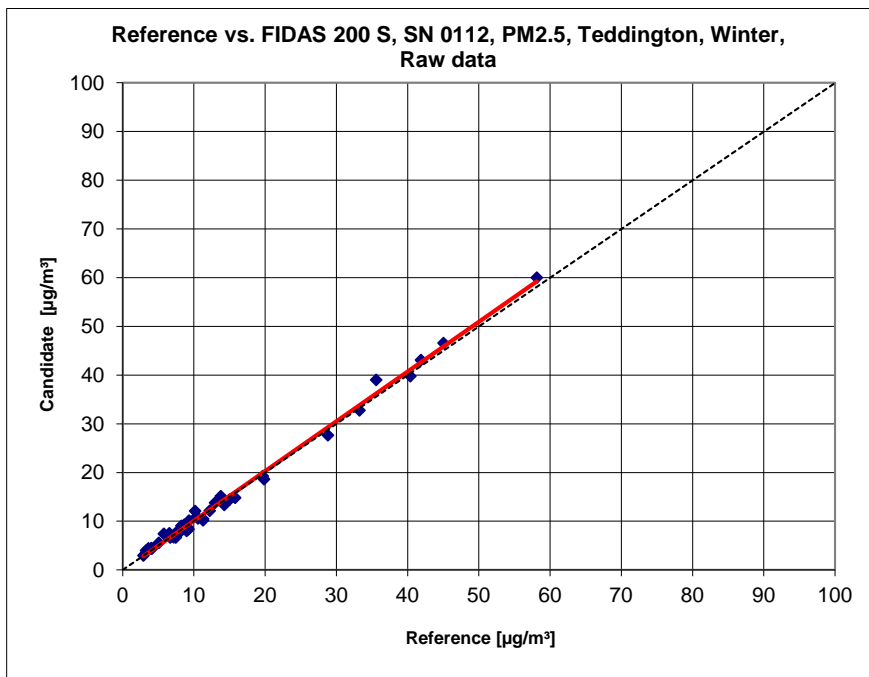


Figure 115: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, Teddington, winter, PM_ENVIRO_0011

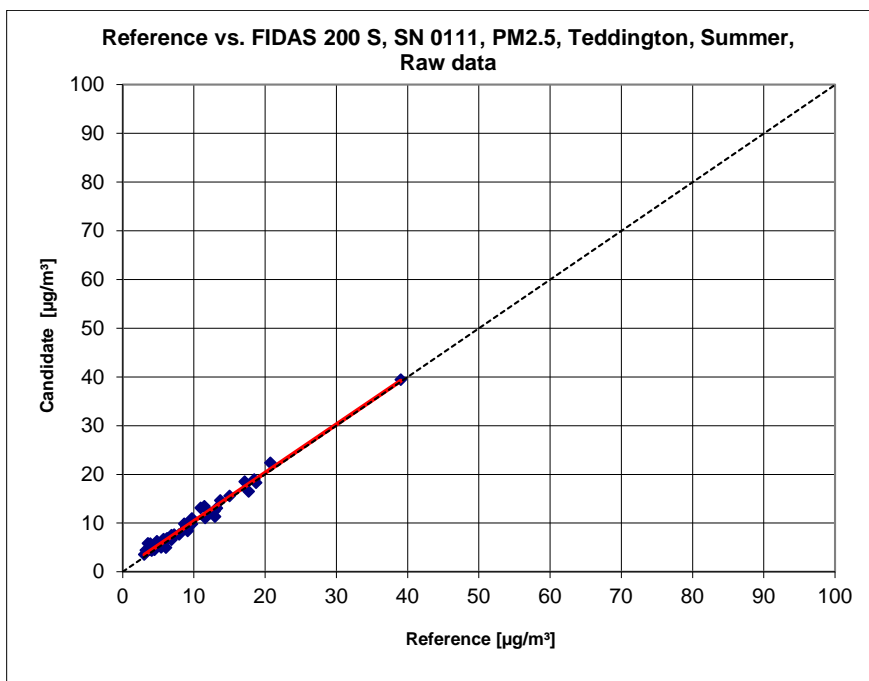


Figure 116: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, Teddington, summer, PM_ENVIRO_0011

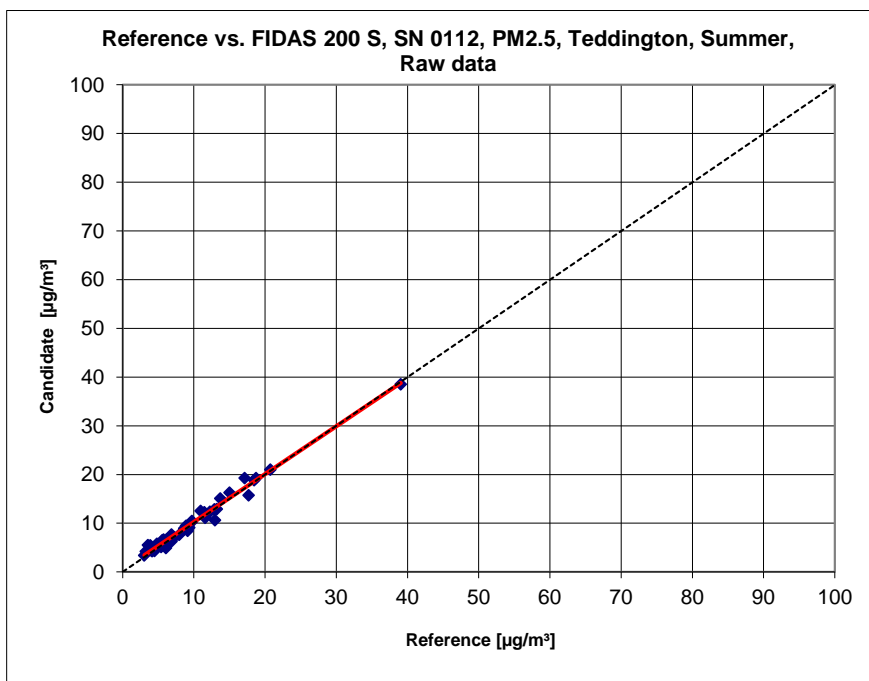


Figure 117: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, Teddington, summer, PM_ENVIRO_0011

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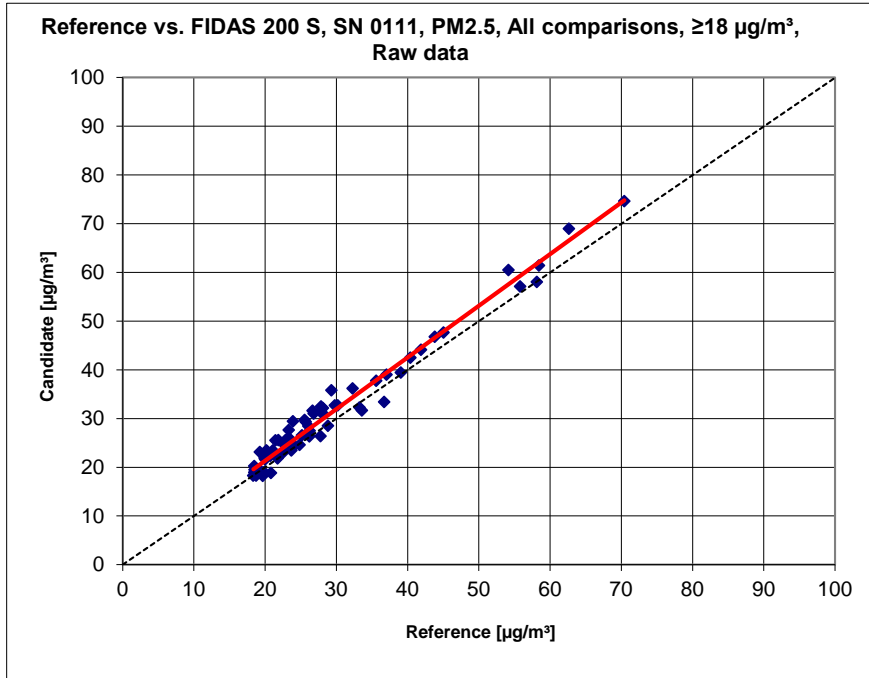


Figure 118: Reference device vs. candidate, SN 0111, measured component PM_{2.5}, values $\geq 18 \mu\text{g}/\text{m}^3$ (GER+UK), PM_ENVIRO_0011

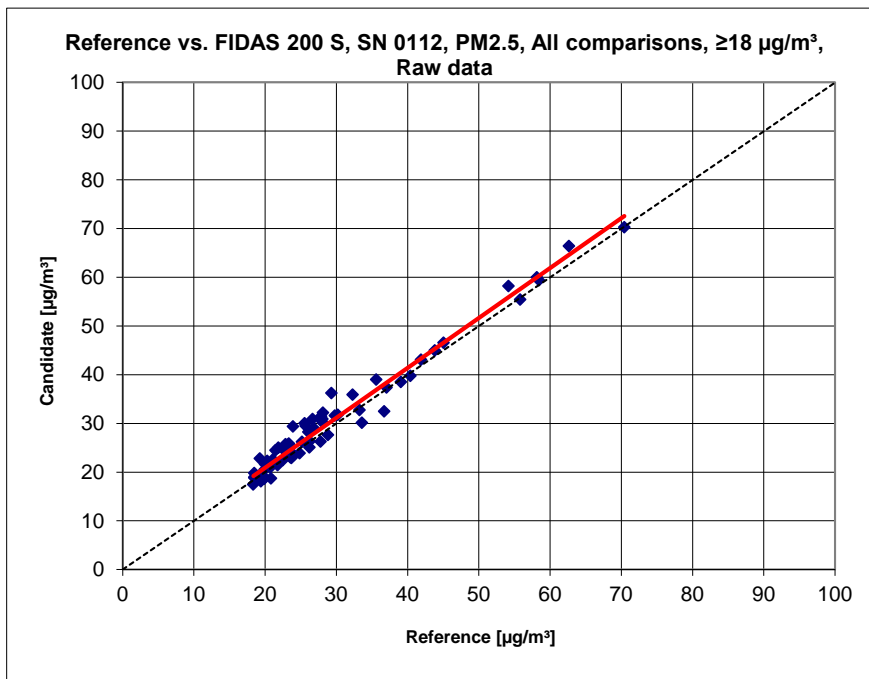


Figure 119: Reference device vs. candidate, SN 0112, measured component PM_{2.5}, values $\geq 18 \mu\text{g}/\text{m}^3$ (GER+UK), PM_ENVIRO_0011

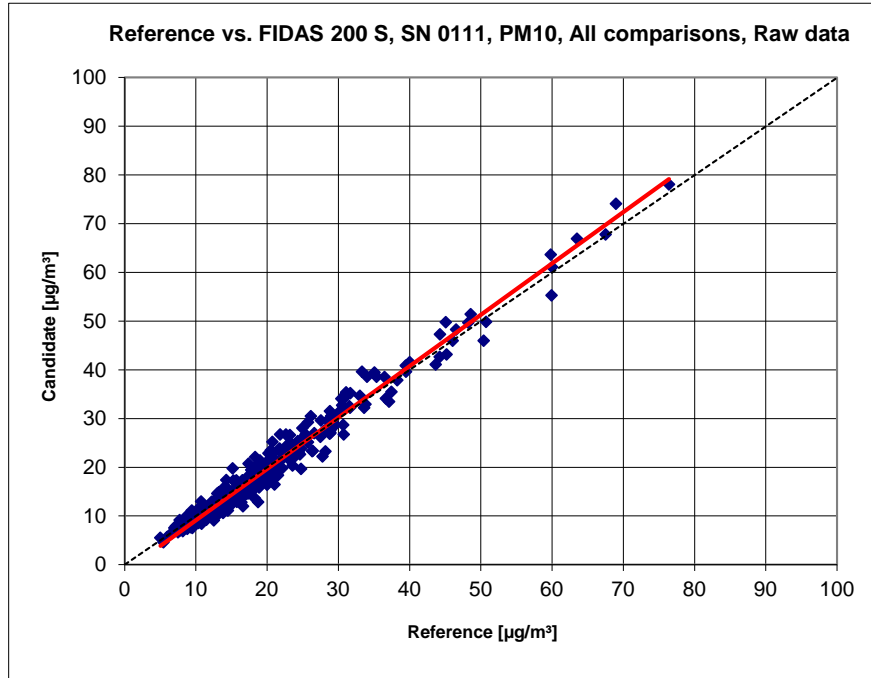


Figure 120: Reference device vs. candidate, SN 0111, measured component PM₁₀, all test sites (GER+UK), PM_ENVIRO_0011

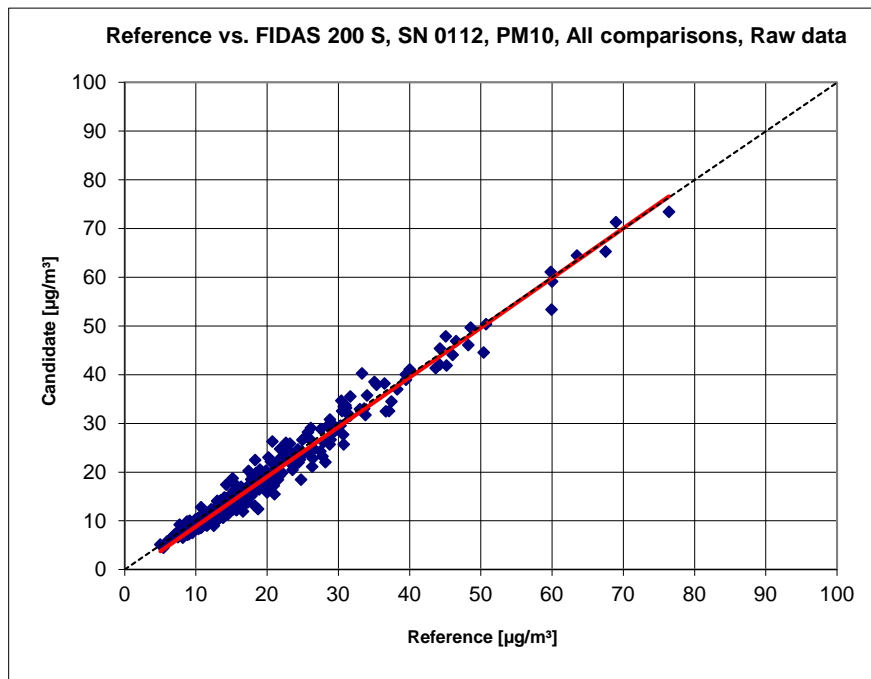


Figure 121: Reference device vs. candidate, SN 0112, measured component PM₁₀, all test sites (GER+UK), PM_ENVIRO_0011

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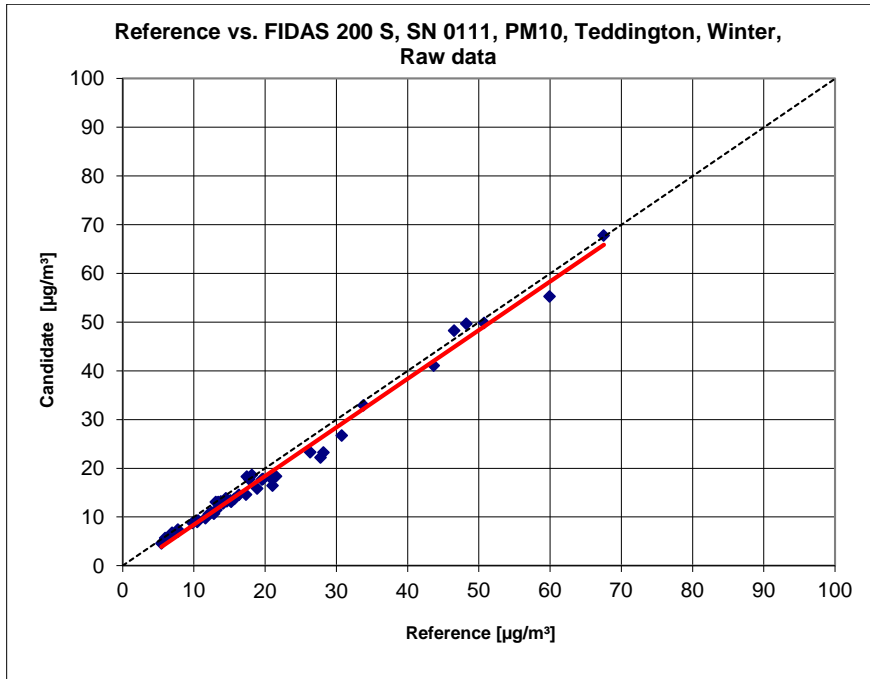


Figure 122: Reference device vs. candidate, SN 0111, measured component PM₁₀, Teddington, winter, PM_ENVIRO_0011

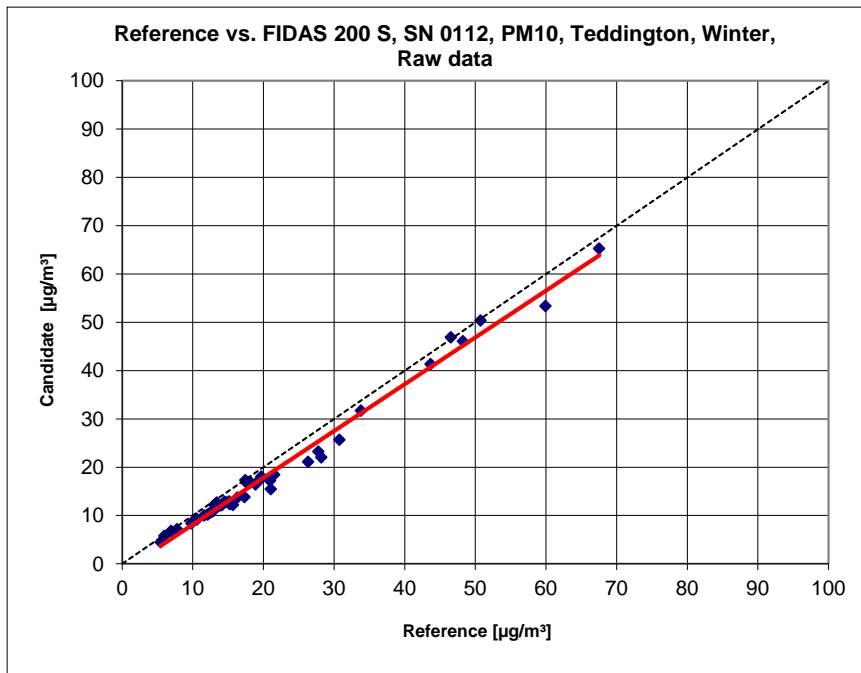


Figure 123: Reference device vs. candidate, SN 0112, measured component PM₁₀, Teddington, winter, PM_ENVIRO_0011

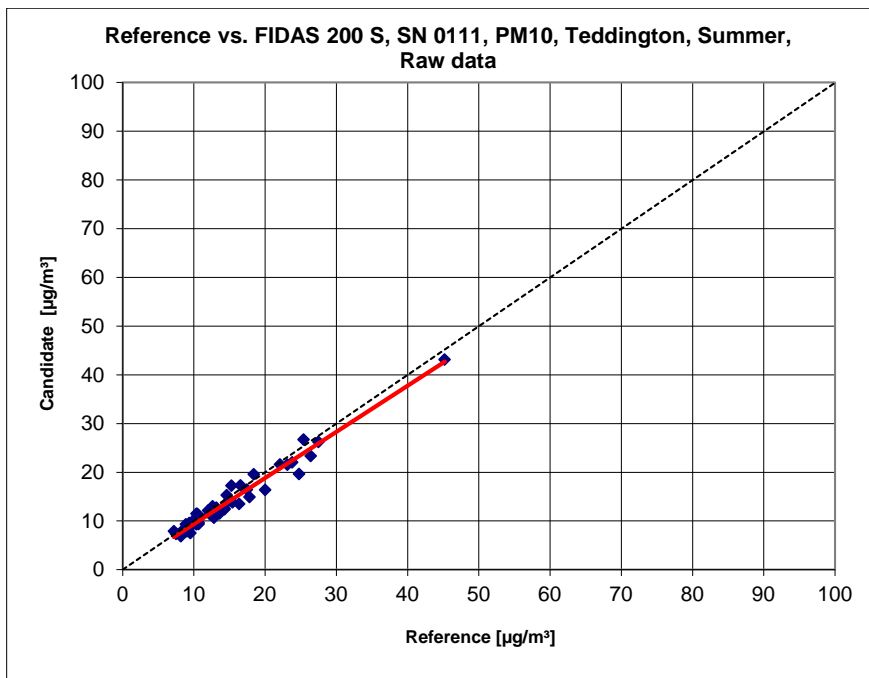


Figure 124: Reference device vs. candidate, SN 0111, measured component PM₁₀, Teddington, summer, PM_ENVIRO_0011

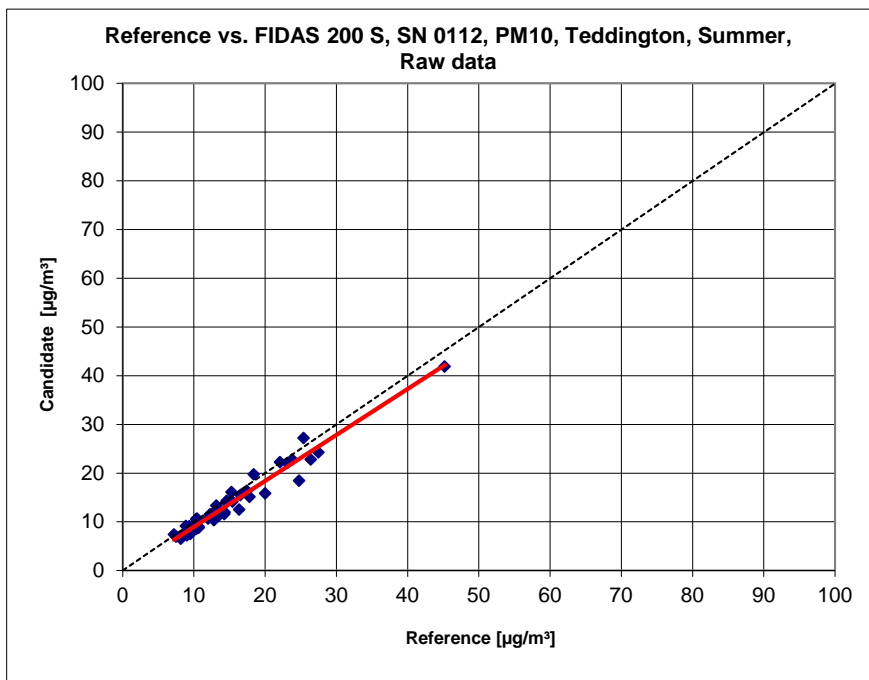


Figure 125: Reference device vs. candidate, SN 0112, measured component PM₁₀, Teddington, summer, PM_ENVIRO_0011

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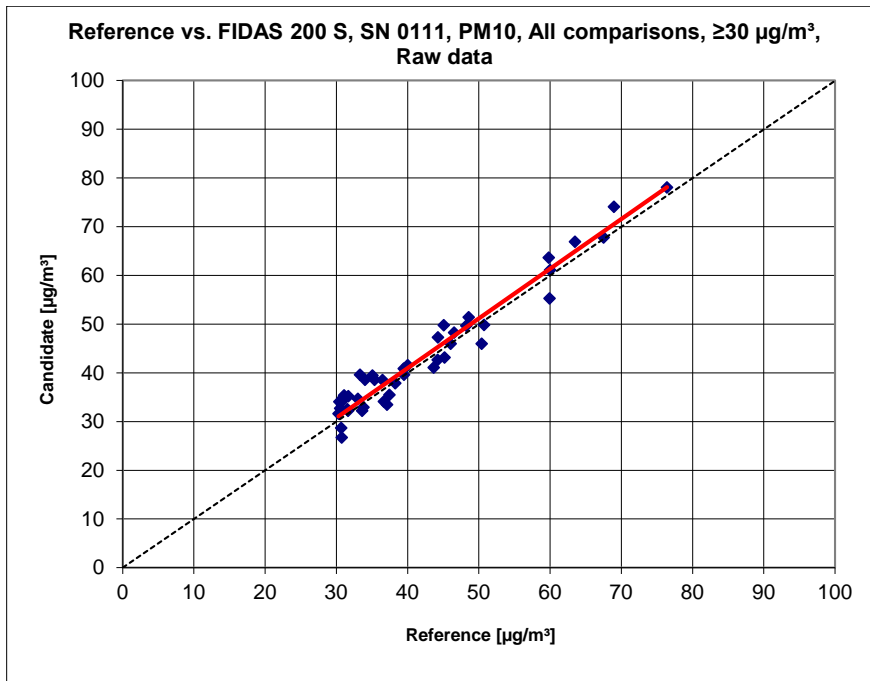


Figure 126: Reference device vs. candidate, SN 0111, measured component PM₁₀, values $\geq 30 \mu\text{g}/\text{m}^3$ (GER+UK), PM_ENVIRO_0011

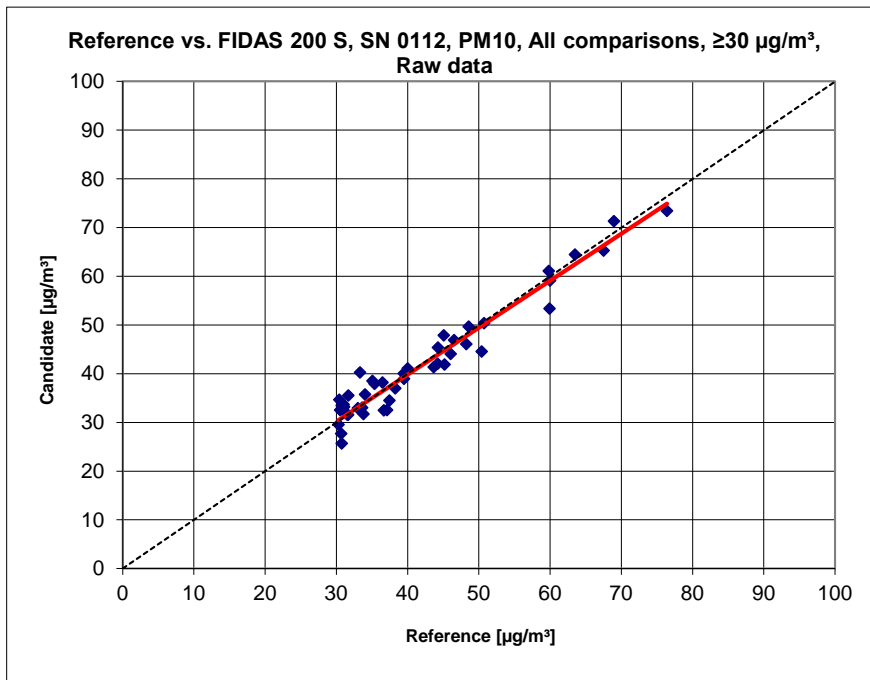


Figure 127: Reference device vs. candidate, SN 0112, measured component PM₁₀, values $\geq 30 \mu\text{g}/\text{m}^3$ (GER+UK), PM_ENVIRO_0011

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 PM₁₀.

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.

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

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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

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

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:

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

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

The specified expanded relative uncertainty $W_{d,qo}$ 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 PM₁₀. For PM₁₀, 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

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The evaluation of the complete dataset for PM_{2.5} shows a significant slope and for PM₁₀ 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 PM₁₀:

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 PM₁₀, 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 PM₁₀, 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 PM₁₀: 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	
Status of measured values	Slope corrected	Limit value	30	µg/m ³
		Allowed uncertainty	25	%
All comparisons				
Uncertainty between Reference	0.53			µg/m ³
Uncertainty between Candidates	0.45			µg/m ³
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/m ³
Uncertainty between Candidates	0.80			µg/m ³
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/m ³
Uncertainty between Candidates	0.31			µg/m ³
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			%

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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
Status of measured values	Slope corrected		Limit value	µg/m ³
			Allowed uncertainty	%
Cologne, Summer				
Uncertainty between Reference	0.66	µg/m ³		
Uncertainty between Candidates	0.11	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.52	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.66	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.47	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.52	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.35	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.80	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.31	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.45	µg/m ³		
	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	%

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Table 59: Summary of the results of the equivalence test, SN 0111 & SN 0112, measured component PM₁₀ 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	
Status of measured values	Slope & offset corrected	Limit value	50	µg/m ³
		Allowed uncertainty	25	%
All comparisons				
Uncertainty between Reference	0.58			µg/m ³
Uncertainty between Candidates	0.65			µg/m ³
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/m ³
Uncertainty between Candidates	1.15			µg/m ³
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/m ³
Uncertainty between Candidates	0.55			µg/m ³
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			%

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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
Status of measured values	Slope & offset corrected		Limit value	µg/m ³
			Allowed uncertainty	%
Cologne, Summer				
Uncertainty between Reference	0.80	µg/m ³		
Uncertainty between Candidates	0.26	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.64	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.87	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.84	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.73	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.54	µg/m ³		
	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/m ³		
Uncertainty between Candidates	1.15	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.55	µg/m ³		
	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/m ³		
Uncertainty between Candidates	0.65	µg/m ³		
	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).

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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 PM₁₀ 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 $\mu\text{g}/\text{m}^3$ per temperature level in relation to the default temperature of 20 °C is considered.

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

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 $5.5 \times 10^{-5} \mu\text{g}/\text{m}^3$ for PM_{2.5} and $5.7 \times 10^{-5} \mu\text{g}/\text{m}^3$ for PM₁₀

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} respectively > -2.2 % for PM₁₀ 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.

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Detailed presentation of test results:

Table 60: Dependence of zero point on ambient temperature, deviations in µg/m³, mean value of three measurements, PM₁₀, SN 5048 & SN 5049

Ambient temperature		Deviation	
Start temperature	End temperature	SN 5048	SN 5049
°C	°C	µg/m ³	µg/m ³
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/m ³	µg/m ³
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, PM₁₀, 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

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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)

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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.

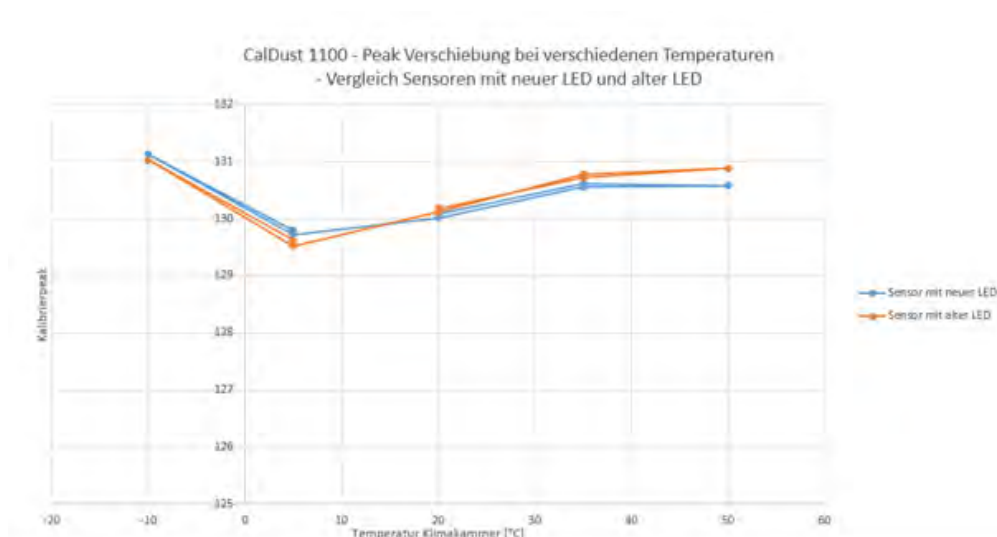


Figure 130: Comparison of temperature behaviour between -10°C and +50°C, LED, old vs. LED, new

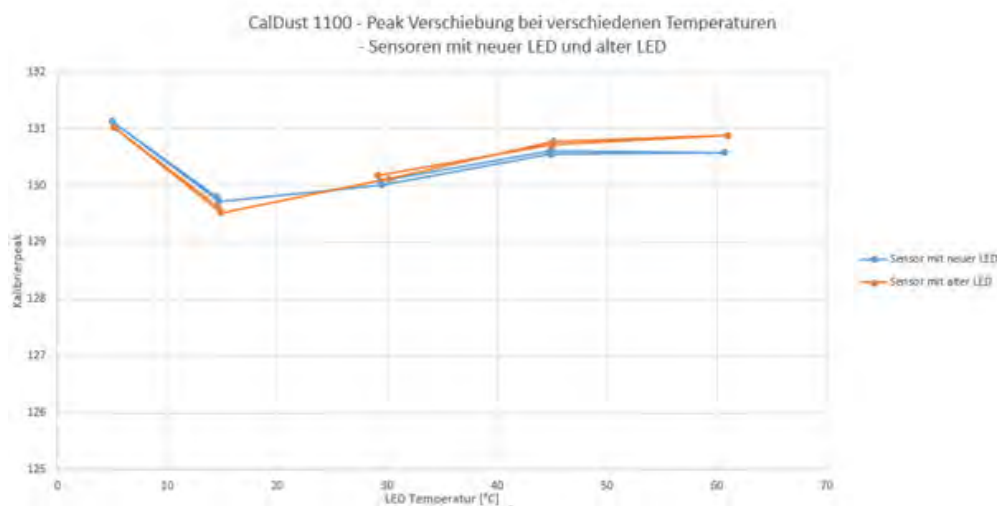


Figure 131: Comparison of temperature behaviour between -+5°C and +60°C, LED, old vs. LED, new

It is demonstrated, that there is no significant difference in the temperature behavior between the old LED and the new LED.

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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 PM₁₀ have been offered to the instruments. Based on the comparison measurements, the slope (mean value of PM_{2.5} and PM₁₀) 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

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- g) Various modifications, which are only relevant for the measuring systems UF-CPC and Fidas mobile, but not for Fidas 200.
- h) Additional 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 increase of safe operation.

The current firmware version (Panel) is now 100380.

The modifications of the firmware (SLA) comprise additional modes for signal acquisition 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

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Firmware Ver. 100380.0014.0001.0001.0011

Fidas 200 0101
MMS-SLA 14, 22-09-2014 12:37:18

operation modus:

auto manual scope idle shut down

particle size measurement:

particle size distributions
statistics
time chart

settings:

sensor/calibration
performance
datalogger
interfaces
system

accessories:

suction pump/signals/digital IO

menu 0 S scope started 89 % signals coinc 00:00:00.000 DD.MM.YYYY

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).

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 PM_{2.5}, Report no.: 936/21227195/A

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, 09th March 2015
936/21227195/A

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; PM_{2.5})"; 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 PM₁₀ and PM_{2.5}

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 PM_{2,5}, Report no.: 936/21227195/A

5.1 Fidas® 200 S für Schwebstaub PM₁₀ und PM_{2,5}

Hersteller:

PALAS GmbH, Karlsruhe

Eignung:

Zur kontinuierlichen parallelen Immissionsmessung der PM₁₀- und der PM_{2,5}-Fraktion im Schwebstaub im stationären Einsatz

Messbereiche in der Eignungsprüfung:

Komponente	Zertifizierungsbereich	Einheit
PM ₁₀	0 – 10 000	µg/m ³
PM _{2,5}	0 – 10 000	µg/m ³

Softwareversionen: Messsystem: 100327

Implementierter Auswertalgorithmus: 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 PM₁₀ und PM_{2,5} eingehalten.
2. Die Anforderungen an den Variationskoeffizienten R² 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 PM₁₀-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 PM₁₀ 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 PM₁₀ 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 überarbeitet.

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

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, Report no.: 936/21227195/A

Annex 1

Detection limit

Manufacturer Palas					Standards ZP Zero filter
Type FIDAS 200					
Serial-No. SN 0111 / SN 0112					
No.	Date	Measured values [µg/m ³] SN 0111	Date	Measured values [µg/m ³] SN 0112	$s_{x_0} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \bar{x}_0)^2}$
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		
Mean		0.0001924	Mean		
Standard deviation s _{x0}		0.0004064	Standard deviation s _{x0}		
Detection limit x		8.7E-04	Detection limit x		

Annex 1

Detection limit

Manufacturer Palas					Standards ZP Zero filter
Type FIDAS 200					
Serial-No. SN 0111 / SN 0112					
No.	Date	Measured values [µg/m³] SN 0111	Date	Measured values [µg/m³] SN 0112	$s_{x_0} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \bar{x}_0)^2}$
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		
Mean		0.0001638	Mean		
Standard deviation s_{x_0}		0.0004036	Standard deviation s_{x_0}		
Detection limit x		8.7E-04	Detection limit x		

Annex 2

Dependence of zero point on ambient temperature (PM10)

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/m ³]	Dev. [µg/m ³]	Measured value [µg/m ³]	Dev. [µg/m ³]	Measured value [µg/m ³]	Dev. [µg/m ³]		
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/m ³]	Dev. [µg/m ³]	Measured value [µg/m ³]	Dev. [µg/m ³]	Measured value [µg/m ³]	Dev. [µg/m ³]		
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				Standards		ZP		Zero filter	
Type FIDAS 200									
Serial-No. SN 0111 / SN 0112									
		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	0.000000	-	0.000000	-	0.000000	-	
	2	-20	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	
	3	20	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	
	4	50	0.000005	0.000005	0.000014	0.000014	0.000014	0.000014	
	5	20	0.000000	0.000000	0.000008	0.000008	0.000000	0.000000	
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	0.000003	-	0.000000	-	0.0000332	-	
	2	-20	0.000000	-0.000003	0.000017	0.000017	0.000000	-0.0000332	
	3	20	0.000000	-0.000003	0.000001	0.000001	0.000040	-0.0000292	
	4	50	0.000000	-0.000003	0.000000	0.000000	0.000000	-0.0000332	
	5	20	0.000006	0.000003	0.000000	0.000000	0.000000	-0.0000332	

Annex 3

Dependence of measured value on ambient temperature (PM10)

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. [%]				
RP	1	20	40.0	-	40.0	-	40.0	-				
	2	-20	38.2	-4.4	38.2	-4.4	38.2	-4.4				
	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. [%]				
RP	1	20	40.0	-	40.0	-	40.0	-				
	2	-20	41.8	4.6	41.8	4.6	41.8	4.6				
	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)

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. [%]	
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	

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Annex 4

Dependence of measured value on mains voltage (PM10)

Manufacturer PALAS				Standards		CalDust 1100			
Type FIDAS 200									
Serial-No. SN 0111 / SN 0112									
		Cycle 1		Cycle 2		Cycle 3			
SN 0111	No.	Mains voltage [V]	Measured value	Dev. [%]	Measured value	Dev. [%]	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				Standards				CalDust 1100	
Type FIDAS 200									
Serial-No. SN 0111 / SN 0112									
				Cycle 1		Cycle 2		Cycle 3	
SN 0111	No.	Mains voltage [V]	Measured value	Dev. [%]	Measured value	Dev. [%]	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	

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, Report no.: 936/21227195/A

Annex 5

Measured values from field test sites, related to actual conditions

Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112												PM10 and PM2.5 Measured values in µg/m ³ (ACT)	
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/m ³]	Ref. 2 PM10 [µg/m ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM2,5 [µg/m ³]	SN 0112 PM2,5 [µg/m ³]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	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

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	Inlet -> Zero filter Zero filter Zero filter	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												
34	6/16/2012												
35	6/17/2012												
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			

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Annex 5

Measured values from field test sites, related to actual conditions

Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112												PM10 and PM2.5 Measured values in µg/m ³ (ACT)	
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/m ³]	Ref. 2 PM10 [µg/m ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	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			

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Measured values from field test sites, related to actual conditions

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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	Zero filter Zero filter Zero filter	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												
97	8/18/2012												
98	8/19/2012												
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 Zero filter	Cologne, winter	
114	11/20/2012												
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			

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, Report no.: 936/21227195/A

Annex 5

Measured values from field test sites, related to actual conditions

Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112												PM10 and PM2.5 Measured values in µg/m ³ (ACT)
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/m ³]	Ref. 2 PM10 [µg/m ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	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			
129	12/5/2012	8.7	8.5	12.1	12.5	69.8		9.6		12.1	SN 0112 Fuse for heater burned 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 SN 0112 Fuse for heater burned	
133	12/9/2012	5.5	5.8	10.1	8.9	59.5	7.2		9.8			
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		

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Measured values from field test sites, related to actual conditions

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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												
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	Power failure		
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			

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, Report no.: 936/21227195/A

Annex 5

Measured values from field test sites, related to actual conditions

Manufacturer		PALAS									PM10 and PM2.5		
Type of instrument		FIDAS 200 S									Measured values in µg/m ³ (ACT)		
Serial-No.		SN 0111 / SN 0112											
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/m ³]	Ref. 2 PM10 [µg/m ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	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			Bonn, winter
192	2/6/2013									Zero filter			
193	2/27/2013									Zero filter			
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

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		

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, Report no.: 936/21227195/A

Annex 5

Measured values from field test sites, related to actual conditions

Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112											PM10 and PM2.5 Measured values in µg/m ³ (ACT)	
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/m ³]	Ref. 2 PM10 [µg/m ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	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	Zero filter Zero filter Zero filter	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											
252	4/27/2013											
253	4/28/2013											
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 Zero filter	Bornheim, summer
262	5/15/2013											
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		
269	5/22/2013						6.9	6.9	11.1	10.8		
270	5/23/2013						5.5	5.5	7.4	7.2		
										Power failure Ref. PM2,5 Device#1		

Annex 5

Measured values from field test sites, related to actual conditions

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		

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Annex 5

Measured values from field test sites, related to actual conditions

Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112												PM10 and PM2.5 Measured values in µg/m ³ (ACT)	
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/m ³]	Ref. 2 PM10 [µg/m ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	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

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

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Manufacturer		PALAS							PM10		Remark	Test site
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]				
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				

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Annex 5

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112										
PM10 Measured values in µg/m ³ (STD)										
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/Nm ³]	Ref. 2 PM10 [µg/Nm ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm ³]	SN 0112 PM10 [µg/Nm ³]	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	-	-			-				
34	6/16/2012	-	-			-				
35	6/17/2012	-	-			-				
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

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

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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			

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Annex 5

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112										
										PM10 Measured values in µg/m ³ (STD)
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/Nm ³]	Ref. 2 PM10 [µg/Nm ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm ³]	SN 0112 PM10 [µg/Nm ³]	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

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

Manufacturer		PALAS								PM10	
Type of instrument		FIDAS 200 S								Measured values in µg/m ³ (STD)	
Serial-No.		SN 0111 / SN 0112									
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/Nm ³]	Ref. 2 PM10 [µg/Nm ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm ³]	SN 0112 PM10 [µg/Nm ³]	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			

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PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

Manufacturer		PALAS								PM10	
Type of instrument		FIDAS 200 S								Measured values in µg/m ³ (STD)	
Serial-No.		SN 0111 / SN 0112									
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/Nm ³]	Ref. 2 PM10 [µg/Nm ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm ³]	SN 0112 PM10 [µg/Nm ³]	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

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

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Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112										PM10 Measured values in µg/m ³ (STD)
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/Nm ³]	Ref. 2 PM10 [µg/Nm ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm ³]	SN 0112 PM10 [µg/Nm ³]	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	
194	2/28/2013	-	-	-	-	-	-	-	Zero filter	
195	3/1/2013	-	-	36.6	37.1	-	38.9	38.5		Bonn, winter
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		

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PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

Manufacturer PALAS Type of instrument FIDAS 200 S Serial-No. SN 0111 / SN 0112										PM10 Measured values in µg/m ³ (STD)
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/Nm ³]	Ref. 2 PM10 [µg/Nm ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm ³]	SN 0112 PM10 [µg/Nm ³]	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

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

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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	
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		
269	5/22/2013	-	-	-	-	-	11.5	11.3		
270	5/23/2013	-	-	-	-	-	7.6	7.5	Power failure Ref. PM2,5 Device#1	

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Annex 5

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

Manufacturer		PALAS								PM10	
Type of instrument		FIDAS 200 S								Measured values in µg/m ³ (STD)	
Serial-No.		SN 0111 / SN 0112									
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/Nm ³]	Ref. 2 PM10 [µg/Nm ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/Nm ³]	SN 0112 PM10 [µg/Nm ³]	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

PM₁₀-measured values from field test sites, related to standard conditions [EN 12431]

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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	
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			

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Annex 6

Ambient conditions from field test sites

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

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

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Annex 6

Ambient conditions from field test sites

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

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		

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Annex 6

Ambient conditions from field test sites

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

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

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Ambient conditions from field test sites

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

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

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Ambient conditions from field test sites

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		No weather data available						
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

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

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Ambient conditions from field test sites

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

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	
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												

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, Report no.: 936/21227195/A

Annex 7

Measured values from UK field test sites, related to actual conditions

Manufacturer		PALAS									PM10 and PM2.5		
Type of instrument		FIDAS 200 S									Measured values in µg/m ³ (ACT)		
Serial-No.		SN 0111 / SN 0112											
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/m ³]	Ref. 2 PM10 [µg/m ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	Remark	Test site	
31	29.03.2014											Outlier Ref. PM10	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			
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

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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	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	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			

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Annex 7

Measured values from UK field test sites, related to actual conditions

Manufacturer		PALAS									PM10 and PM2.5	
Type of instrument		FIDAS 200 S									Measured values in µg/m ³ (ACT)	
Serial-No.		SN 0111 / SN 0112										
No.	Date	Ref. 1 PM2,5 [µg/m ³]	Ref. 2 PM2,5 [µg/m ³]	Ref. 1 PM10 [µg/m ³]	Ref. 2 PM10 [µg/m ³]	Ratio PM2,5/PM10 [%]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	SN 0111 PM10 [µg/m ³]	SN 0112 PM10 [µg/m ³]	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

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								

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Ambient conditions from field test sites, UK

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

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Ambient conditions from field test sites, UK

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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

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, Report no.: 936/21227195/A

Annex 8

Ambient conditions from field test sites, UK

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:

$$\text{Dust} = \text{MF}_{\text{post}} - (M_{\text{Tara}} \times (\text{MKon}_{\text{post}} / \text{MKon}_{\text{pre}})) \quad (\text{F1})$$

MKon_{pre} = mean mass of the 3 control filters after 48 h and 72 h pre-weighing

$\text{MKon}_{\text{post}}$ = 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.

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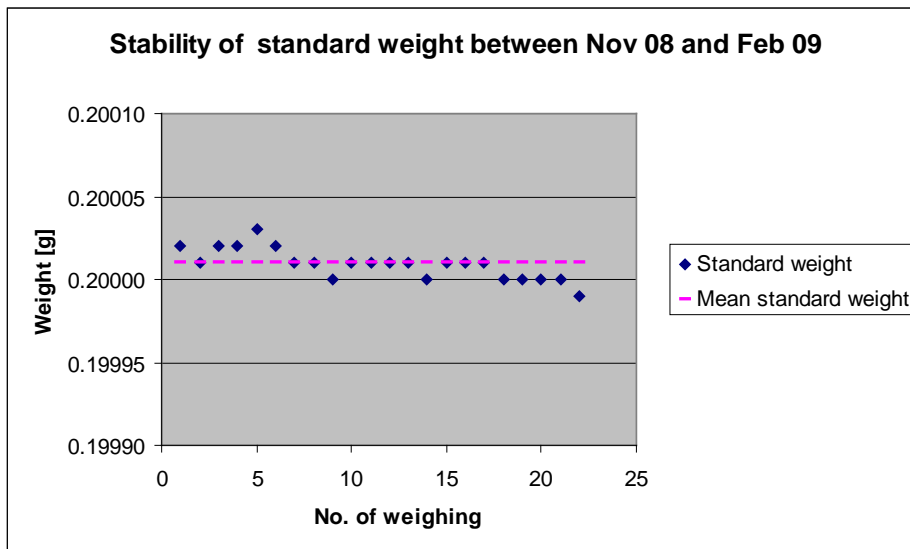


Figure 134: Stability of standard weight

Table 64: Stability of standard weight

Date	Weighing No.	Standard weight g	Difference to the previous weighing 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

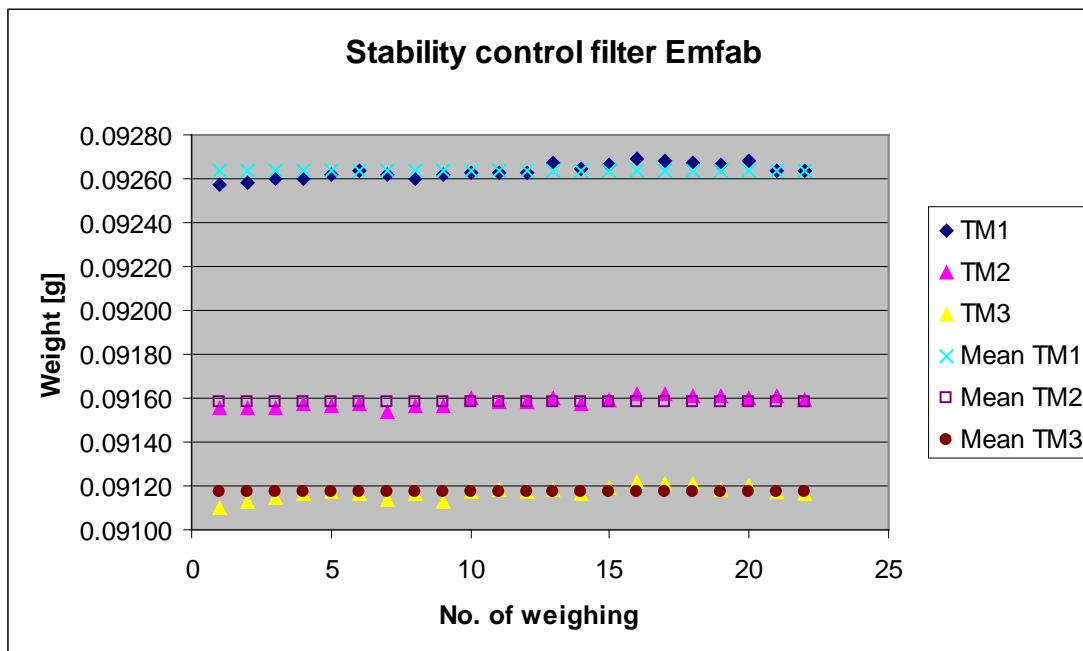


Figure 135: Stability of the control filters

Table 65: Stability of the control filters

Weighing no.	Control filter 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

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 PM_{2,5}, Report no.: 936/21227195/A

Appendix 3

Manuals

Operating Manual

Fine Dust Monitor System

Fidas®

Fidas® 100
Fidas® 200/200 S/200 E



Model 100/200



Model 200 S

PALASCOUNTS

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IMPORTANT NOTES !!!

- Please check immediately after unpacking the instrument if there are obvious transportation damages. If any damages of the instrument are visible, don't connect it to mains and don't switch it on. Call the manufacturer to check if the instrument can be operated safely.
- It is essential to read the operating instructions thoroughly before operating Fidas®!!
- The manufacturer is not liable for damages caused by improper operating, incorrect cleaning or the measurement of aerosols with a gas condition or composition the instrument is not specified for.
- The instrument may only be operated in dry rooms under atmospheric environmental pressure at temperatures between -20°C and +50°C (Fidas® 200 S) respectively +5°C and +40°C (Fidas® 200 and Fidas® 200 E).
The manufacturer will not be liable with regard to the operating guarantee, if operating takes place under different environmental conditions, such as corrosive or explosive environment, electric or electromagnetic fields, operating within areas of ionising radiation, within areas conducive to shock or vibration.
- **To switch-off Fidas®, use the "shut down" button before switching off the mains button in the back of the instrument. It is not advised to switch off the mains switch, before the operating system has powered down as file corruption could occur in this case!**
- Fidas® was manufactured for the system voltage defined in the correspondent order. Please check if the system voltage indicated on the identification plate corresponds to the system voltage at the place of operation.
- Only use original spare parts! Please contact the manufacturer to order spare parts.
- The measurement procedure of the Fidas® system is not gravimetric, it is an equivalent method. Therefore an exact matching to gravimetry cannot be guaranteed in all cases.
- The measurement system has to be regularly calibrated onsite with the gravimetric PM₁₀ reference procedure according to DIN EN 12341.
- The measurement system has to be regularly calibrated onsite with the gravimetric PM_{2.5} reference procedure according to DIN EN 14907.
- **Attention:** Aerosols might be dangerous to your health. Depending on the local situation it might be necessary to wear protection (e.g. dust mask). Please pay attention to the correspondent standards and safety rules.

- General information on optical particle counters, such as resolution capacity, detection limit and counting efficiency, can be found in the VDI-guideline 3489, Part 3.
- **The Fidas® 200 S is shipped as it participated in the TÜV equivalency test. This also applies for the instrument versions Fidas® 200 and Fidas® 200 E. If any correction should be applied see section 3.3.**

1 Installation and first operation

1.1 Mains voltage check

The Fidas® was set by the manufacturer to the mains voltage requested in the order. Please verify, if the mains voltage indicated on the type label corresponds to the mains voltage at the respective place of the installation.

The manufacturer is not liable for damages resulting from operation with improper mains voltage!!!

1.2 Check of the completeness of delivery

For the transport by a forwarding company, the Fidas® system was decomposed in its components. Before the first operation, the system has to be recomposed. The following parts should be available:

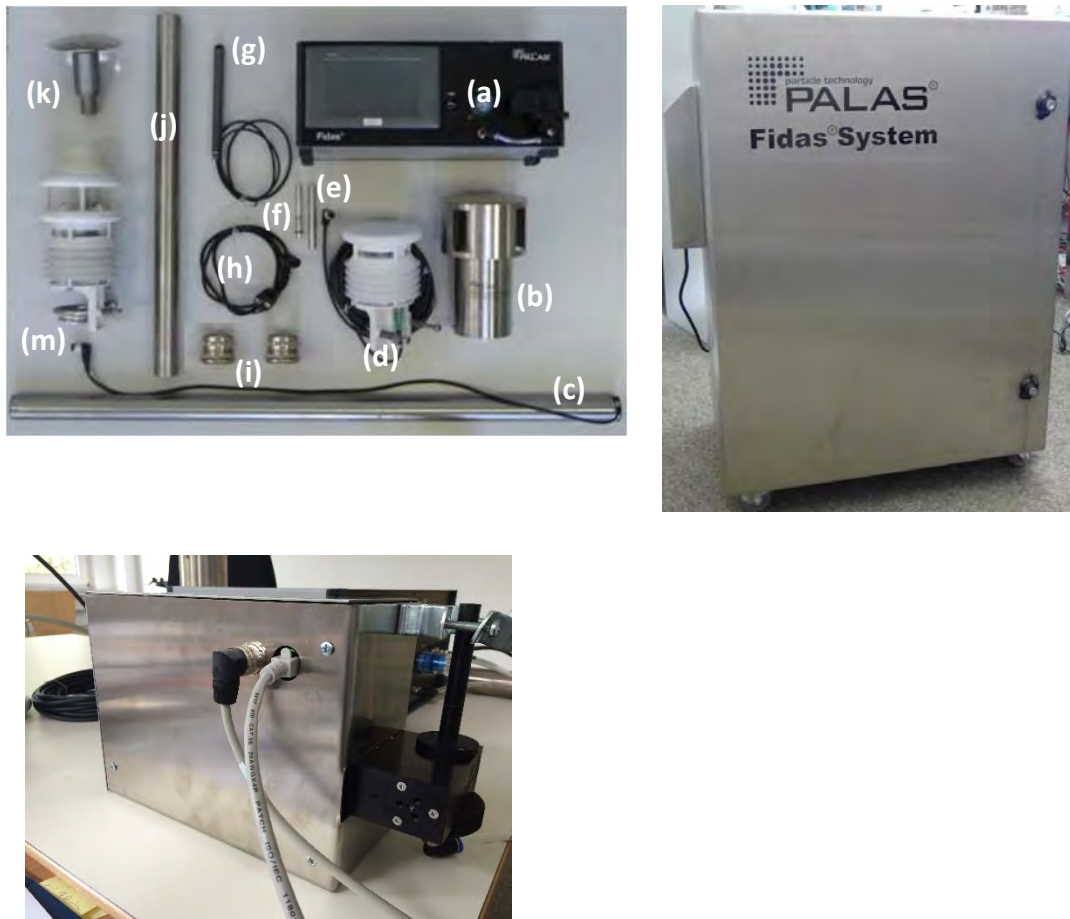


Fig. 1 A+B+C: on the top left components of a Fidas® system, on the top right IP-65 weather protective housing, on the bottom left external aerosol sensor unit for Fidas® 200 E

For all versions, the following components and documentation should be available (the letters in parenthesis refer to the indications in figure 1):

- Fidas® control unit (a)
- Aerosol inlet tube (f)
- Power cable (h)
- Plastic cube approx. 30 cm for calibration and verification
- 1 bottle MonoDust 1500 for calibration and verification
- Cleaning kit with optical wipes
- Manual Fidas® Fine Dust Monitor System (printed)
- Description Fidas® Firmware (printed)
- Manual PDAnalyze (printed)
- Manual weather station WS300-UMB resp. WS600-UMB
- Calibration certificate (printed)
- CD or USB flash drive with evaluation software PDAnalyze
- Serial cable (null-modem)
- Pointer for touch screen

Depending on the model, the following components are additionally included in the delivery:

Only Fidas® 100:

- Sensor for temperature, relative humidity and pressure

Only Fidas® 200:

- Weather station WS300-UMB (d) – optional instead also WS600-UMB (m)
- Sampling tube with IADS (c)
- Connection sampling head to sampling tube (e)
- Sampling head Sigma-2 (b) – optional additional also PM-10 or PM-2.5 sampling head (not certified) (k)

Only Fidas® 200 E:

- Weather station WS300-UMB (d) – optional instead also WS600-UMB (m)
- Sampling tube with IADS (c)
- Connection sampling head to sampling tube (e)
- Sampling head Sigma-2 (b) – optional additional also PM-10 or PM-2.5 sampling head (not certified) (k)
- External aerosol sensor unit with connecting lines

Only Fidas® 200 S:

- Weather station WS300-UMB (d) – optional instead also WS600-UMB (m)
- Sampling tube with IADS (c)
- Connection sampling head to sampling tube (e)
- Sampling head Sigma-2 (b) – optional additional also PM-10 or PM-2.5 sampling head (not certified) (k)
- 2x fixing of the sampling tube and the weather station tube at the housing (i)
- Tube for weather station (j)
- Antenna – optional and can look differently (g)
- IP-65 weather-protective housing

1.3 Equipment overview

1.3.1 Front panel of the Fidas® control unit

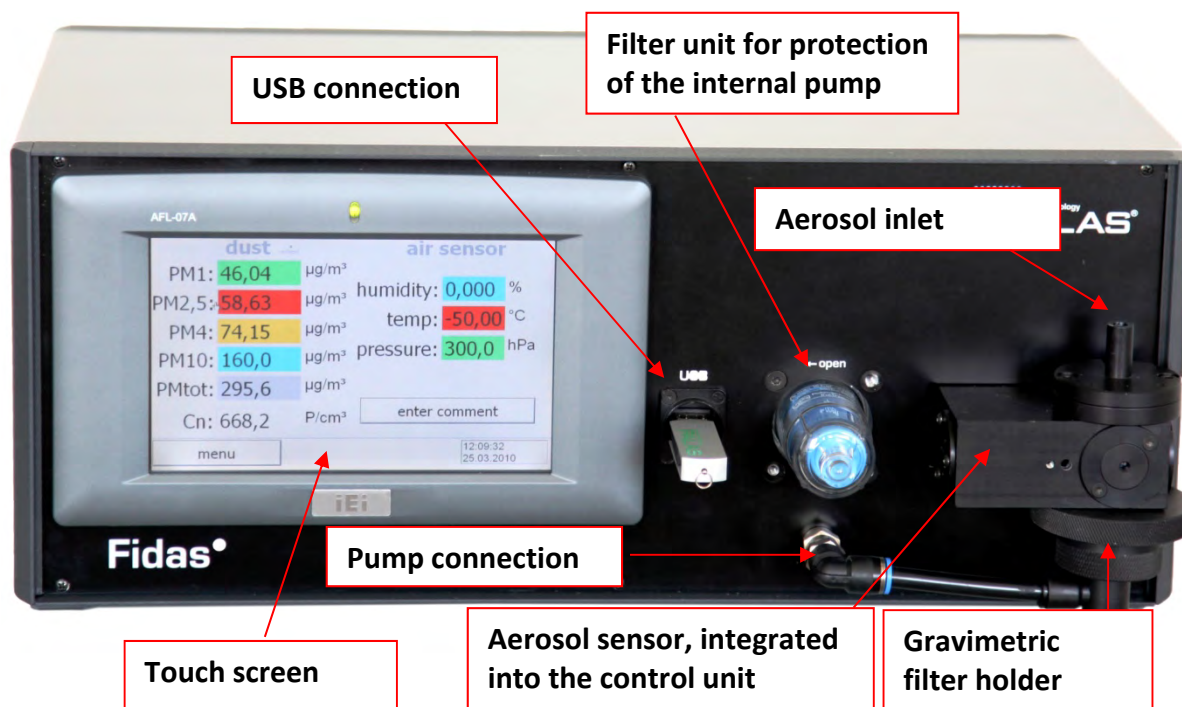


Fig. 2: Front panel of the Fidas® control unit

The Fidas® system is operated via the touch screen (please see separate manual Fidas® Firmware for detailed information on the user interface).

The data can be readout via the USB connection and processed further on an external PC with the additional PDAnalyze software (included in the delivery) or transmitted via RS-232 or the Ethernet port and one of the possible communication protocols.

Note: Different as shown on figure 2 all Fidas® units are shipped with “ears” to facilitate an easier 19” rack installation from 1. January 2014.

1.3.2 Back side of the Fidas® control unit

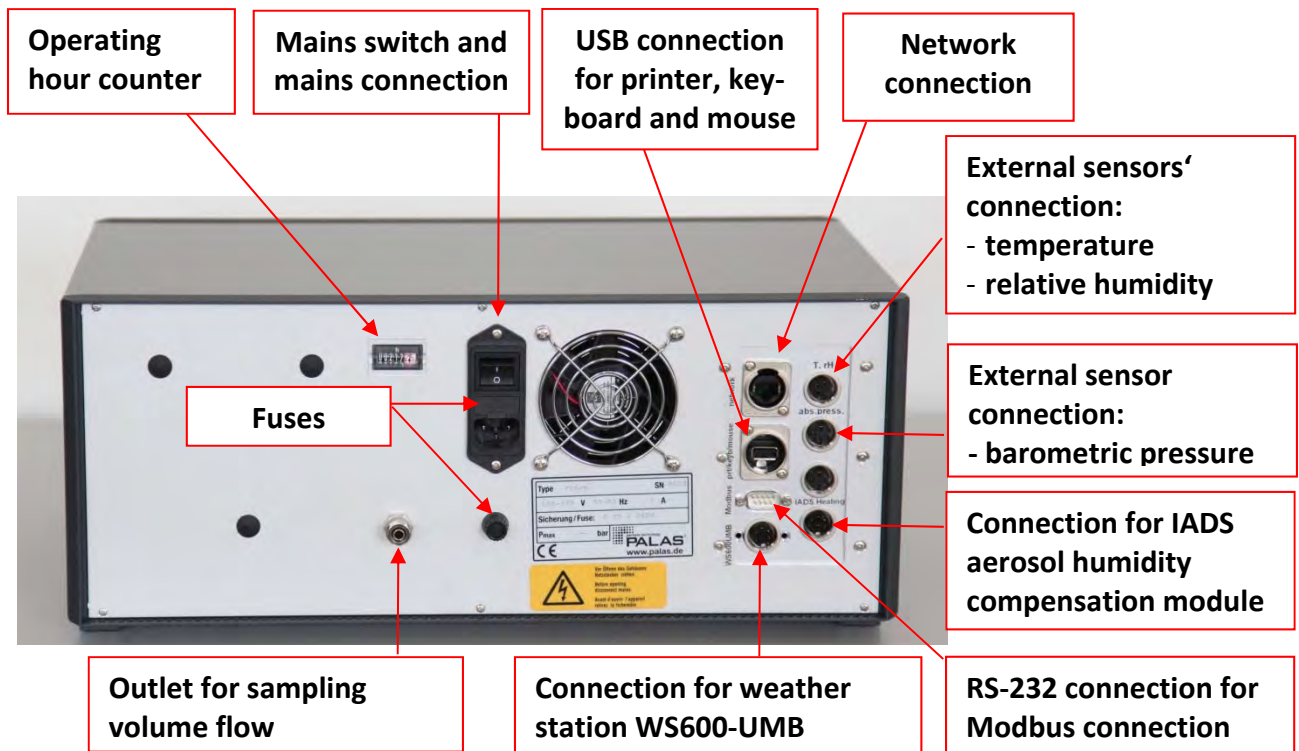


Fig. 3: Back side of the Fidas® control unit

The control unit is switched on and off with the mains switch. There are two fuses, T 2 A / 250 V, at the back side.

The LED is switched on by the mains switch. The operating hour counter runs as long as the device is switched on. The LED has a life time expectancy of > 20,000 operating hours if operated at full power. In the Fidas® the LED is run at 20% power and with controlled lower temperature which increases the expected lifetime considerably.

1.3.3 Connections on the back side of the Fidas® control unit

On the right, there are the following connection possibilities:

- **Network**, to connect the Fidas® System to a network, e.g. for online remote service and for transfer of software updates.
- **USB connection**, e.g. for a printer, keyboard, mouse or USB stick.
- Modbus via **RS 232** connection for remote enquiry of the measured values and external control of the measurement device (WebAccess).
- **Connection for weather station WS600-UMB / WS300-UMB** (Fidas® 200 S systems) for recording of:
 - wind speed (only WS600-UMB)
 - wind direction (only WS600-UMB)
 - precipitation quantity (only WS600-UMB)
 - type of precipitation (only WS600-UMB)
 - temperature
 - humidity
 - pressure
- **Connection for external sensors** for recording the temperature and relative humidity
- **Connection for external sensor** for recording the barometric pressure
- **Connection for aerosol humidity compensation module IADS** (Intelligent Aerosol Drying System)

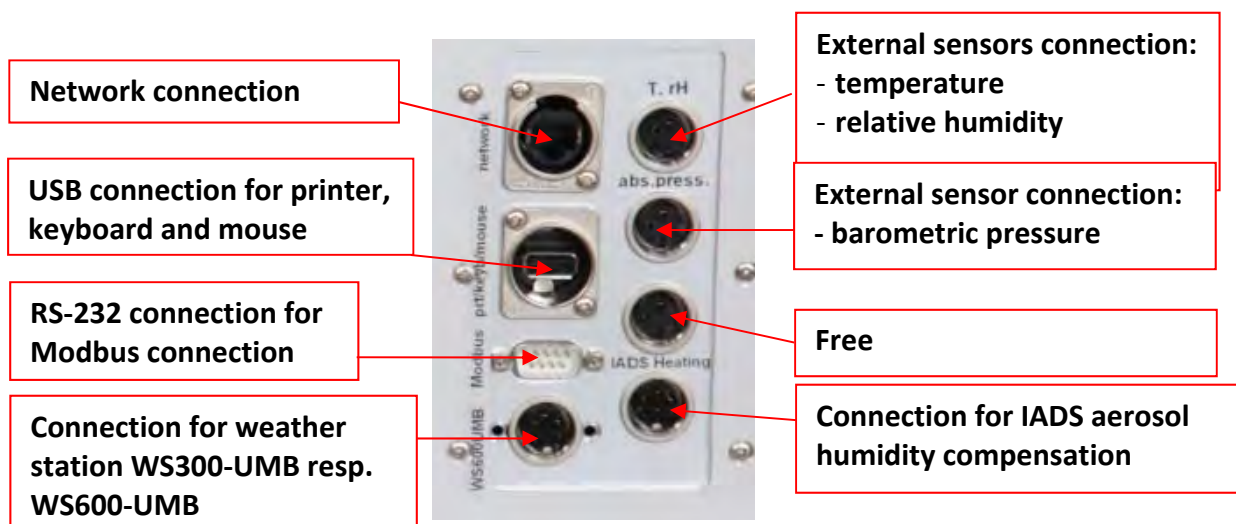


Fig. 4: Connection possibilities on the back side of the Fidas® control unit

1.3.4 Fidas® 200 E – Connection of the external aerosol sensor unit

For the Fidas® 200 E, the complete aerosol sensor unit is separated from the control unit and is located in a separate housing, which easily allows for a flexible installation in a measuring cabinet / station. The connection between control unit and sensor unit is carried out with 3 connecting lines:

- Connecting line for data transmission (LAN cable)
- Connecting line for power supply / LED temperature measurement
- Hose connection for sample flow

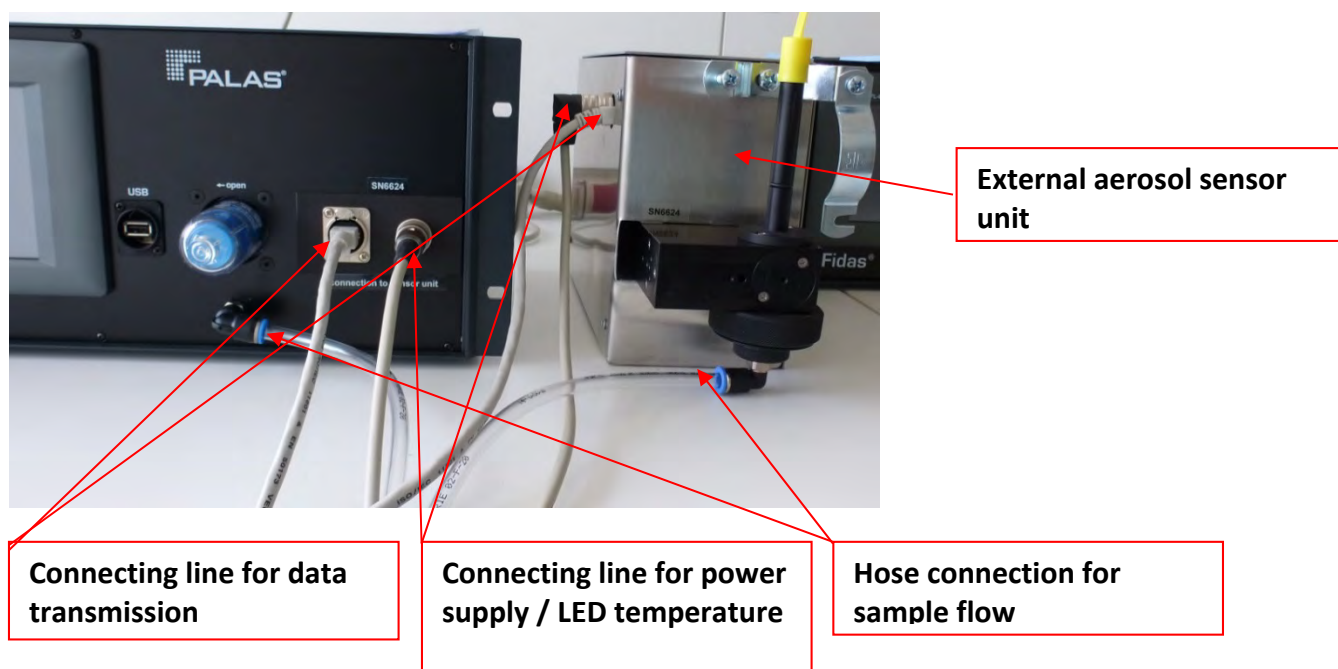


Fig. 5: Connection of the external aerosol sensor unit

The standard length for the connecting lines is 3 m (other lengths available on request).

Further installation / connections of the measuring instrument is carried out as for Fidas® 200 respectively Fidas® 200 S.

The measuring instrument Fidas® 200 E can be dismantled to the Fidas® 200, this means the external sensor can be re-installed into the control unit.

1.4 First measurement

Switch on the instrument with the I/O switch on the back side of the Fidas® control unit. By switching on the instrument, the measurement procedure automatically starts. Even all measured data are automatically saved in the internal memory. After starting the device, the main menu appears (see figure 6).

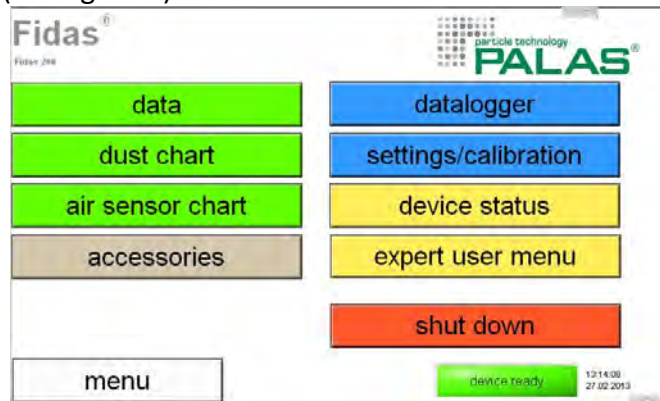


Fig 6: Start screen

The user can now change from one display option to another by using the touch display. Figure 7 shows for example an overview of the dust values:

- PM 1
- PM 2.5
- PM 4
- PM 10
- PM total (total mass concentration)
- Cn: Particle concentration in P/cm^3

Air sensors: (data from the weather station)

- Relative humidity
- Ambient temperature
- Barometric pressure

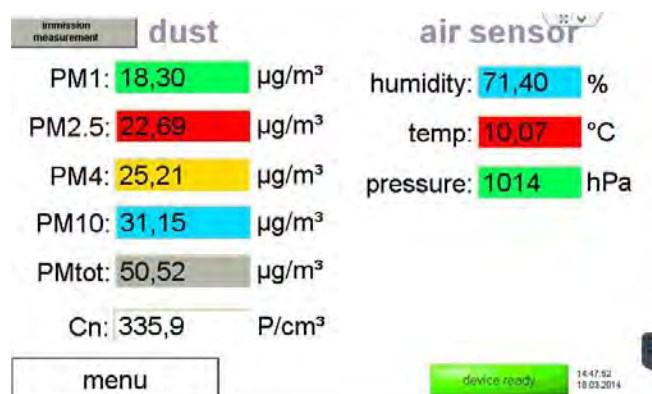


Fig. 7: Data overview, e.g. PM values

Please see separate manual Fidas® Firmware for detailed information on the user menus.

Note: A value of “NaN” (not a number) is shown shortly after startup before the first measurement data appear or while calibration/maintenance activities are performed.

2 Fidas® 200 / 200 S / 200 E – Installation instructions

2.1 Mounting of the weather station at the IP65- weather protective housing (Fidas® 200 S)

The shorter stainless steel tube is the mounting of the weather station. You need the following components:

- Short stainless steel tube
- Fixing of the tube at the housing
- Weather station WS300-UMB – or optional instead WS600-UMB

You need the following tools:

- 13 mm open-end wrench
- 40 mm open-end wrench or adjustable tongs

Figure 8 shows the components of the fixing. Please take care that the sealing rings are also used and that they are in an undamaged condition. These rings serve as sealing in order to avoid that water enters the housing. If water enters from outside the housing, it is possible that the control unit is damaged or even that the Fidas® breaks down.

Palas® assumes no liability for damages arising from a leak in the fixing.



Fig. 8: Components of the fixing of the weather station tube

Please make sure that all components are available. Then, combine the first 5 components (from left to right in figure 8) and move them over the tube (there is a cover on the top and under it there is the passage for the cable to the weather station. Then proceed with this part of the fixing and the lower part of the tube from the outside through the left rear opening of the weather-protective housing.

Then attach from inside first the sealing ring (shown in Figure 8, far right) and then the thin nut (second from right in figure 8). Then screw tightly both the inner and outer nut with a wrench or adjustable tongs.



Fig. 9: Fixing of the weather station tube

Figure 9 shows how the fixing of the weather station tube should look like.

Before mounting the weather station at the tube, please verify that the tube has a cover on the top. Then slide the weather station on the tube (figure 10) and tighten the nuts slightly (the weather station must rotate easily!).



Fig. 10: Mounting of the weather station (here: WS600-UMB) at the tube

Set up the weather station to the north of.

Then tighten the two nuts on alternate so tight that the weather station can no longer move.

Attention: if you tighten the nuts too tight, the mounting of the weather station can split!

Then, connect the cable with the weather station (hand-tight!) as shown in figure 11.



Fig. 11: Connection of the cable with the weather station

2.2 Mounting of the antenna at the IP65- weather protective housing (Fidas® 200 S)

The antenna consists of a plastic part that has to be mounted at the outside of the housing, a sealing ring, a serrated washer, a nut and a cable as shown in figure 12.



Fig. 12: The antenna (can be different to the example shown)

Direct the cable from the outside through the small hole on the top of the housing. Then attach the antenna from the inside by means of the serrated washer and the nut. Make also sure that the sealing ring seals the opening, but do not tighten the nut too tight as the plastic may crack then.

2.3 Mounting of the sampling tube at the IP65- weather protective housing (Fidas® 200 S)

For the mounting of the sampling tube at the weather-protective housing, the same fixing is used than for the mounting of the weather station tube. Figure 8 shows the components. The sampling tube includes the heating for the IADS (intelligent aerosol drying system), therefore a cable is connected.

First, direct the bottom end with the cable from the outside through the hole on the right front (see figure 13). Then place the first sampling tube on the base of the control unit (not on the control unit itself).



Fig. 13: Insert the sampling tube

Then slide the outer parts of the fixing on the sampling tube.

Figure 14 shows how the rubber gasket is directed from the top in the gray sleeve. What remains are still the big outer nut which is mounted only at the very end, and the sealing ring and the nut, which are inserted from the inside.

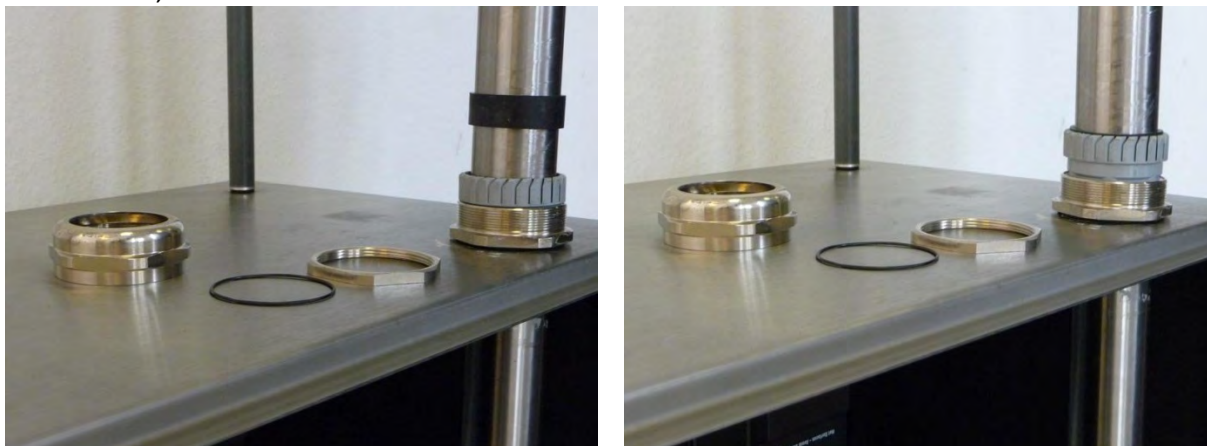


Fig. 14 A+B: Outer fixing of the sampling tube

Then attach first the remaining thin ring via the cable from the inside and then the thin nut at the rest of the fixing. Tighten the nut.

However, please take care that sampling tube can still move for the later installation of the Fidas® control unit.

2.4 Installation of the Fidas® control unit (Fidas® 200 / 200 S / 200 E)

Only Fidas® 200 S: Insertion of Fidas® control unit into the IP-65 weather protective housing

Lift the Fidas® control unit carefully and insert it as shown in figure 15 into the weather-protective housing and place it on the platform.



Fig. 15: Insertion of the Fidas® control unit

Fidas® 200 / 200 S / 200 E:

Then connect the cables from the weather station and the IADS (sampling tube) with the appropriate and designated ports (places shown in figure 16 can vary depending on model). Also, connect the power cable (and possibly a network cable), but do not switch the Fidas® on!



Fig. 16: Connection of the weather station, IADS with the ports on the back side

Then place the control unit so that you are exactly under the sampling tube with the opening of the sampling inlet tube. You must have previously lifted the sampling tube.

Then direct carefully (!) the sampling tube through the sampling inlet guide tube as shown in Figure 17.

The sampling tube should be as vertical as possible, if necessary, please change the position of the control unit accordingly.



Fig. 17: Connection of the sampling tube with the sampling inlet tube and the control unit

Continue like this until the sampling tube rests on the sensor unit, i.e. there should be no gap. Figure 18 on the right shows the correct position.



Fig. 18 A+B: on the left wrong position of the sampling tube, on the right correct position

Only Fidas® 200 E:

Connect the Fidas® control unit via the connecting lines with the external aerosol sensor as described in chapter 1.3.4 .

Only Fidas® 200 S:

Then slide the large remaining nut of the fixation of the sampling tube over the rest and tighten it (figure 19). Make also sure that sealing ring seals the opening.

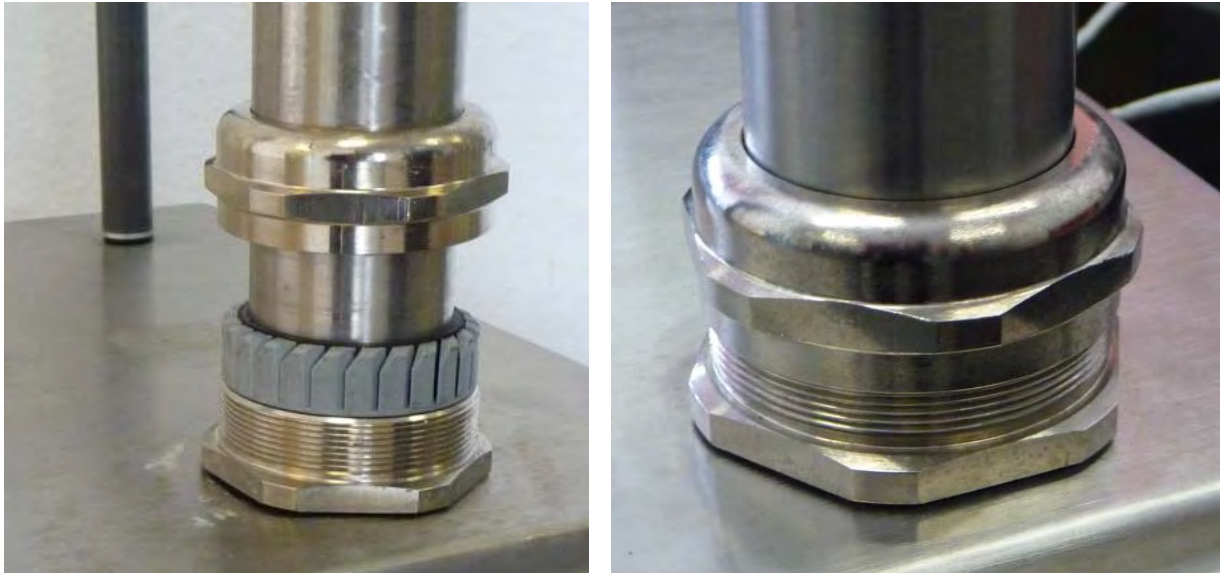


Fig. 19 A+B: Final fixing of the sampling tube

2.5 Mounting of the Sigma-2 sampling head (Fidas® 200 / 200 S / 200 E)

First, please place the connection piece sampling head to sampling tube as shown in figure 20:



Fig. 20 A+B: Placing of the connection piece

Then slide the sigma-2 sampling head on this connection piece (it should rest on the sampling tube) and then fix the sampling head with the size 2 Allen key (see figure 21).

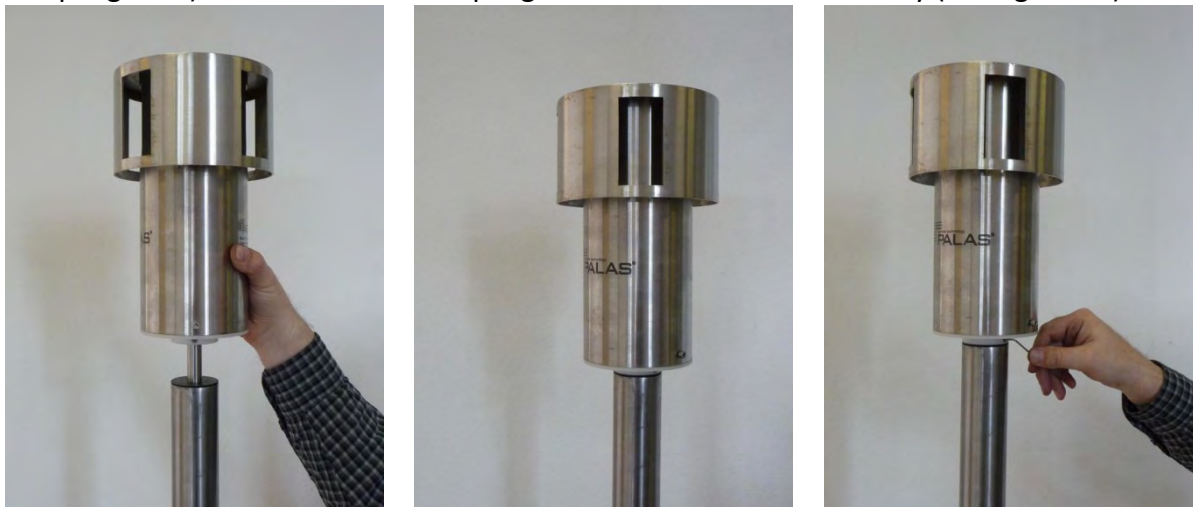


Fig. 21 A-C: Mounting of the Sigma-2 sampling head

If you use a PM-10 or PM-2.5 sampling head instead of the Sigma-2 sampling head, then you can proceed accordingly.

2.6 Final handholds (Fidas® 200 S)

Please connect the power cable on the spot with the corresponding port of the weather-protective housing. Then slide the cover over this port (figure 22).



Fig. 22 A+B: Power connection of the weather-protective housing

2.7 Switching on the measuring system (Fidas® 200 / 200 S / 200 E)

Please Then press the power button on the back of Fidas® control unit. After booting up the Windows operating system and the Fidas® start-up manager, you can see the screen with the various PM fractions, particle number concentration and the ambient conditions (temperature, relative humidity, atmospheric pressure). For the first values of the PM fractions you must wait about 4 minutes due to the averaging.

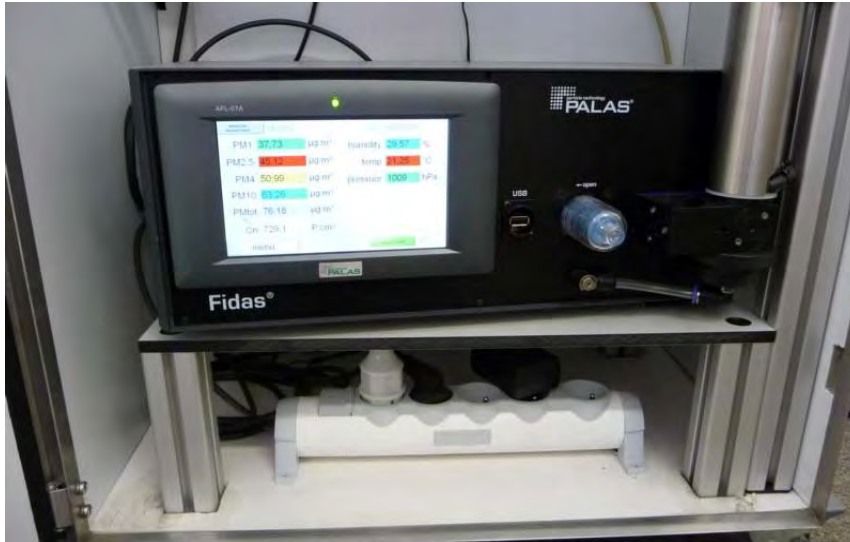


Fig. 23: Fidas® during operation

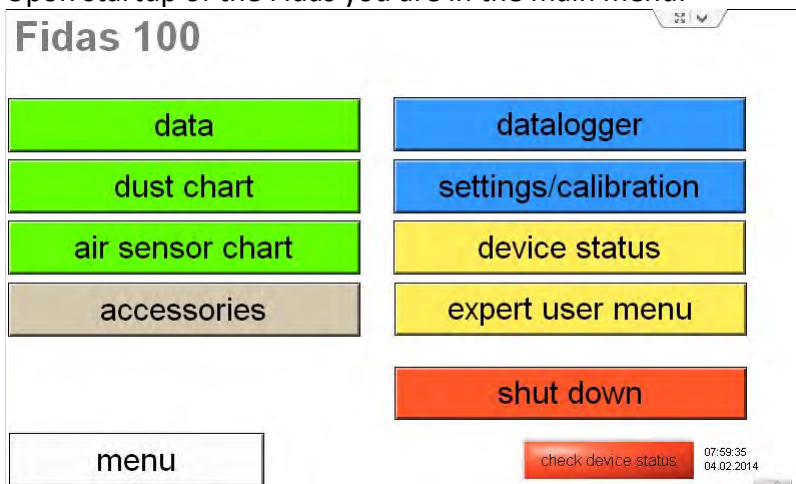
3 System annotations

3.1 Activation of coincidence correction

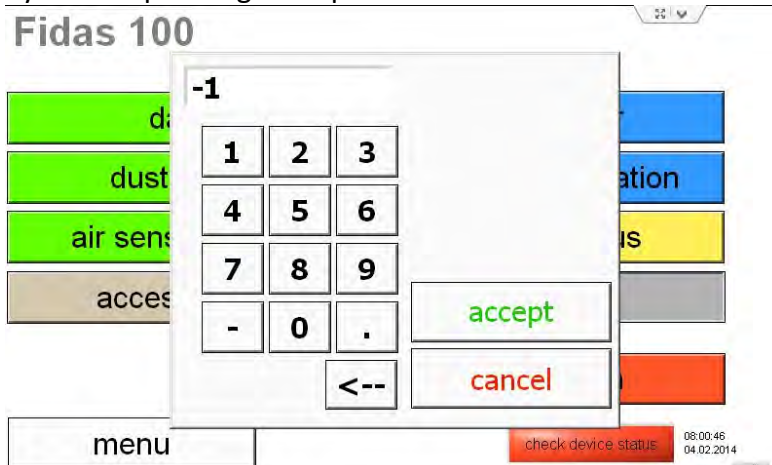
As a standard setting the coincidence correction is not turned on when the Fidas® is shipped. If the Fidas® is used at locations with significantly higher concentrations and if the Fidas® reports a coincidence value that is higher than 10 % it can be necessary to turn on the coincidence correction to extend the original concentration range of 0 to 10,000 µg/m³ significantly.

The following steps explain how to turn the coincidence correction on:

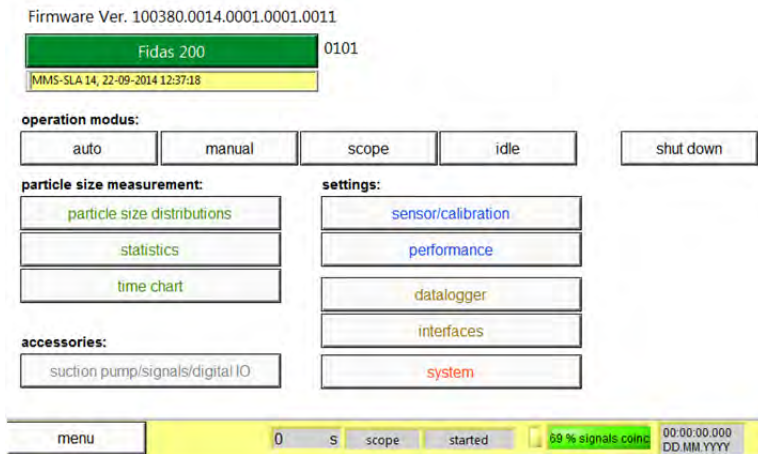
Upon startup of the Fidas you are in the main menu:



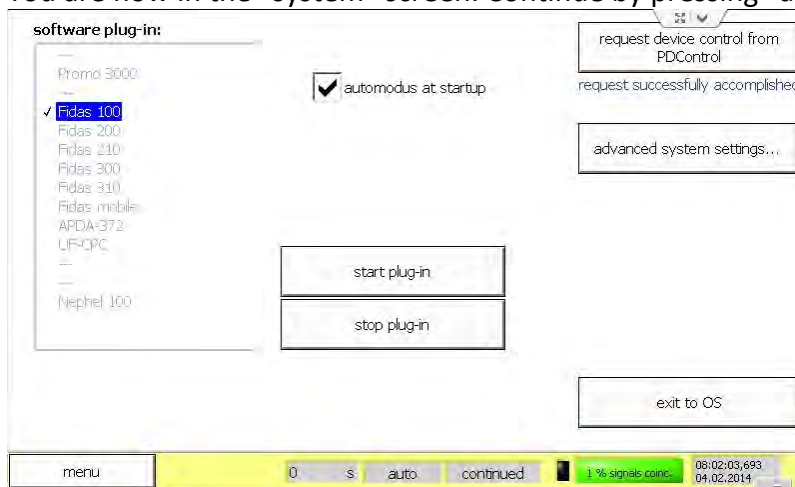
Switch to the expert user menu by pressing “expert user menu, then entering “1” followed by “-” and pressing “accept”:



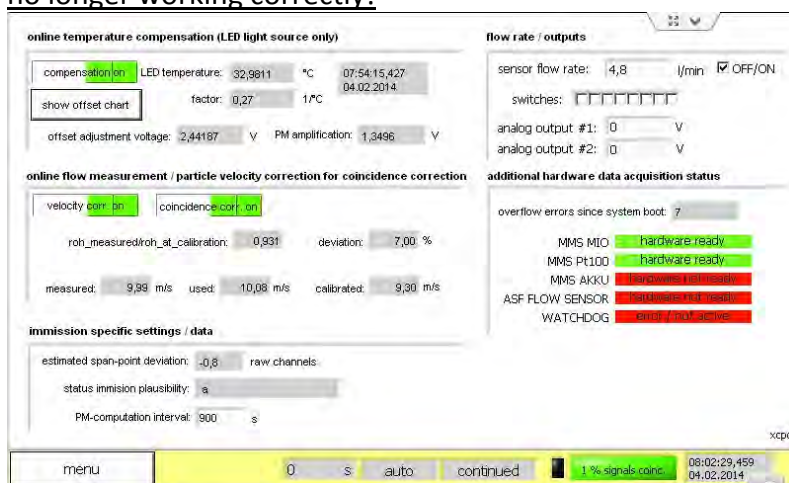
You are now in the expert user menu from which you return to the Fidas main menu by pressing on the green Fidas 100 bar on the upper left corner. Please continue by pressing “system”:



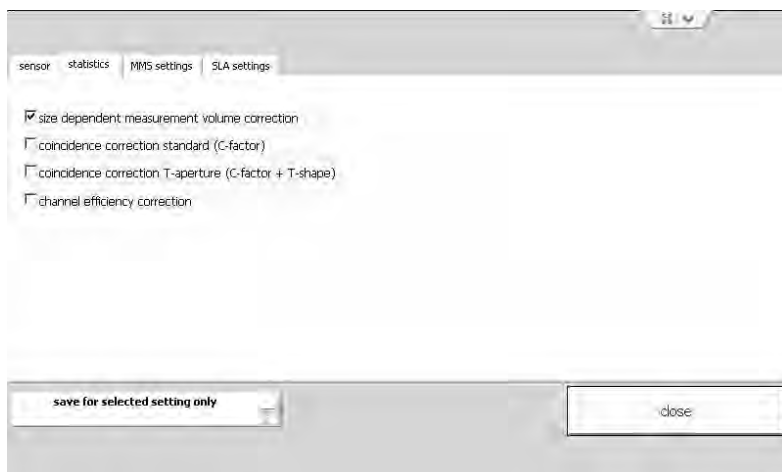
You are now in the “system” screen. Continue by pressing “advanced system settings”:



You are now in the “advanced system settings” screen. Please connect a USB keyboard and make sure it’s recognized by the system (typically by hearing a ping sound). Then press “c” on this keyboard. This will open a hidden calibration screen with several tabs. Please do not change anything else but only what is described below, else you risk that your instrument is no longer working correctly!



You are now in the hidden calibration screen, switch to the tab “statistics” and activate “coincidence correction T-aperture (C-factor + T-shape). Then press “save for selected settings only” followed by “close”



3.2 Switching the time base of the sliding average for Fidas® measurements

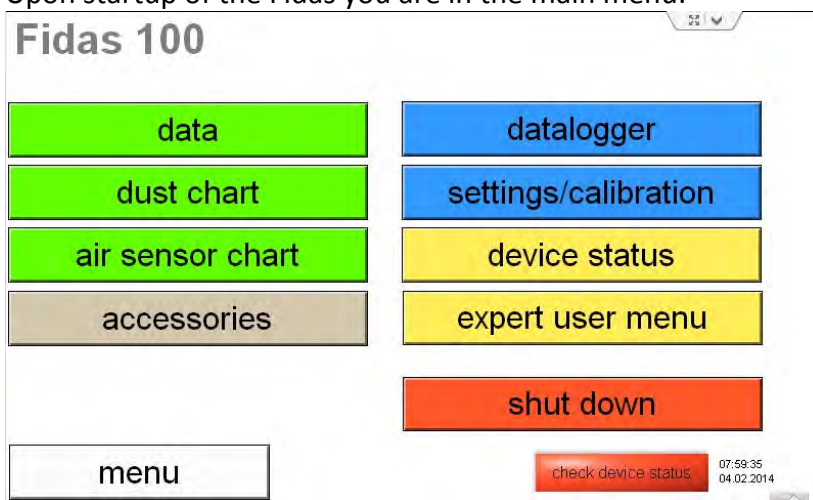
The PM-values are reported based on a sliding average with a time base of 900 s. This is the same time base that was used in the TÜV equivalency and approval testing.

If desired to change this time base please be aware that then the configuration diverts from the certified state and no information exists on the results of this change, i.e. whether the correlation to gravimetry is maintained.

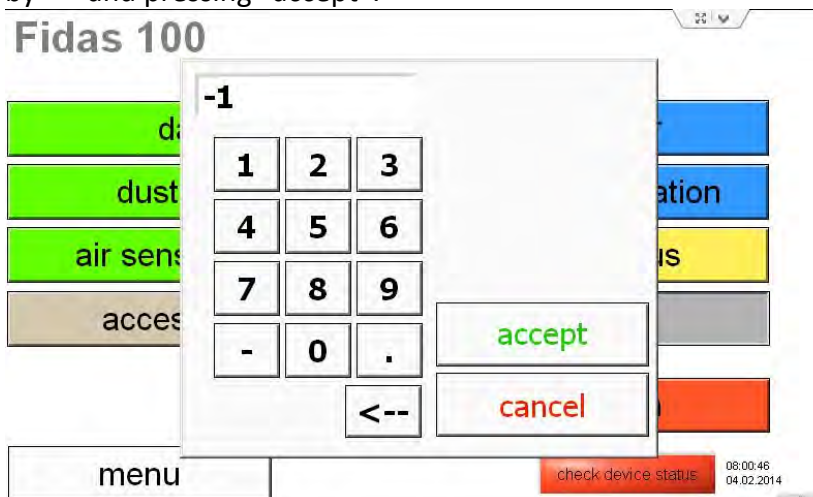
So if this value is changed it's at the own risk of the user.

However, under certain circumstances it can be beneficial to change the time base, the following steps explain how to do this:

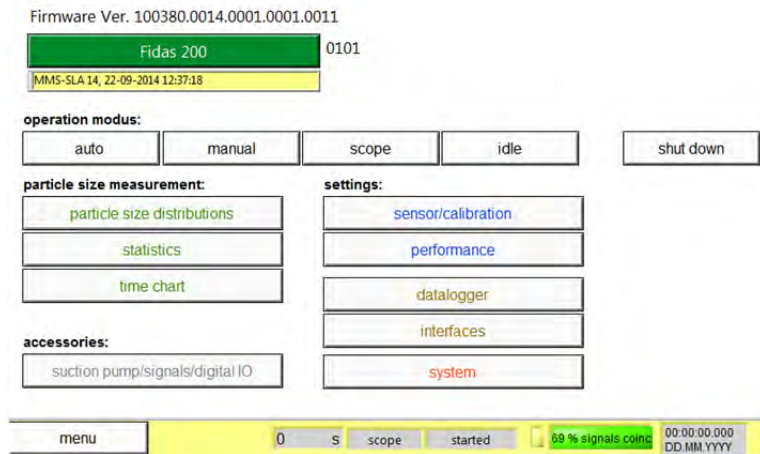
Upon startup of the Fidas you are in the main menu:



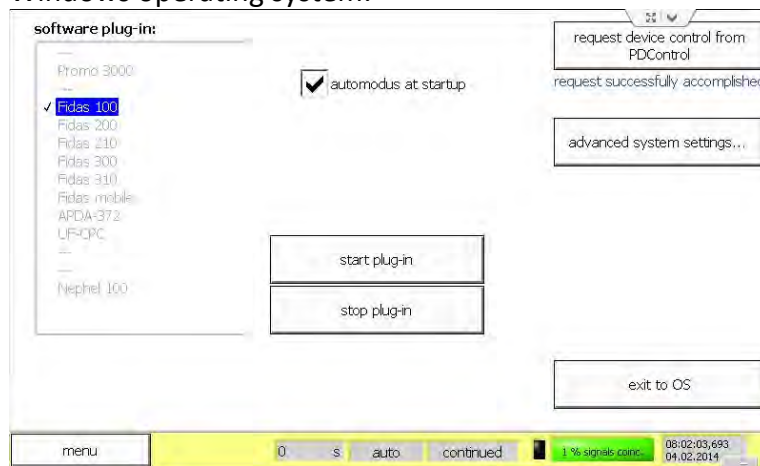
Switch to the expert user menu by pressing “expert user menu, then entering “1” followed by “-” and pressing “accept”:



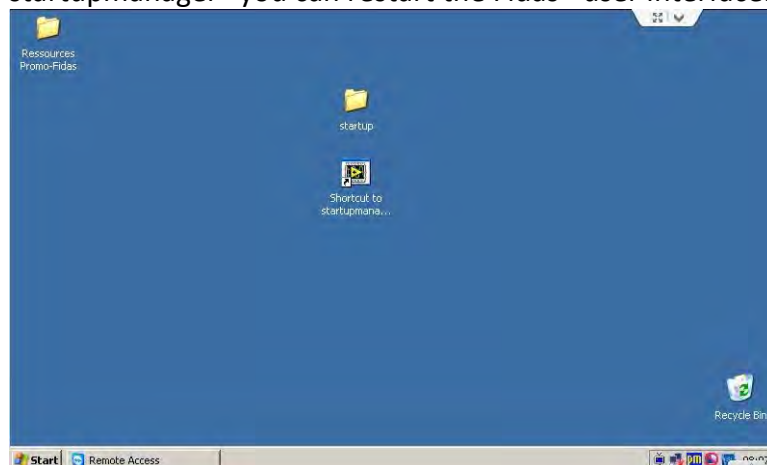
You are now in the expert user menu from which you return to the Fidas main menu by pressing on the green Fidas 100 bar on the upper left corner. Please continue by pressing “system”:



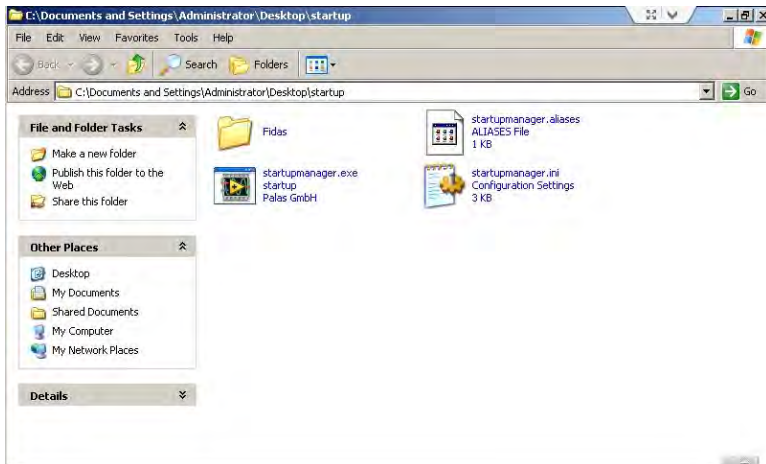
You are now in the “system” screen. Continue by pressing “exit to OS” to access the Windows operating system:



On the Windows desktop you see an icon and a folder. With the icon “Shortcut to startupmanager” you can restart the Fidas® user interface. Please go to the “startup” folder:

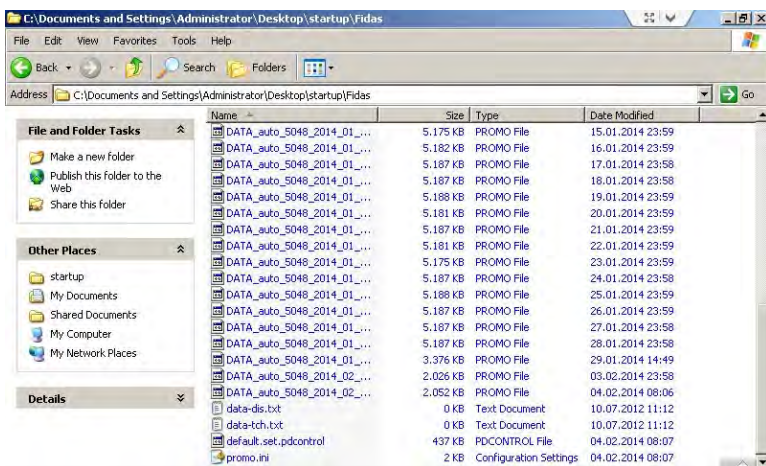
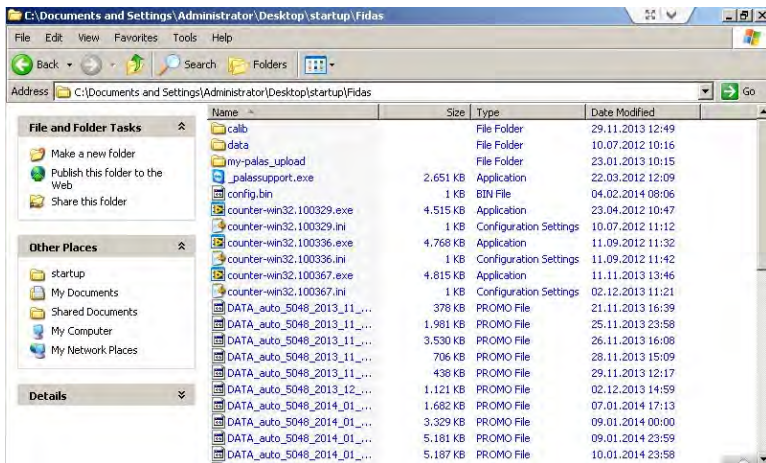


You are in the “startup” folder, next go to the “Fidas” folder:



In this folder you see several important files (scroll down to see the second half):

- “_palassupport.exe” Teamviewer module for remote support and control
- “counter-win32.100###.exe” Fidas® user interface firmware, highest number is most current version
- “DATA_auto_5048_...” Fidas® data files
- “promo.ini” Fidas® *.ini file with permanent settings



Please open the “promo.ini” file:

For the Fidas® 100/200/200 S it should look like:

```
promo_Fidas.ini - Editor
Datei Bearbeiten Format Ansicht ?

[system]
type=Fidas 200
ser#=
password=

[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-palاس.com]
my-palاس.com_autostart=no

[Fidas]
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          Enabling textfile data logging
textfile_interval=60s and setting timebase
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=
```

By scrolling down you can see the second half of the settings:


```
[Promo3000]
interval=300
sensor1=15.000000
sensor2=33.000000

[hardware]
weatherstation_connected=yes
weatherstation_comport=4
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           Setting time base for sliding average
IP_UDP_broadcast=127.0.0.1 Recommended and TUV approved setting: 900s
PLC_interface=1
temperature_compensation=yes
temperature_slope=0.25
velocity_correction=yes
velocity_calibration_enabled=no
flow_calibration_enabled=yes
server_IP-accesslist=+*
RSBaudRate=57600           Setting RS-232 baud rate
BayerHessen_DA_commmmand=60>60,61>61,62>62,63>63,64>64,65>65
```

Please check and if necessary set the time base for the sliding average to 900s (i.e. 15 minutes).

Save and close the “promo.ini” file and restart the Fidas® user interface.

3.3 Applying algorithm corrections, e.g. TÜV correction for PM_{2.5} and PM₁₀

Based on the report from TÜV Rheinland on performance testing of the Fidas® 200 S measuring system manufactured by PALAS GmbH for the components suspended particulate matter PM₁₀ and PM_{2.5}, report number: 936/21218896/A it was determined that the correlation of PM₁₀ and PM_{2.5} to gravimetry is better if the slope and offset of the data conversion is adjusted.

It was found (section 6.5 in report) that the best correlation was obtained with a function with:

PM _{2.5} :	slope: 1.076	intercept: -0.339
PM ₁₀ :	slope: 1.058	intercept: -1.505

In order to implement the correction, the reverse values of the above are used, i.e.:
Correction = 1/slope *y – intercept/slope

PM _{2.5} :	cslope: 0.929	cintercept: -0.315
PM ₁₀ :	cslope: 0.945	cintercept: -1.422

If this correction should be applied to the measurement data, it needs to be entered in the promo.ini file. If other corrections, e.g. a location factor, should be applied the steps to do that are the same.

Example: In order to apply the correction obtained in the TÜV Rheinland performance testing, the promo.ini needs to be modified as follows:.

```
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
```

3.4 System watchdog

All units since fall 2013 are shipped with an active watchdog. If the firmware is not running or frozen, the system automatically restarts after 255 seconds. This also means that accessing the Windows operating system is limited to 255 seconds if done through “expert user menu”->”system”->”exit to OS”.

In order to access the Windows operating system without this clock running select “Ver.exe” during start-up of the Fidas® startup-manager.



3.5 System changes and the installation of additional software under Windows

All units since fall 2013 are shipped with a file base write filter (FBWF). The purpose of this protection is to prevent degradation of the Windows operating system or the possible installation of malware. With this filter the original state of the operating system is preserved.

However, any changes to the operating system or any installed files will be not be saved permanently and reverted upon the next start of the system. This includes for example setting the Windows system time and date.

The only exclusion is all data saved on the desktop. Also the Fidas® data and system files are saved on the desktop and can be changed, files added etc. at any time.

In order to be able to permanently save system changes please activate the batch file from the folder “/startup/Fidas” on the desktop. After a restart of the Windows operating system the system changes are permanent (e.g. setting time and date).

It is recommended to run the batch file to activate the FBWF protection after all intended changes have been made. This also requires another restart before the protection is active again.

Note: While it is possible to run the system without the FBWF being active it is recommended to have the FBWF turned on.

3.6 The promo.ini file

The promo.ini file contains important settings for the Fidas® user interface. A detailed presentation of the entries in the promo.ini file is given below. Be aware that almost all changes affect the firmware a lot, so changes should be limited to the absolute necessary and only made when the effect is understood.

	<u>Explanation:</u>
<u>Note:</u> entries not pertaining to the Fidas® are cancelled.	
[system] type=Fidas 200 ser#=[REDACTED] password=[REDACTED]	Instrument model, note that Fidas® 200 S will also show Fidas® 200 Serial number of instrument [Do not change!] Password for internal use [Do not change!]
[plugin] Promo 3000_enabled=no Fidas 100_enabled=yes Fidas 200/210_enabled=yes Fidas 300/310_enabled=yes Fidas mobile_enabled=no Nephel 100_enabled=no stop_enabled=yes start_enabled=yes	Plugins (top level user interfaces) that are enabled [Do not change!]
[my-palas.com] my-palas.com_autostart=no	Automatically connect to the Palas® website for data upload and remote control (yes/no)
[Fidas] PM10_slope=0.945 PM10_intercept=1.4 PM4_slope=1.000 PM4_intercept=0 PM2.5_slope=0.929 PM2.5_intercept=0.3 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	any corrections to slope and offset are entered here <u>Note:</u> the applied correction in this example stems from report 936/21218896/A Display of alternative PM-values under „accessories“ active Text file logging enabled Timebase for text file logging, i.e. data saved every 60 s [Do not change!] Operating mode of IADS [Do not change!] [Do not change!] Automated cleaning deactivated Limit value of PM-fraction that triggers digital alarm (digital out) Specified PM-fraction that is used to trigger alarm (e.g. PM2.5) E-Mail address to which notification is sent in case of status error Password for switching to expert user mode

Continued on next page

Explanation:

Note: entries not pertaining to the Fidas® are cancelled.

```
{Promo3000}-----
interval=300-----
sensor1=15.000000-----
sensor2=33.000000-----
```

[hardware]

```
weatherstation_connected=yes weather station is expected to be connected
weatherstation_comport=4 Com-port of connected weather station
GPS_connected=no GPS is not expected to be connected (no longer supported!)
GPS_comport=8 Com-port of GPS
discmini_connected=no DiSCmini is not expected to be connected
discmini_comport=81 Com-port of DiSCmini
discmini_interval=300s Time interval of reported data from DiSCmini
```

```
{UF-GPG}-----
```

```
liquid_pump_impulsinterval=45 s
liquid_pump_impulsamplitude=0.5 V
```

[settings]

```
sensor_selection=2 [Do not change!]
PM_interval=900s Timebase for sliding average of PM-fractions (same as for TÜV test)
IP_UDP_broadcast=127.0.0.1 If pushing data, this is the UDP address
PLC_interface=1 Selected communication protocol upon startup (see below)
temperature_compensation=yes LED temperature control [Do not change!]
temperature_slope=0.25 [Do not change!]
velocity_correction=yes [Do not change!]
velocity_calibration_enabled=no [Do not change!]
flow_calibration_enabled=yes Easy flow calibration mode is activated (extra button visible)
server_IP_accesslist=+*-----
RSBaudRate=57600 Baud-rate for data transmission
BayerHessen_DA_commmand=60>60,61>61,62>62,63>63,64>64,65>65
Mapping of addresses for Bayern-Hessen protocol
```

Selected communication protocol upon startup:

- 0 Modbus
- 1 Bayern/Hessen
- 2 UDP ASCII
- 3 UDP single particle data stream
- 4 Modbus with UDP
- 5 Seriell ASCII

4 Maintenance

We recommend to check continuously the correct function of the Fidas® (please see 3.1). Otherwise the device has to be maintained only, if one of the error bits starts up (please see figure 24).

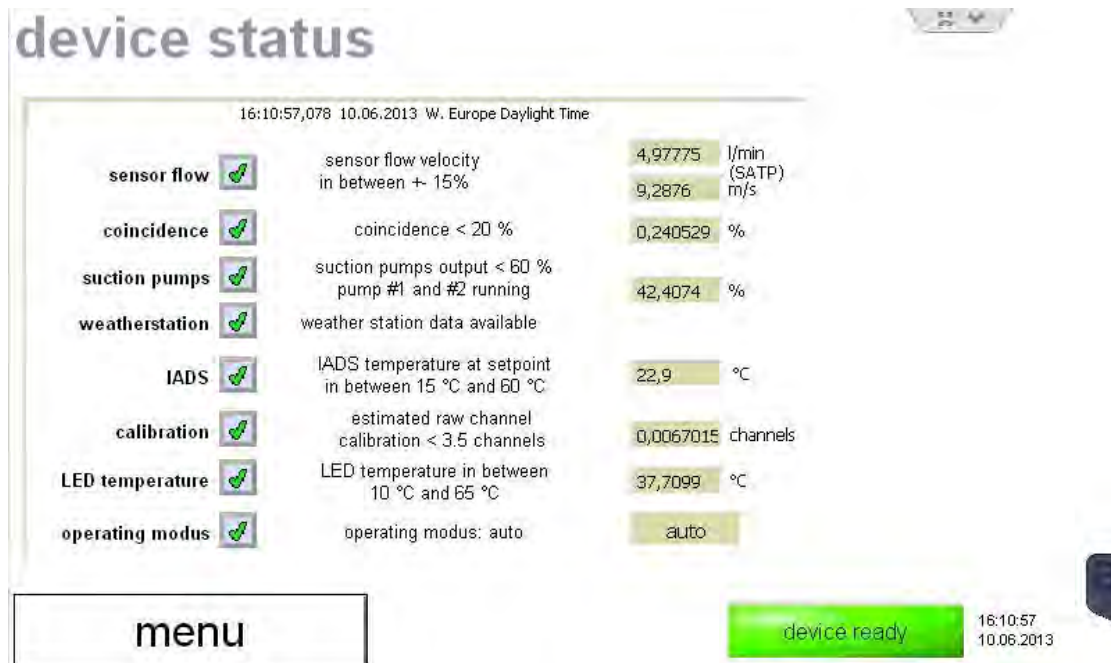


Fig. 24: The status overview shows the different sensor information, which is necessary for the correct operation of the Fidas®. This information is saved in form of an error byte with every data record.

In detail:

Sensor flow By means of a circuit with mass flow meters and including the measured values for temperature and air pressure the volume flow through the Fidas® 100 or 200 is regulated to 4.8 l/min. The volume flow is then standardized to „standard atmospheric temperature and pressure (SATP)“, i.e. with regard to 25°C & 1013 hPa.

The second value shows the particle velocity through the optical detection volume.

An error occurs, if the volume flow differs more than 15 % from the set value or if the particle velocity differs too much from the regulated volume flow.

Coincidence Detection of more than one particle in the optical detection volume. Error output if it occurs with a frequency of more than 20 %.

Suction pumps In Fidas® 100 und 200 two pumps (connected in parallel) provide the volume flow. If one pump fails, the other one can take it over, but then

the input is higher which leads to an error. If both pumps consistently age, an error occurs if they increase 60 %. It is important to know that the device continues to measure correctly, but the user has to change the pumps soon.

Weather station Shows that the weather station is connected correctly and provides values

IADS Shows that the IADS is connected correctly and the temperature corresponds to the given set point

Calibration Controls the calibration online, if it differs for more than 3.5 raw data channels, an error occurs.

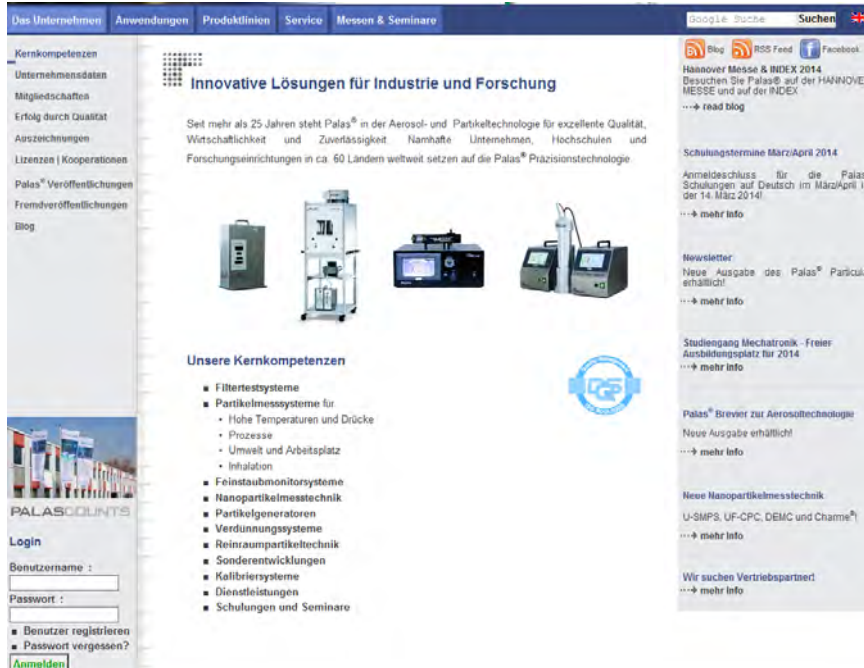
Please note: In some cases this value can be outside the measurement, however the device will function properly. Need for action (i.e. a field calibration with calibration dust) is only necessary, if a long-term trend (>40 hours) can be seen.

LED temperature The LED light source is temperature controlled. If there is a problem in this control loop an error bit is set.

Operating modus The operation mode should be set to „auto“, otherwise the data are not saved correctly or the device does not start independently after a blackout.

4.1 Remote Support

Every customer is advised to register under the Palas® homepage to gain access to the password protected user area:



The login is located at the bottom left of the homepage. Once logged in the user has the following options (via “to the user area”):



This includes download of software and firmware updates, remotely managing the instrument, and creating customer support tickets.

4.2 Calibration/Verification of the Fidas®

A calibration of the instrument should always be performed before the beginning of a measurement campaign. During an actual measurement campaign, the calibration should be performed periodically (see table 1).

Before calibration, the instrument must be in operation for at least one hour so that it is in a thermally stable condition. The ambient temperature must be within 5 and 35°C.

Note:

When calibrating the instrument with MonoDust, this calibration is only valid if performed at a temperature within the range +10°C to +40°C!

To calibrate, the device has to be in the calibration mode. At the beginning of the calibration procedure, first the IADS (drying system) is heated up or cooled down to 35 °C so that the volume flow and the gas dynamics are always the same and the dust that is used for calibration is conditioned. Usually, you have to wait at least ten minutes. During this procedure the temperature is displayed and the calibration begins if the user sees that the temperature is stable at 35°C (+/- 0.1°C).

The complete calibration consists of 5 steps:

- 1.) Automatic offset adjustment
- 2.) Check of the tightness of the total system
- 3.) Adjustment of the sensitivity of the particle sensor
- 4.) Check of the particle flow in the particle sensor
- 5.) Check of the volume flow

The different steps are described in the following:

4.2.1 Automatic offset adjustment

The electronic zero point of the system is aligned at the offset adjustment (see figure 27). Thus, the inherent noise of the instrument is minimized. The offset adjustment is performed fully automatically and is started via the button „adjust offset“. The adjustment lasts about two minutes. The minimum of the measured offset voltage must be less than 0.2 mV, the offset adjustment voltage must be within 2 and 3 V.

4.2.2 Check of the tightness of the total system

The tightness of the whole system is a precondition for a successful calibration. The Fidas® 200 has a flow sensor that is directly in front of the pump (see figure 25). The indicated volume flow has to decrease below 0.3 l/min (deducted the flow-offset). This flow-offset can be found among “Settings/calibration” as “calibrate flow sensor offset”.

Adjustment of the sensitivity of the particle sensor

For the adjustment of the sensitivity of the particle sensor, the dust (MonoDust 1500 which is included in the delivery) is applied with particles of a defined size. The particle size distribution of this dust is monodisperse. The instrument shows the raw data distribution of the measurement (see figure 26). In this case, the peak of the raw data distribution has to be in channel 141 (the respective peak position is to be retrieved from the test certificate, which is delivered with the bottle with calibration dust). This corresponds to a particle size of 1.26 µm.

In the case of a deviation of 1.5 channels the instrument has to be calibrated again. In this case, the voltage of the photomultiplier has to be changed and the procedure must be repeated then. The voltage can be changed via the button „calibrate PM amplification“. In this case, if the peak is < 139.5, the voltage of the photomultiplier must be increased. If the peak is > 142.5 the voltage of the photomultiplier must be decreased. Through this adjustment of the photomultiplier voltage at a particle size, the sensitivity of the measurement device for all particle sizes is automatically adjusted as the instruments works - unlike other manufacturers of aerosol spectrometers - with only one A/D converter. Please repeat this procedure until the peak of the raw data distribution is at the respective nominal value (± 0.5), in this case at 141 (± 0.5).

An evaluation of the effect of a peak shift in the raw data channels on the mass concentration was performed in the report 936/21218896/A by TÜV Rheinland with CalDust 1100 (Nominal value 130) – the evaluation procedure itself remains untouched in case of using MonoDust 1500 instead of CalDust 1100:

Table 3: Matrix on the influence of a peak shift on the mass concentration

channel shift	PM2,5		PM10	
	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:

$$\text{PM}_{2,5_actual} = 1.086 \cdot \text{PM}_{2,5_hypothetical} + 0.03889$$

$$\text{PM}_{10_actual} = 1.0877 \cdot \text{PM}_{10_hypothetical} + 0.0331.$$

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 PM₁₀ were defined. The concentration value to be expected depending on the peak shift was then calculated according to the following matrix

4.2.3 Check of the particle flow in the particle sensor

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 particles in the sensor, since the height of the optical measuring 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 guide in the sensor is disturbed. For this reason, the velocity must be checked; otherwise the concentration is determined incorrectly. If the reason for the wrong velocity calibration is no leakage, the device must be returned to the manufacturer. To calibrate the velocity also MonoDust 1500 is used since particles of different sizes show slightly different velocities. By using MonoDust 1500, the same particle size is always used also for the velocity calibration. The lower diagram (see figure 26) in the calibration mode shows the signal length distribution. Two maxima can be seen. The left maximum is the length of the signals in the border zone of the sensor (T-aperture), the right maximum is at the length of the signals through the core zone. If you use the arrow keys to direct the crosshair in the right maximum, you get the velocity with this signal length ("measured velocity"). This velocity must match the velocity set by the factory (+ - 0.2 m/s). Due to manufacturing tolerances in the nozzle, the velocities in individual units are slightly different.

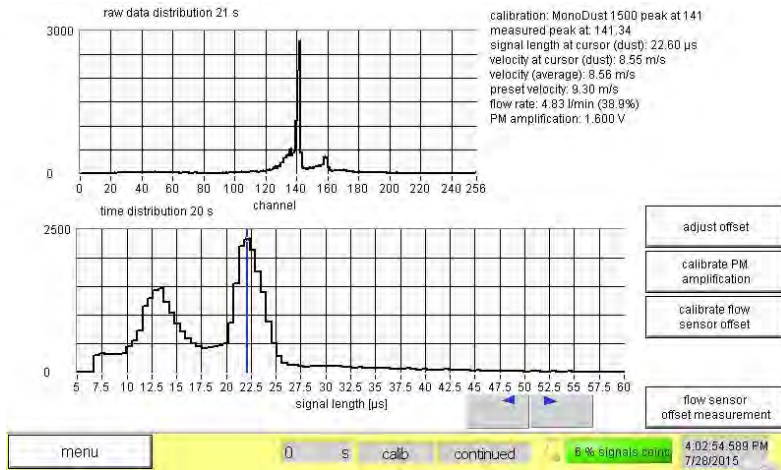
4.2.4 Check of the volume flow

The volume flow of the Fidas® is regulated to mass flow with a mass flow meter, i.e. the volume flow changes with temperature and pressure. The volume flow is regulated to 4.8 l/min (± 0.15 l/min). The volume flow is then standardized to „standard atmospheric temperature and pressure (SATP)“, i.e. with regard to 25°C & 1013 hPa.

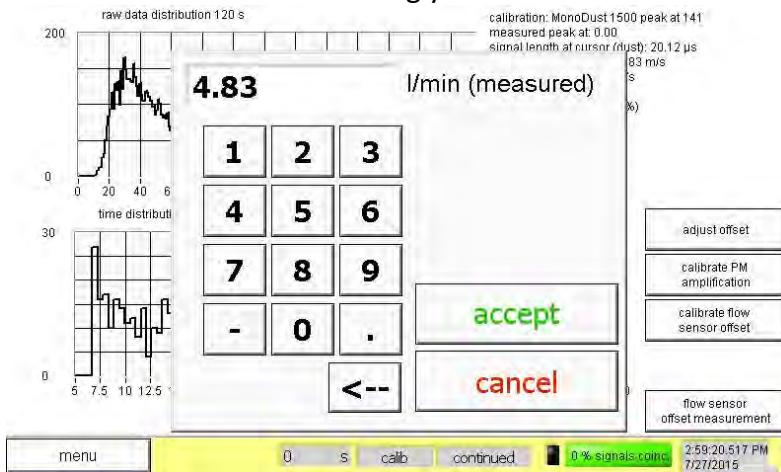
This can be verified for example with a „Bubble-flow-meter“. If the device is tight (point 2) and if the velocity of the particle flow in the sensor is correct (point 4), then a check of the volume flow is not necessary.

The particle velocity is not calibrated and kept at a steady value of 9.3 m/s. The measured concentrations refer to operating conditions based on the measured (with the weather station) ambient temperature and pressure.

Under “settings/calibration” -> “sensor calibration” there is a button “calibrate flow sensor offset”.



In order to calibrate the flow, enter the measured flow (as displayed on your flow meter) and the firmware will correct the flow accordingly.



Important note: As the flow is referenced to SATP (standard ambient temperature and pressure), please make sure your flow meter references to the same temperature (25 °C) and pressure (1013 hPa). If not you need to correct this manually before entering the measured flow into the firmware!

Note: If this button is not visible the following entry needs to be added to the promo.ini file:
 In section [settings]:
 flow_calibration_enabled=yes

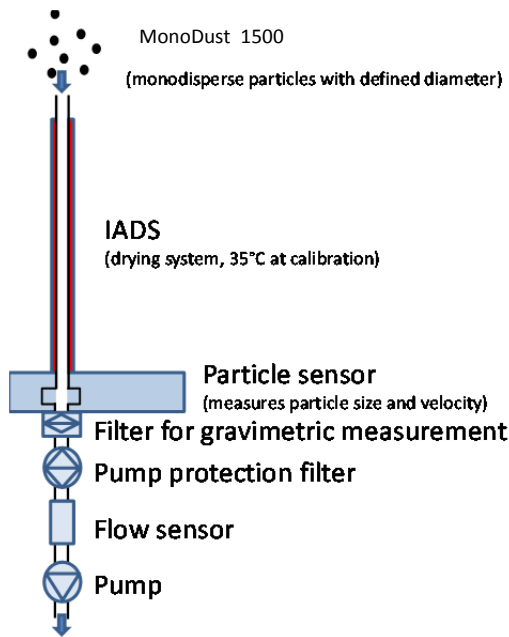


Fig. 25: Schematic set-up of the flow of the sampling volume flow

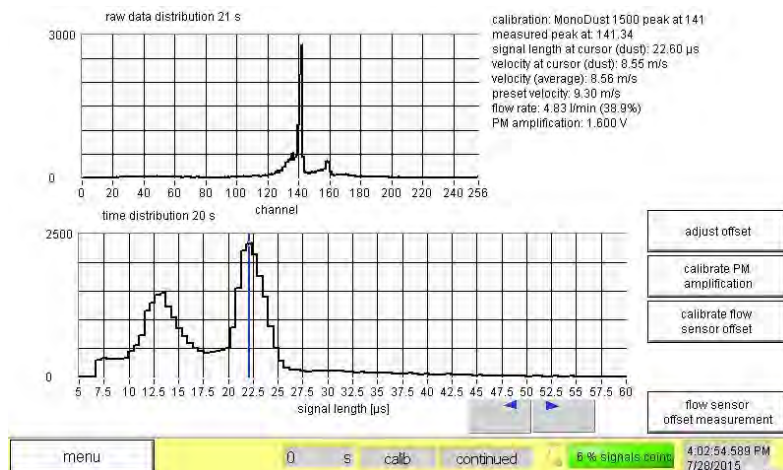


Fig. 26: Screen display during calibration (on the top: raw data distribution of channel 60 to 250 with maximum at 141.34; at the bottom: measured signal length distribution with accordingly determined velocity – here 8.55 m/s)

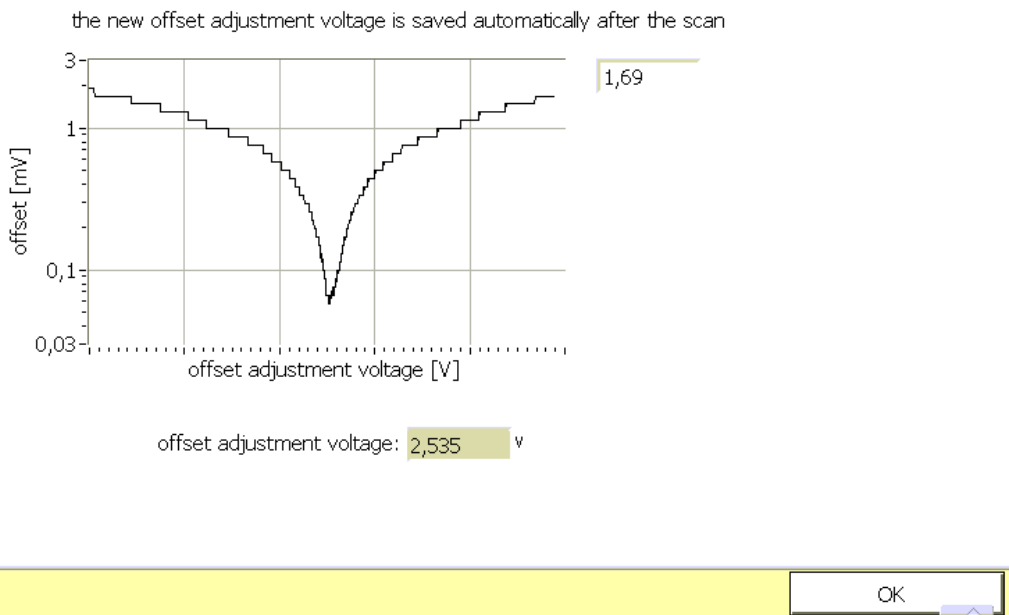


Fig. 27: Screen display during automatic offset adjustment

Procedure (incl. test intervall)	Size to be calibrated	Limits	Remark
Automatic offset adjustment (3 month)	offset	< 0.2 mV	fully automated
	offset adjustment voltage	> 2 V; < 3 V	fully automated
Check of the tightness of the total system (3 month)	flow rate	< 0.3 l/min (not including the pump offset)	by sealing the inlet
Adjustment of the sensitivity of the particle sensor (1 month)	measured peak	Nominal value* $\pm 0,5$ *refer to delivered test certificate of MonoDust 1500	with calibration dust MonoDust 1500
Check of the particle flow in the particle sensor (3 month)	velocity (MonoDust)	+ - 0.2 m/s of the factory setting* *refer to delivered test certificate of the Fidas®	with calibration dust MonoDust 1500 by marking the right maximum
Check of the volume flow (3 month)		4.8 l/min ± 0.15 l/min referring to 25°C und 1013 hPa (Standard Ambient Temperature and Pressure - SATP)	with gauged volume flow measurement device

Table 1: Calibration procedure

4.3 Demounting/exchanging the gravimetric filter

To demount the gravimetric filter, the gravimetric filter holder at the bottom side of the aerosol sensor must be removed.

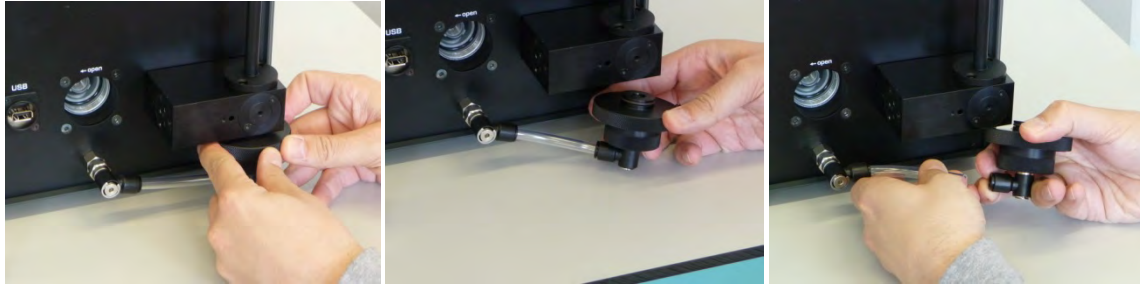


Fig. 28 A-C: Removing the filter holder

The filter holder (Fig. 28 A) can easily be detached by a downward movement (Fig. 28 B). Then, the plug connection of the suction tube can be loosened. Therefore, press the plug connection backwards and at the same time remove the tube with your other hand (Fig. 28 C).

Now, the filter holder can easily be opened by a counter-clockwise rotation.



Fig. 29 A: Setup of the filter holder

The filter holder consists of an upper and a lower part which are connected to each other by a screw closure (see Fig. 29 A and B). Additionally, on the bottom side, a little fence serves as support for the gravimetric filter.

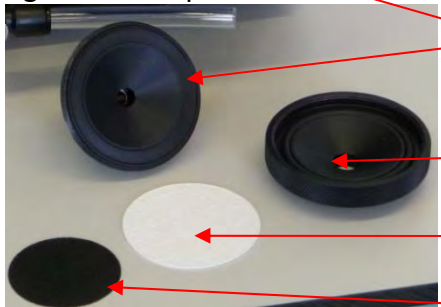


Fig. 29 B: Setup of the filter holder

- Lower part of the filter holder with connection for the suction tube
- Upper part of the filter holder with connection for the aerosol sensor
- Gravimetric filter
- Support fence for the gravimetric filter

4.4 Cleaning of the optical sensor

A cleaning of the optical sensor is only necessary, if the photomultiplier voltage during the calibration of the optical sensor (please see 3.1) is more than 15 % above the value of the calibration after the last cleaning respectively the delivery state.

4.4.1 For Fidas® 200/200 S/200 E systems

The IADS has to be removed from the aerosol inlet of the sensor in order to move the control unit with the integrated sensor sideways.



Please unfix the fixation of the IADS carefully.
Then, the IADS can be completely moved upwards, so that the aerosol inlet can easily be accessed.

Fig. 30: Connection of the aerosol inlet with the IADS

4.4.2 For all Fidas® Systems

To clean the internal optical glasses of the aerosol sensor, the filter holder has to be removed from the sensor outlet. Additionally, the plug connection between the filter holder and the inlet of the suction pump has to be removed.



Fig. 31 A-C: Removing the filter holder

The filter holder (Fig. 31 A) can now easily be detached by a downward movement (Fig. 31 B). Then, the plug connection of the suction tube can be loosened. Therefore, press the plug connection backwards and at the same time remove the tube with your other hand (Fig. 31 C).

Then, loosen the two M3 cross-head screws with an adequate screwdriver.



Fig. 32: Loosening the M3 cross-head screws

Loosening the two M3 cross-head screws



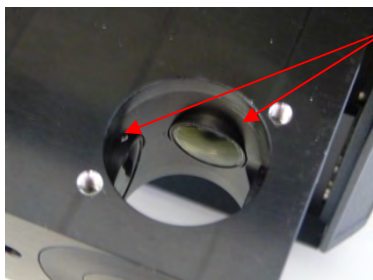
Then, the cuvette can carefully be removed upwards from the aerosol sensor by simultaneously pushing at the bottom side and pulling at the upper side.

Fig. 33: Removing the cuvette

Attention:

When removing the cuvette, take care that the optical glasses lying inside the aerosol sensor are not scratched or damaged with the cuvette!

Now, the two optical glasses inside the aerosol inlet can be cleaned. This must only be done with an optical wipe (included in the delivery)!

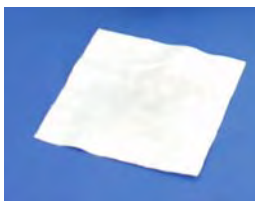


The two optical glasses inside the aerosol inlet

Attention:

Do not touch the glasses with your fingers!
Cleaning only with optical wipes!

Fig. 34: Optical glasses inside the aerosol sensor



Optical wipe to clean the optical glasses

Fig. 35: Optical wipe

The cuvette can be cleaned with compressed air.

4.5 Cleaning/Changing of the suction filter of the internal pump

The filter has to be cleaned or changed if the performance of the suction pump is more than 50 %.



Loosen the protection cap of the suction filter (Fig. 37) by a counter clockwise rotation and remove it.

The filter itself can be removed the same way (Fig. 39)



To be loosen by a left rotation

Fig. 36: Removing the protection cap

Fig. 37: Filter without protection cap



The filter can either be cleaned with compressed air or be exchanged, if it is too soiled

Filter of the internal suction

Protection cap

Fig. 38: Removing the filter

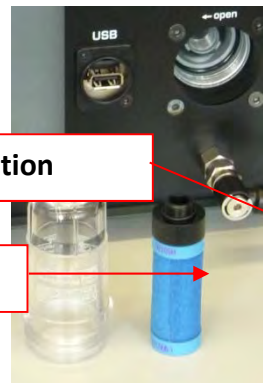


Fig. 39: Removed filter and protection cap

For installation of filter and protection cap, please proceed vice versa.

4.6 Cleaning of Sigma-2 head

The Sigma-2 head should be checked up on dirt every three month (in combination with the calibration) and if necessary should be cleaned.

4.7 Replacing O-ring seals

If a leak check or visual check requires replacement of O-ring seals we recommend to use only O-rings supplied by Palas® to replace them. Palas® offers a "Sealing ring set for Fidas® 200" as spare part. This set contains the following O-rings:



Figure 40: Sealing ring set for Fidas® 200

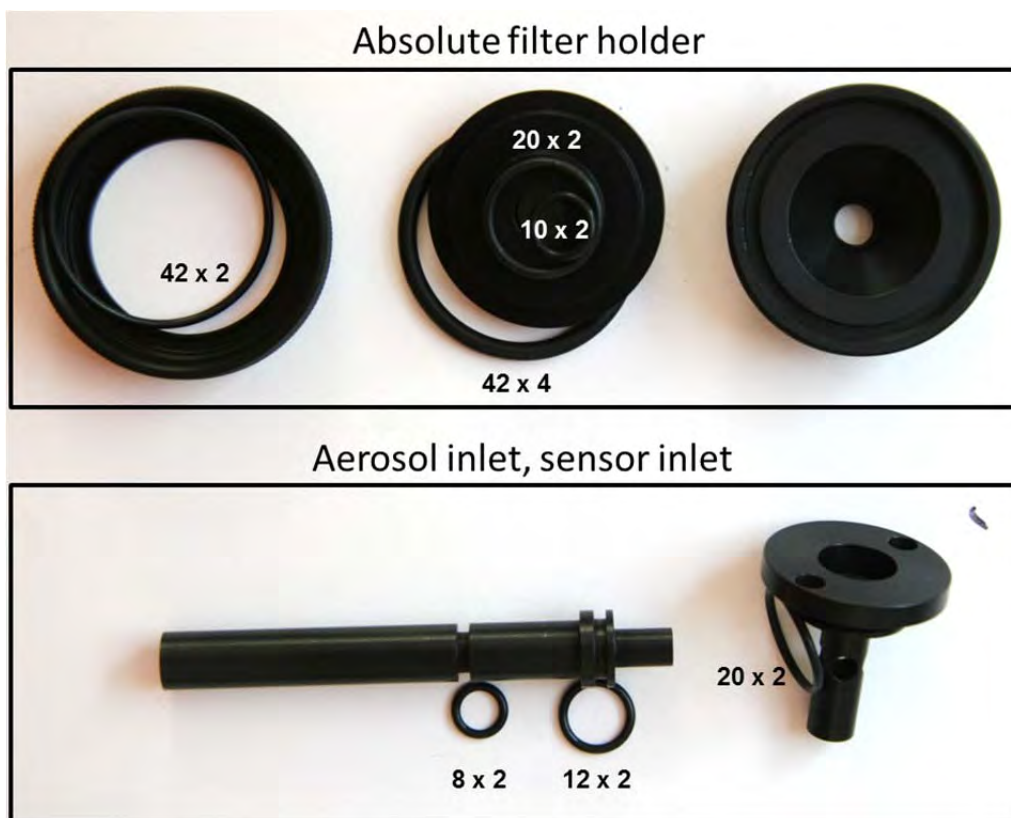


Figure 41: Application of the O-rings

5 Particle measurement with the Fidas® System

The Fidas® is an optical aerosol spectrometer, determining the particle size via scattered light at the single particle according to Lorenz-Mie.

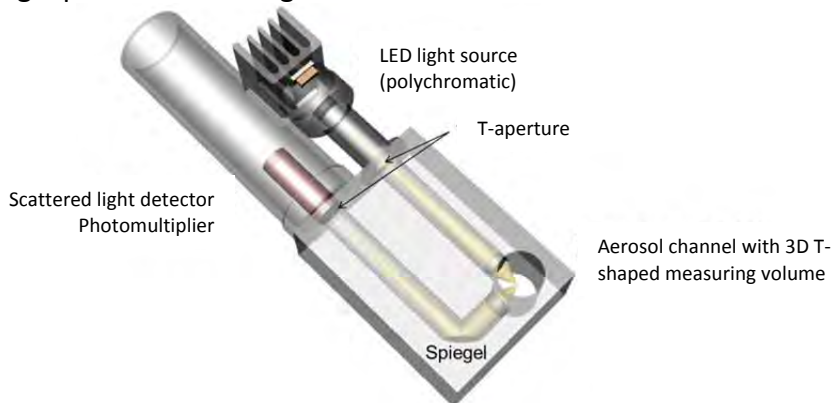


Fig. 42: Set-up of the sensor of the Fidas® measurement system

The particles move separately through an optically differentiated measurement volume, homogeneously illuminated with polychromatic light.

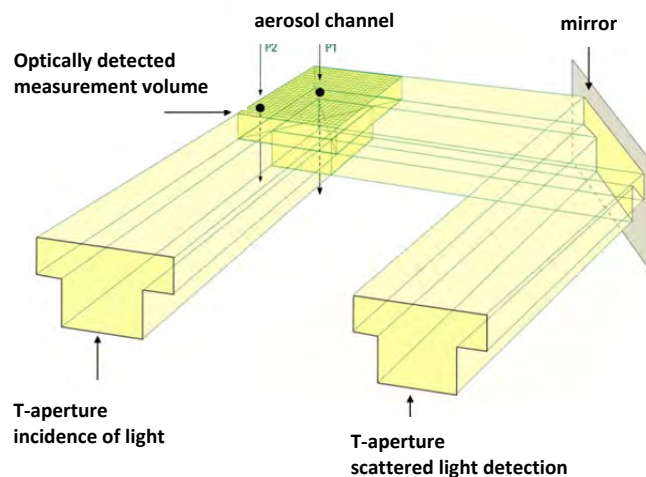


Fig. 43: Illustration of T-aperture

Using a polychromatic light source (LED) in combination with a 90° scattered light detection, a precise calibration curve without ambiguity in the Mie-range can be achieved. This results in a high size resolution.

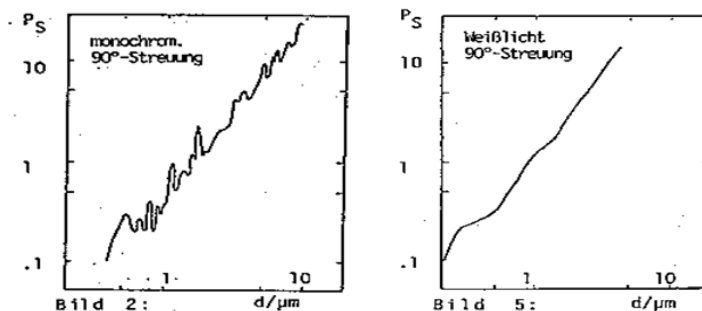


Fig. 44: Calibration curve for 90° scattered light detection with monochromatic light source (left) and polychromatic light source (right)

Each particle generates a scattered light impulse, detected at an angle of 85° to 95° degrees. The number concentration is deduced from the number of scattered light impulses. The amplitude (height) of the scattered light impulse is a measure for the particle size diameter.

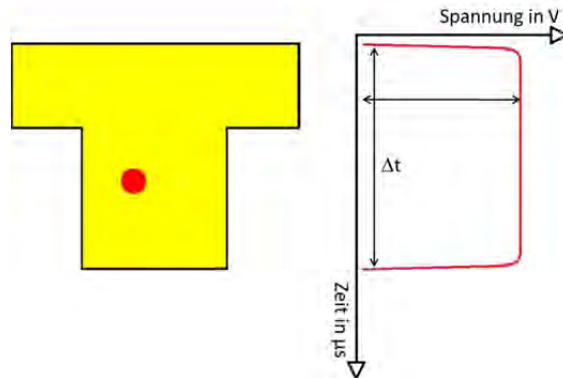


Fig. 45: Measurement of scattered light impulse at the single particle. Amplitude and signal length are measured

The border zone error can be eliminated by using the patented T-aperture and simultaneous measurements of the signal length. The border zone error is characterized by the partial illumination of particles at the border of the measurement range. This partial illumination implicates that particles are smaller size classified than they actually are (see figure 46, red curve). Via the T-aperture particles flying only through the arm of the T (shorter signal length) differ from those flying through the middle part of the T (longer signal length). The latter are completely illuminated in the upper section. Therefore no border zone error occurs by using the Fidas® (Fig. 46, blue curve).

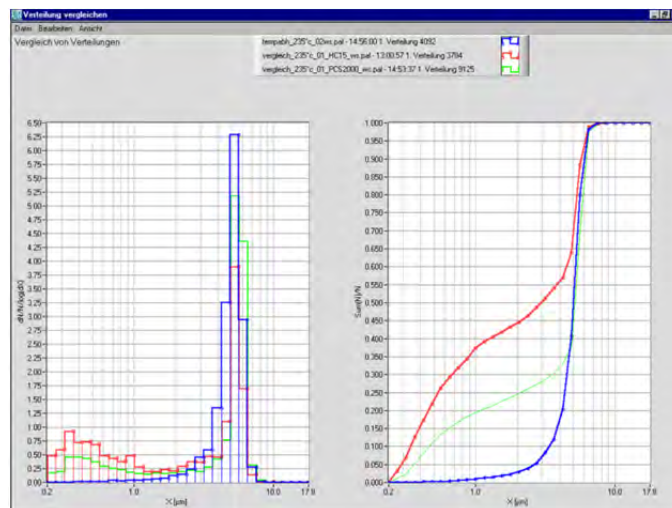


Fig. 46: Comparison of an optical scattered light spectrometer with simple rectangular aperture (HC15, red) with an optical scattered light spectrometer with T-aperture (welas®, blue) by using monodisperse particles in the size of 5 µm.

The measurement of the signal length enables a detection of coincidence (more than one particle in the optical detection volume) as the signal length is longer in this case. Furthermore this coincidence can be corrected by a correction determined and verified by Dr.-Ing. Umhauer and Prof. Sachweh.

The lower detection limit for immission measurements was reduced to 180 nm by using optimised optics, higher light density by using a new white light LED as light source and improved signal analysis (logarithmic A/D converter). In this way, smaller particles, measured roadside in high concentration, can be reproduced better (figure 47).

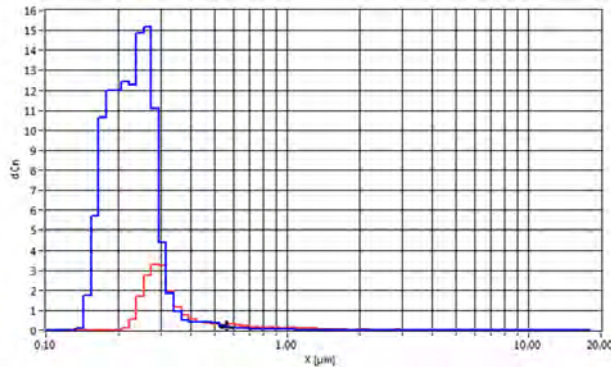


Fig. 47: Measurements with the Fidas® roadside (size range from 0.18 µm, blue curve) compared to a different optical measurement system (size range from 0.25 µm, red curve)

5.1 The Fidas® system is characterized by the following features

By using these techniques

- Unambiguous calibration curve (polychromatic light and 90° scattered light detection)
- No border zone error (patented T-aperture technology)
- Coincidence detection and coincidence correction (digital single particle analysis)

the following important advantages can be achieved

- Very good size resolution (high number of raw data channels)
- Very good size classification accuracy
- Exact concentration determination

In summary:

Only with a very good size resolution and very good size classification accuracy as well as with an exact concentration determination the mass concentration can be determined reliably.

5.2 Schematic setup of the measurement system by example of Fidas® 200 S

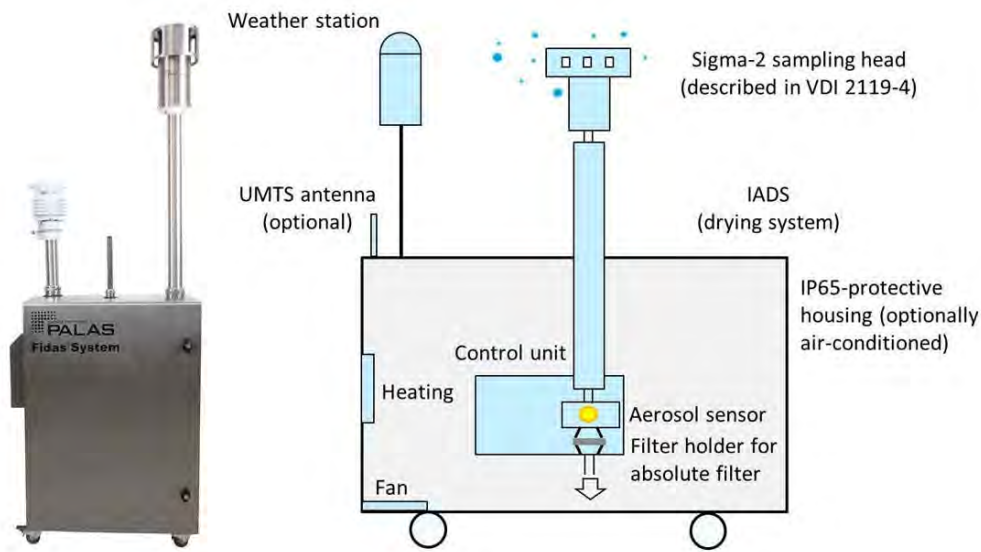
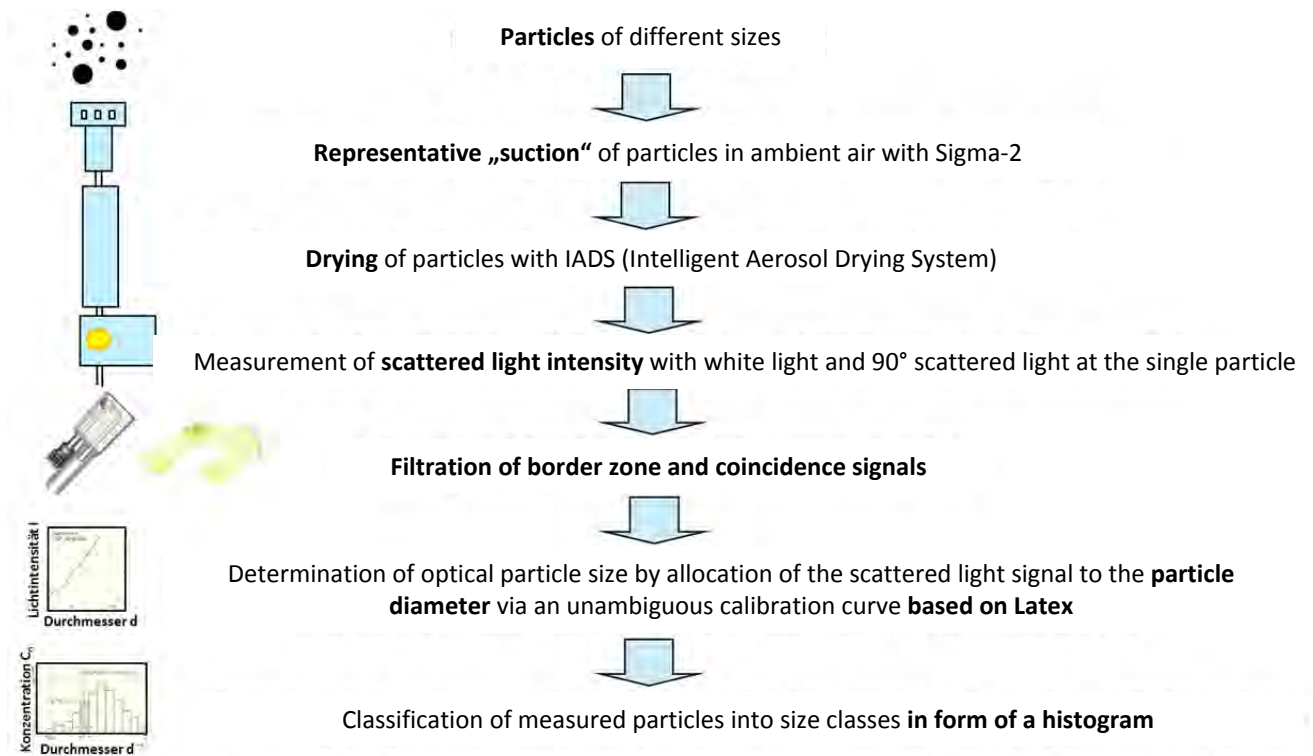
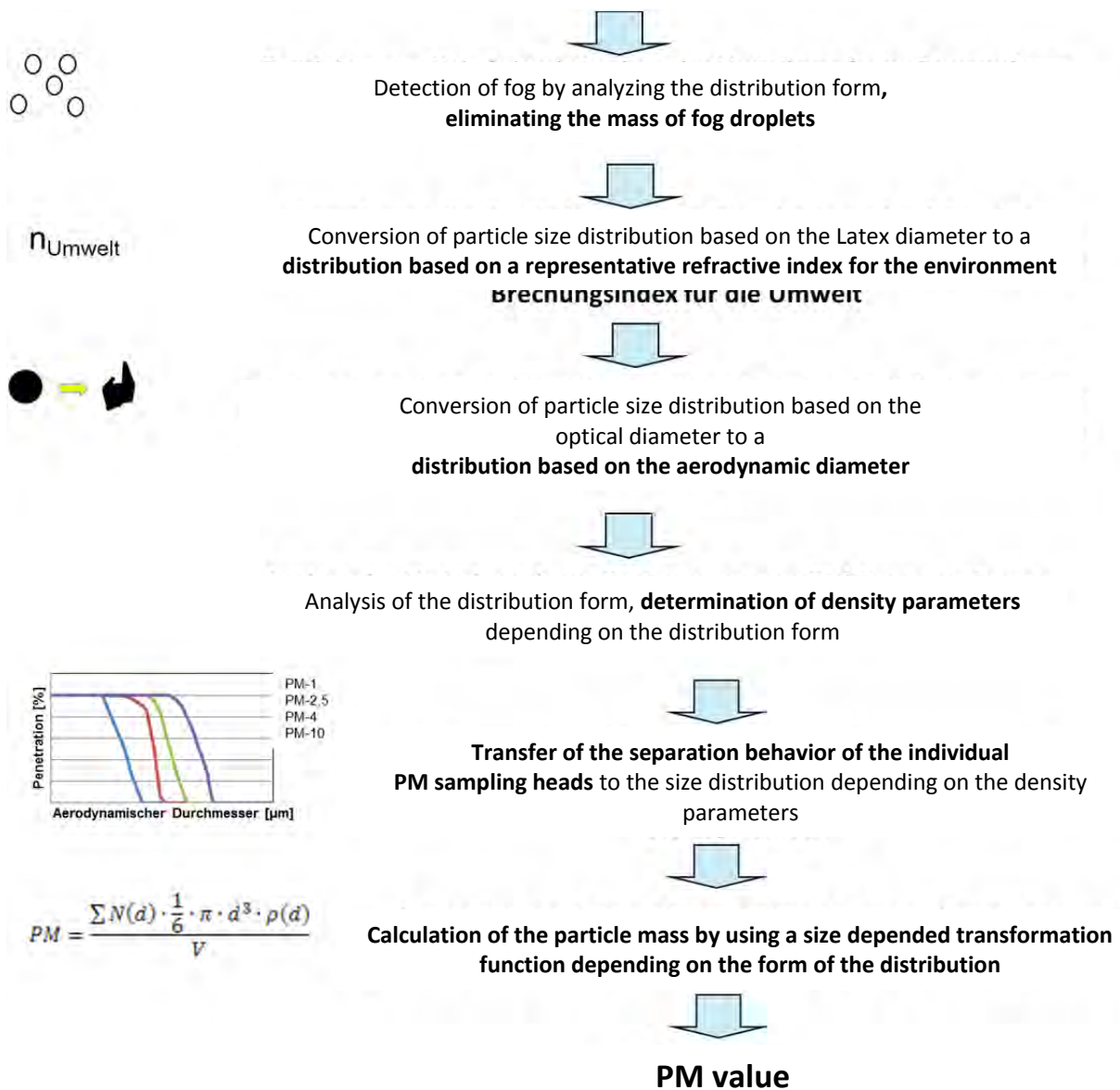


Fig. 48: Schematic setup of the Fidas® 200 S measurement system

5.3 Overview of the individual measurement steps





The Fidas® uses the measured particle size information for the calculation of the following dust values:

PM-1 [µg/m³]: dust content smaller than $d_{50,Aero} = 1 \mu\text{m}$ according to US-EPA

P-2.5 [µg/m³]: dust content smaller than $d_{50,Aero} = 2.5 \mu\text{m}$ according to US-EPA

PM-4 [µg/m³]: dust content smaller than $d_{50,Aero} = 4 \mu\text{m}$

PM-10 [µg/m³]: dust content smaller than $d_{50,Aero} = 10 \mu\text{m}$ according US-EPA

PM-Breast [µg/m³]: dust content, going into the bronchi

PM-alveoli [µg/m³]: dust content, going into the alveoli

PM-inhalable [µg/m³]: total inhaled dust content

PM-total [µg/m³]: measured total dust

The above mentioned dust contents are calculated by using the penetration curves for standardized sampling heads according to EN 481 (PM-inhalable, PM-breast and PM-alveoli) as well as according to US-EPA (PM-1, PM-2.5, PM-10).

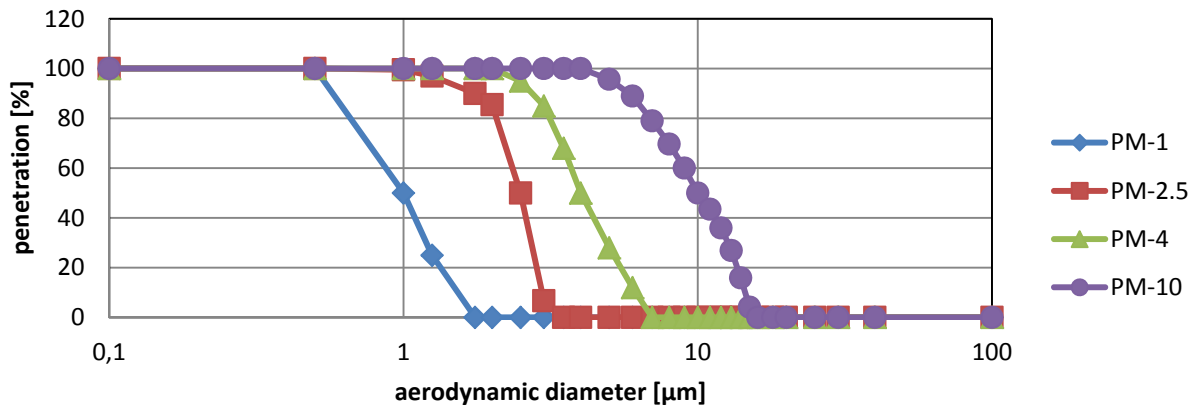


Figure 49: Used penetration curves for PM-1, PM-2.5, PM-4, PM-10 (US-EPA)

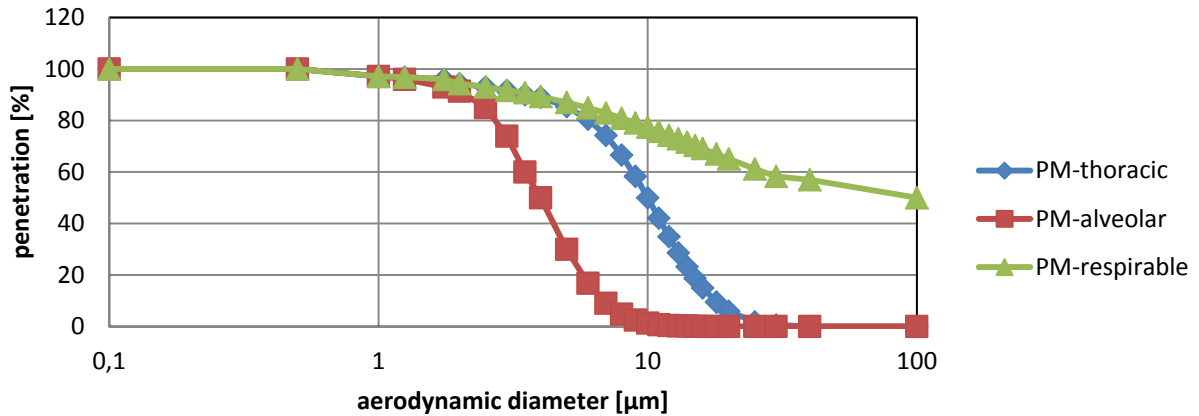


Figure 50: Used penetration curves for dust measurements at workplaces in the health related sector (EN 481)

Table 2: Used penetrations for the determination of dust mass concentration

Aerodynamic diameter [µm]	PM-1 [%]	PM-2.5 [%]	PM-4 [%]	PM-10 [%]	PM-breast [%]	PM-alveoli [%]	PM-inhalable [%]
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

The above mentioned dust contents are based on the aerodynamical diameter. The aerodynamical diameter can be calculated as follows:

$$x_{aerodynamic} = x \cdot \sqrt{\frac{\rho_{particle}}{1 \frac{g}{cm^3} \cdot \chi}}$$

In general the density of the particles $\rho_{particle}$ is between 0.7 and 3 g/cm³, the form factor χ is between 1 and 1.5. For the calculation of PM-fractions the Fidas® assumes a density of 1.5 g/cm³ and a form factor of 1. These values are suitable for most aerosols. The Fidas® is equipped with a gravimetric filter holder, which can be used for the measurement of the correction factor C. This system considers as well the influence of the refractive index on measured PM-values. Using this factor C the PM-values are corrected as follows:

$$PM_{corrected} = C \cdot PM.$$

5.4 Further advantages

Beneath the PM-fractions, which are measured continuously and simultaneously, the measured particle number concentration and particle size distribution with a high time and size resolution (up to 128 size classes) are available.

These additional information can be used to conduct a „Source Apportionment“ or to evaluate the health-related relevance (larger particles go deeper into the human respiratory tract).

Figure 51 shows an example from Vienna around Easter. During the chronological sequence of the PM fractions suddenly a significant increase could be seen, going down slowly afterwards. The analysis of the phenomenon under consideration of the particle size distribution showed, that this was caused by a significant increase of the particle concentration of small particles, typical for combustion processes.

In fact a significantly increased particle concentration can be seen in many cities in Germany and Austria in the night to Easter Sunday. This is caused by Easter fire – a tradition from

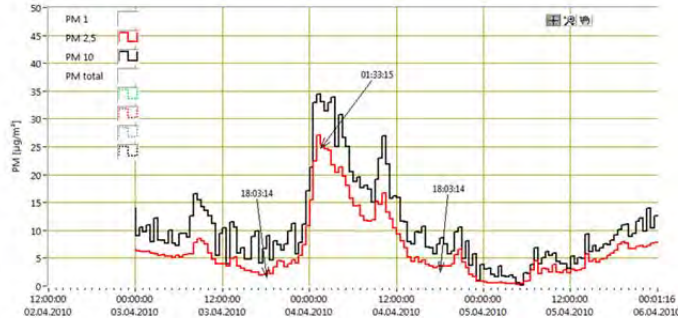
olden times, which is used to frighten away and to burn winter. The resulting combustion aerosols contain a high number of small particles.

To model the propagation behavior of fine dust, the particle size distribution is as well important as the high time resolution (a time resolution of one second is technically possible with the Fidas®) as for the forecast of the propagation the physical characteristics of the particles are decisive. The diameter enables a derivation of the sedimentation velocity and the number concentration enables a derivation of the coagulation behavior.

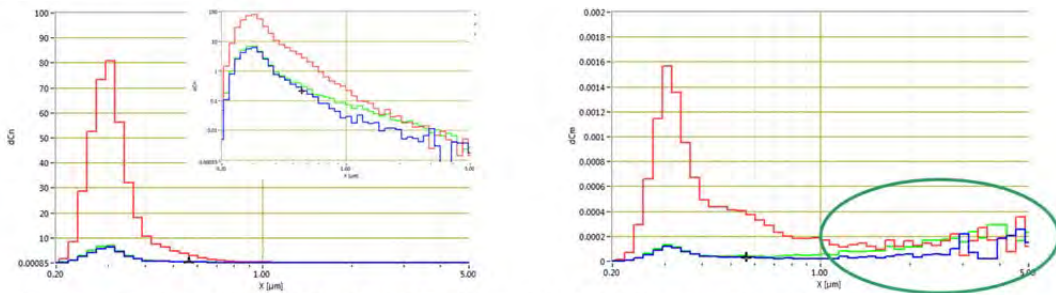


Easter fire

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

Fig. 51: Additional information from particle size distributions during an increase of PM concentrations

5.5 Basic definitions

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?

5.6 Effects of the device's characteristics

- **Border Zone Error**

The particle size spectrum is measured with too many fines. The broader the particle size spectrum is measured, the more important becomes the border zone error.

- **Coincidence Error**

The particle size spectrum is measured too coarse, the particle concentration is measured too small. According to the definition, a coincidence of 10% is tolerable.

- **Counting Efficiency**

The lower counting efficiency results in a shifting of the particle size distribution towards coarse particles because the fines are undervalued. The upper counting efficiency similarly undervalues the coarse particles.

The quantity is determined incorrectly.

When measuring with several particle counters, the counting efficiency difference between the used counters has to be known. Only then, the results are comparable!

- **Classification Accuracy**

During correlation measurements (e.g. with impactors), the correlation factor becomes better, the higher is the classification precision.

Instruments with a good classification precision over the total measurement range supply reliable distributions.

- **Resolution Capacity**

During correlation measurements (e.g. with impactors), the correlation factor becomes better, the higher is the resolution capacity. Instruments with a high resolution capacity are able to measure bi- and tri-modal distributions that are located close to each other.

6 Ensuring correct measurement conditions

In case of disadvantageous test conditions, the measuring result, i.e. the determined particle size distribution of the single measurements, can considerably differ from the actual existing values in the aerosol flow.

Therefore, please pay attention to:

- Representative sample taking
- Minimal particle losses through the aerosol transport
- No coincidence error

Please note: Palas® regularly offers training courses about these topics.

As a basic principle, the Fidas® system can only measure and display data which have been registered in its optical measuring volume. That means the aerosol sampling flow should be lead there as straight as possible.

Therefore, please pay attention to:

- short tubes for the aerosol
- if possible, metal tubes, in no case longer plastic tubes (high particle separation due to electrostatic charging)
- vertical aerosol guiding, as bigger particles (> 5 µm) sediment respectively the aerosol separates

As basic principle of all counting scattered light measuring technologies, just one single particle may be in the optically limited measuring volume of the sensor at the same time. This due to the fact, that the scattered light of the single particle is being evaluated for the determination of the particle size.

If more than one particle is in the measuring volume at the same time, these particles are measured as one, i.e. the particle is being measured too big and the number too small.

If the Fidas® is used at locations with significantly higher concentrations and if the Fidas® reports a coincidence value that is higher than 10 % it can be necessary to turn on the coincidence correction to extend the original concentration range of 0 to 10,000 µg/m³ significantly.

The advices given here are surely not sufficient to ensure a correct measurement in any case. In case of particular problems, please contact Palas® directly.

7 Technical data Fidas® system:

Size of optical measuring volume (WxDxH)	262 µm x 262 µm x 164 µm	
Maximum concentration for 10 % coincidence error	Sensor integrated into the control unit max. concentration up to 4,000 P/cm ³	
Maximum concentration and coincidence detection/correction	20,000 P/cm ³	
Maximum concentration (mass)	10,000 µg/m ³	
Communication between control unit and evaluation PC	RS-232 (Bayern-Hessen, ASCII or Modbus) Ethernet (UDP ASCII, TeamViewer, etc.)	
Suction volume flow	1.4 l/min SATP (Model Fidas® mobile) 4.8 l/min SATP (Models 100 and 200)	
Cleaning	The housings can be cleaned with non-aggressive detergents (e.g. household detergent) or spirit. Cleaning the optical lenses: please see maintenance	
Mains connections (see identification plate!) mains voltage: mains fuse:	230 V, +/-10 % 2 pieces T 2 A / 250 V	115 V, +/-10 % 2 pieces T 4 A / 130 V
Power consumption frequency	200 W 47-63 Hz	
Environmental conditions	Temperature range from -20°C to 50 °C (Fidas® 200 S) Temperature range from 5°C to 40 °C (Fidas® 200, Fidas® 200 E) Sound emission << 85 dBA	
Dimensions (HxWxD)	Control unit incl. integrated sensor: 195 mm x 450 mm x 310 mm Weather protective housing with IADS and weather station: 1810 mm x 600 mm x 400 mm	
Weight	Control unit incl. integrated sensor: 9,3 kg Weather protective housing with IADS, Sigma-2 and weather station: 48 kg	

Technical data are subject to change.

8 Annexes:

8.1 IP65 weather protective housing for Fidas® system:

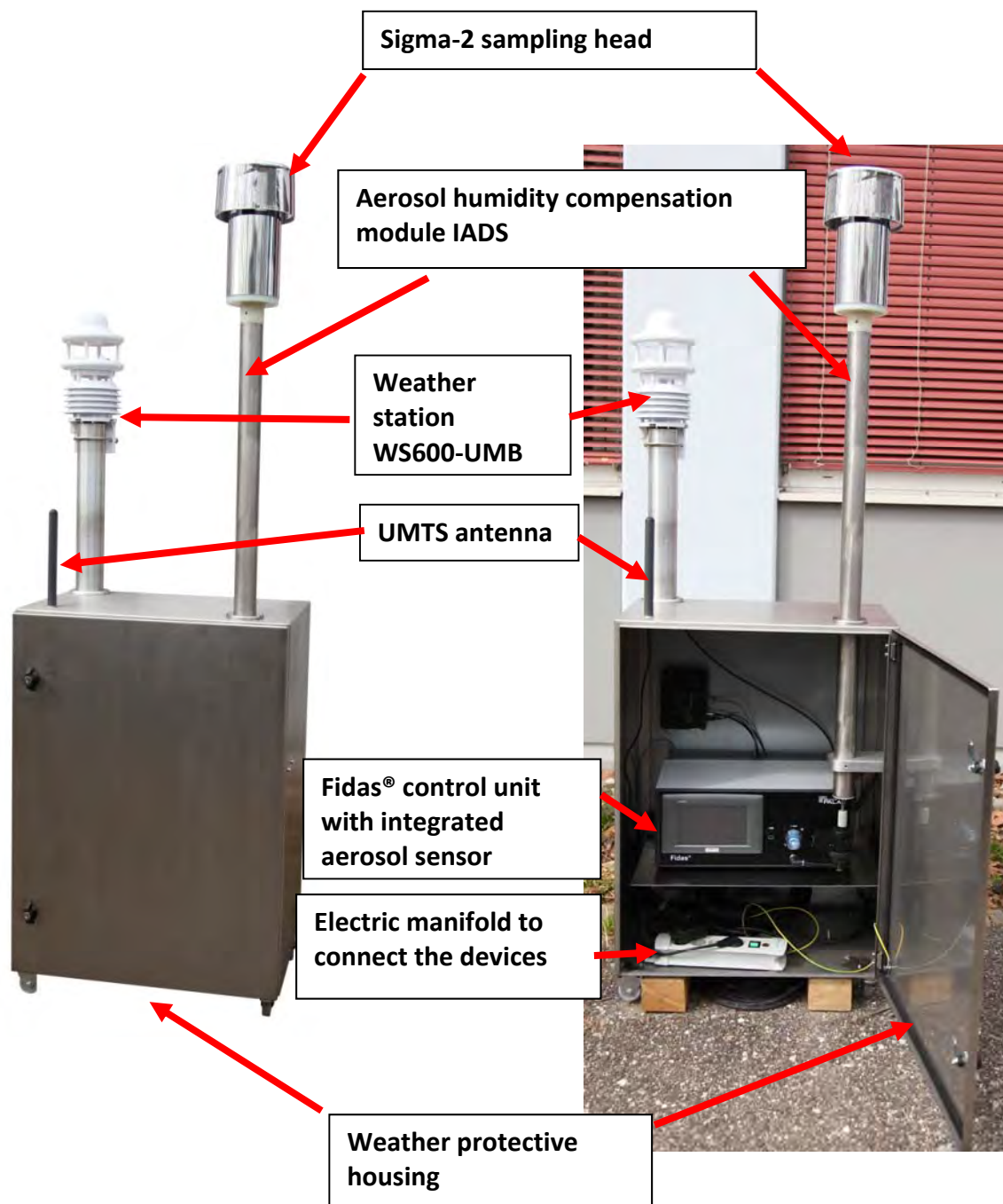


Fig. 52: Weather-protective housing closed

Fig. 53: Weather protective housing open

8.2 Aerosol humidity compensation module IADS

8.2.1 General remarks

With high ambient humidity, water condensates onto the particles and thus falsifies the particle size. This effect can be avoided by use of the aerosol humidity compensation module IADS.

The temperature of the IADS is controlled depending on the ambient temperature and humidity (measured by the weather station).

The minimum temperature is 23°C. The moisture compensation is carried out by a dynamic adjustment of the IADS temperature up to a maximum heating output of 90 watt.

The aerosol humidity compensation module IADS is connected with an adapter to the aerosol sensor of the Fidas® system. For cleaning of the aerosol sensor, the adapter is pushed downwards, so that the IADS can be completely pushed upwards. Then, the aerosol inlet of the sensor is easy to access.

The aerosol humidity compensation module is controlled via the Fidas® firmware (see separate manual Fidas® firmware for detailed information).

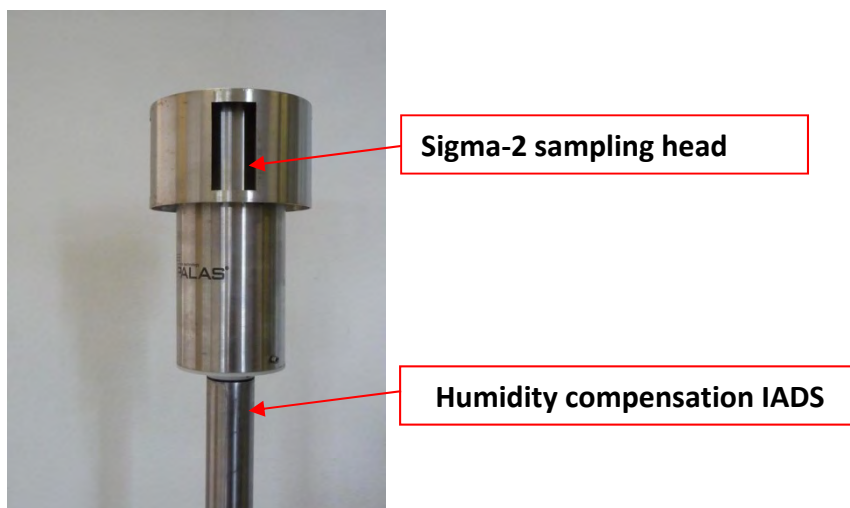


Fig. 54: Sigma-2 sampling head with IADS

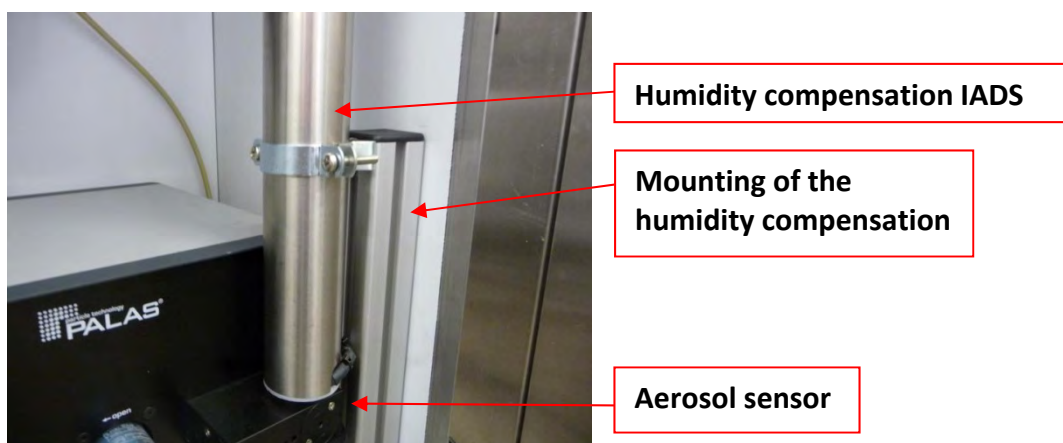


Fig. 55: Fidas® control unit, aerosol sensor with IADS

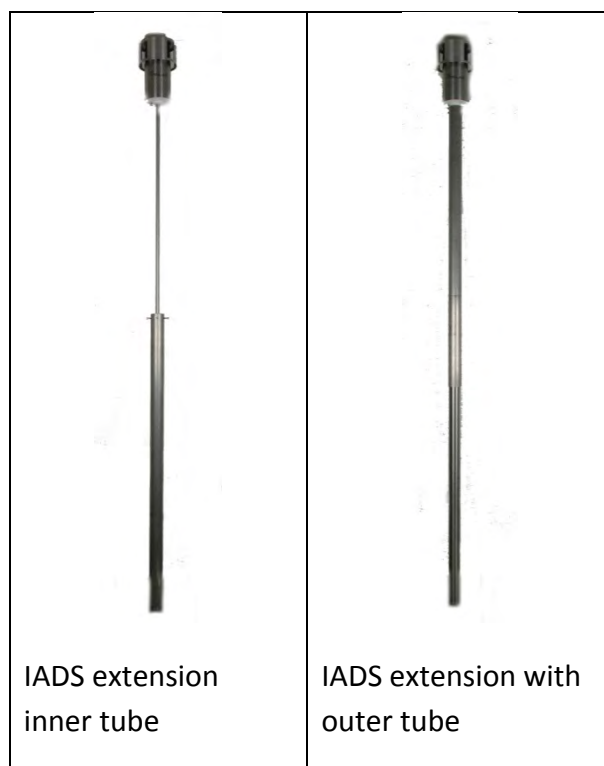
Important technical dimensions of the IADS are:

Length: 1150 mm plus 80 mm small tubing on which the Sigma-2 head is placed

Outer diameter: 48.3 mm

8.2.2 Extended IADS

For the installation of the Fidas® 200 in an existing container Palas® offers the option of using an extension for the IADS:



Length: 1.20 m to 2.10 m (can be cut to fit by user)

The outer tube fits over the original IADS and can thereby be adjusted to accommodate the length of the inner tube that is cut to fit the desired length. The outer tube provides additional support of the sampling head.

When cutting the inner tube of the extension to the desired length using e.g. a metal saw the following important points should be considered:

- the cut should be as straight as possible
- the edge of the cut tube should be deburred
- all shavings need to be removed before installing it

When the extended IADS is shipped the following steps are necessary to assemble it:

- Confirming the components:



- Attaching inner tube for extension to IADS:



slide the inner tube into the IADS until about 4 cm are inside

- Sliding outer tube for extension over inner tube:



Slide outer tube over inner tube, leave 8 cm on top then tighten the four M4 screws in a criss-cross fashion. Then attach Sigma-2 sampling head by sliding it over the 8 cm inner tubing until it rests on the outer tubing.

8.3 Sigma-2 sampling head

The Sigma-2 sampling head according to VDI 2119 for measurements widely independent of wind is simply put on the aerosol inlet of the Fidas® sensor or, if there is one, on the aerosol humidity compensation module IADS.

Using a hexagon socket screw key, it can be fixed by the locking screw.

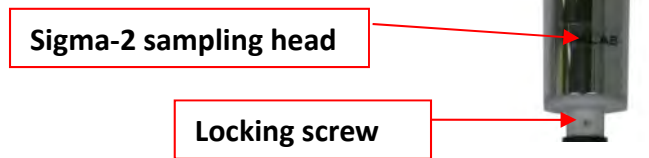


Fig. 56: Sigma-2 sampling head

The Sigma-2 head should be checked up on dirt every three month (in combination with the calibration).

8.4 Compact weather station WS600-UMB respectively WS300-UMB

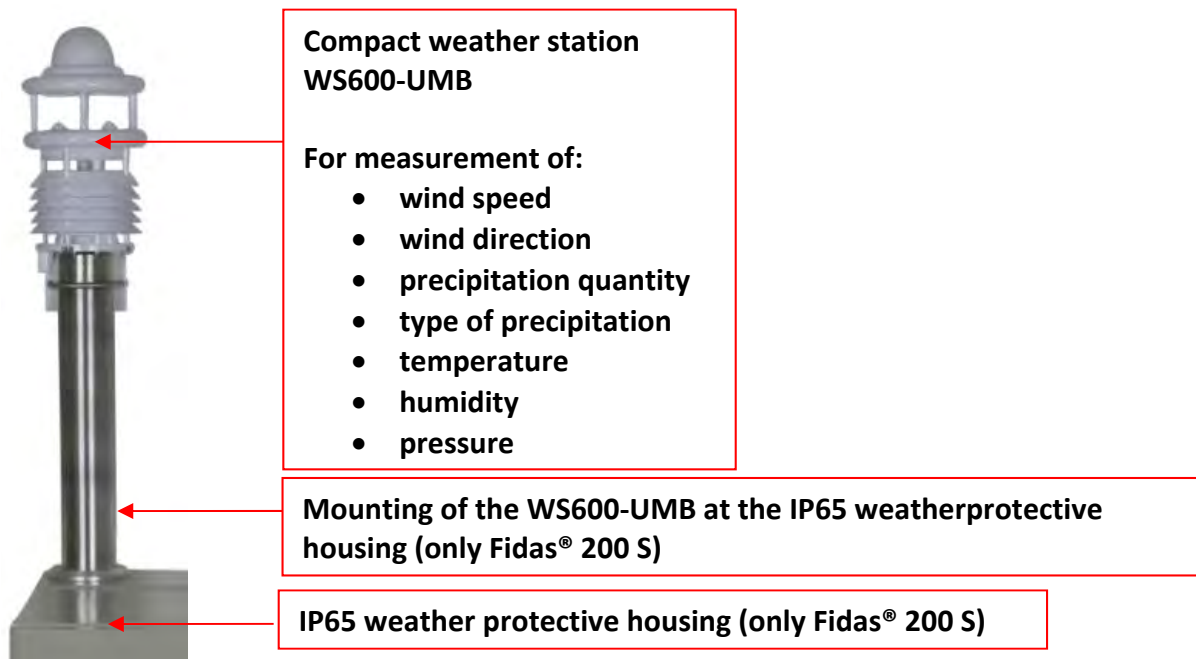


Fig. 57: Compact weather station (here: WS600-UMB)

Remark: The weather station is also available in a smaller version WS300-UMB, which only records the measurands necessary for the operation of the measuring system – namely temperature, humidity and pressure. The applied sensor technique for these three measurands is completely identical with WS600-UMB.

The weather station WS600-UMB respectively WS300-UMB is readout by the Fidas® firmware (see separate manual Fidas® firmware for detailed information).

Special features:

- All in One
- Aspirated temperature/humidity measurement
- Maintenance-free operation
- Open communication protocol
-

Description country version: EU, USA and Canada:

WS600-UMB compact weather station for the measurement of air temperature, relative humidity, precipitation intensity, precipitation type, precipitation quantity, air pressure, wind direction and wind speed. Relative humidity is measured by means of a capacitive sensor element; a precision NTC measuring element is used to measure air temperature. Precipitation is measured by way of a 24 GHz Doppler radar, which measures the drop speed of an individual drop of rain/snow. Precipitation quantity and intensity are calculated from the correlation between drop size and speed. The difference in drop speed determines the type of precipitation (rain/snow). Maintenance-free measurement offers a major advantage over the common tipping spoon and tipping bucket processes. Ultrasonic sensor technology is used to take wind measurements. Measurement data are available for further processing in the form of a standard protocol (Lufft-UMB protocol).

WS300-UMB compact weather station for the measurement of air temperature, relative humidity and air pressure. Relative humidity is measured by means of a capacitive sensor element; a precision NTC measuring element is used to measure air temperature. Measurement data are available for further processing in the form of a standard protocol (Lufft-UMB protocol).

8.4.1 Technical data WS600-UMB

Dimensions	Ø approx. 150 mm, height approx. 345 mm
Weight	Approx. 2.2kg
Interface	RS485, 2-wire, half-duplex
Power supply	24 VDC $\pm 10\%$ <4 VA (without heating)
permitted operating temperature	-50...60°C
Permitted operating rel. humidity	0...100 % r. H.
Heating	40 VA bei 24 VDC
Cable length	10 m
Sensor for temperature:	
Principle	NTC
Measuring range	-50...60°C
Unit	°C
Accuracy	$\pm 0.2^\circ\text{C}$ (-20...50°C), otherwise $\pm 0.5^\circ\text{C}$ (>-30°C)
Sensor for rel. humidity:	
Principle	Capacitive
Measuring range	0...100 % r. H.
Unit	% r. H.
Accuracy	$\pm 2\%$ r. H.
Sensor for air pressure:	
Principle	MEMS capacitive
Measuring range	300...1200 hPa
Unit	hPa
Accuracy	± 1.5 hPa
Sensor for wind direction	
Principle	Ultrasonic
Measuring range	0...359.9°
Unit	°
Accuracy	$\pm 3^\circ$
Sensor for wind speed:	
Principle	Ultrasonic
Measuring range	0...60 m/s
Unit	m/s
Accuracy	± 0.3 m/s oder 3 % (0...35 m/s)
Sensor for precipitation amount:	
Resolution	0.01 mm
Reproducibility	typ.>90 %
Measuring range drop size	0.3...5 mm
Type of precipitation	Rain/snow
Accessories of the WS600-UMB compact weather station:	
UMB interface converter ISOCON	
Mast 4.5 m, hot-dip galvanized, tiltable	
Power supply 24V/4 A	

8.4.2 Technical data WS300-UMB

Dimensions	Ø approx. 150 mm, height approx. 223 mm
Weight	Approx. 1 kg
Interface	RS485, 2-wire, half-duplex
Power supply	4...32 VDC
permitted operating temperature	-50...60°C
Permitted operating rel. humidity	0...100 % r. H.
Cable length	10 m
Sensor for temperature:	
Principle	NTC
Measuring range	-50...60°C
Unit	°C
Accuracy	±0.2°C (-20...50°C), otherwise ±0.5°C (>-30°C)
Sensor for rel. humidity:	
Principle	Capacitive
Measuring range	0...100 % r. H.
Unit	% r. H.
Accuracy	±2 % r. H.
Sensor for air pressure:	
Principle	MEMS capacitive
Measuring range	300...1200 hPa
Unit	hPa
Accuracy	±1.5 hPa
Accessories of the WS300-UMB compact weather station:	
UMB interface converter ISOCON	
Mast 4.5 m, hot-dip galvanized, tiltable	
Power supply 24V/4 A	

9 Reader's comments sheet

In order to improve our manuals continuously we kindly ask you to fill in this questionnaire and to return it to Palas®. Thank you for your cooperation.

How to contact us:

Address: Greschbachstraße 3 b, 76229 Karlsruhe, Germany

Phone: +49 721 96213-0 Fax: +49 721 96213-33 E-mail: mail@palas.de

This evaluation concerns: Fidas® fine dust monitor systems, V0100914

Please inform us about your contact data:

Company: _____

Name: _____

Address: _____

Telephone or e-mail: _____

Were the procedures clearly written and easy to understand?

yes

no

If not, please explain: _____

Did you miss some information?

yes

no

If yes, please explain: _____

Have you been satisfied with the structure of the manual? Did you quickly find the required information?

yes

no

If not, please explain: _____

In case of technical problems, have you been satisfied with the telephone support?

yes

no

If not, please explain: _____

Please feel free to add any comments you may find necessary or helpful:

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User manual

PDAnalyze Software

For use with the:

Fidas[®] series

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1. Overview

The PDAalyze-Fidas is a powerful software package created to evaluate the data of the Fidas® fine dust monitoring systems.

Note: Do not confuse this software that is specifically and only designed for the Fidas® system with the **PDAalyze software** that Palas® provides with the optical aerosol spectrometers (e.g. Promo®) and nanoparticle instrumentation (e.g. UF-CPC, U-SMPS).

2. Installing the PDAalyze-Fidas Software

2.1 Installing from CD or USB stick

Go to Software PC/Software PDAalyze you then see three folders:

Name	Änderungsdatum	Typ
PDAalyze	26.03.2013 09:11	Dateiordner
PDAalyze Fidas	26.03.2013 09:11	Dateiordner
Runtime Installer	26.03.2013 09:10	Dateiordner

Figure 1: Software folders on the supplied CD or USB stick

First, run the setup.exe in the folder “Runtime Installer” to install the required LabView components together with a version of the PDAalyze software (for more information on this evaluation software for general use with Palas® particle measurement systems please see “Manual PDAalyze Software”).

Then copy the files under “PDAalyze Fidas” to a location of your choice on your computer.

Note: Please make sure you have read/write/delete rights in the folder that you copy the files to, otherwise the PDAalyze-Fidas will not run correctly.

2.2 Installing from the Palas® webpage

Sign on to the password protected user area on the Palas® webpage:



PALASCOUNTS

Login

Nickname :

Password :

Register user
 Lost Password?

Figure 2: Login on Palas® webpage

If you have not logged in before, you first have to “Register user” and enter a nickname, password and e-mail address. This generates a request to the Palas® administrator. Upon validation of your request you’ll receive an e-mail notifying you that your access is now active. Please note that the validation process can take up to two business days. In the user area go to “Software Updates” and then to “PDAnalyze and PDAnalyze Fidas”. In the sub-folder select PDAnalyze Fidas, you’ll then see the following files:



Figure 3: Installing PDAnalyze-Fidas via the Palas® webpage

First, download and unzip Volume.zip on your computer. Then run the setup.exe to install the required LabView components together with a version of the PDAnalyze software (for more Information on this evaluation software for general use with Palas® particle measurement systems please see “Manual PDAnalyze Software”).

Next, download and save pdanalyze-fidas.exe to a location of your choice on your computer.

Note: Please make sure you have read/write/delete rights in the folder that you copy the files to, otherwise the PDAnalyze-Fidas will not run correctly.

3. Start of the PDAnalyze Software

Please start **pdanalyze-fidas.exe** to open the data evaluation software.

PDAnalyze is the designated data evaluation software for the Fidas® fine dust monitoring system that includes the following models:

- Fidas® mobile
- Fidas® 100
- Fidas® 200 and 200 S
- Fidas® 300 and 300 S

Figure 4 shows the main screen that is shown upon start-up of the software. It's divided into two sections. The left section shows two tabs

- files selects file location, averaging interval and which files to import
- intervals shows the data files divided into the preset averaging intervals

The right section is devoted to data display and analysis and shows 11 tabs

- PM data displays and exports data by PM fractions
- Internal sensors displays humidity, temperature and pressure data (only if such sensor was connected)
- Filter shows history of filter exchanges with data entered (not applicable to Fidas® mobile and only if filters were manually inserted and changed)
- Operating parameter displays particle velocity, pump performance, LED temperature and flow rate
- Comments displays comments if they were entered during a measurement
- Weather station displays weather station data
- Heating units displays set and measured temperatures for IADS etc.
- Settings displays operational settings of the instrument (same screen as on the instrument itself)
- Status displays instrument status screen
- Specific intervals individually sets custom interval lengths, e.g. if evaluation procedure requires specific intervals
- algorithm selects the algorithm used for evaluating the data (customized algorithms for specific circumstances (e.g. placement of the unit near a cement factory) can be created and applied)

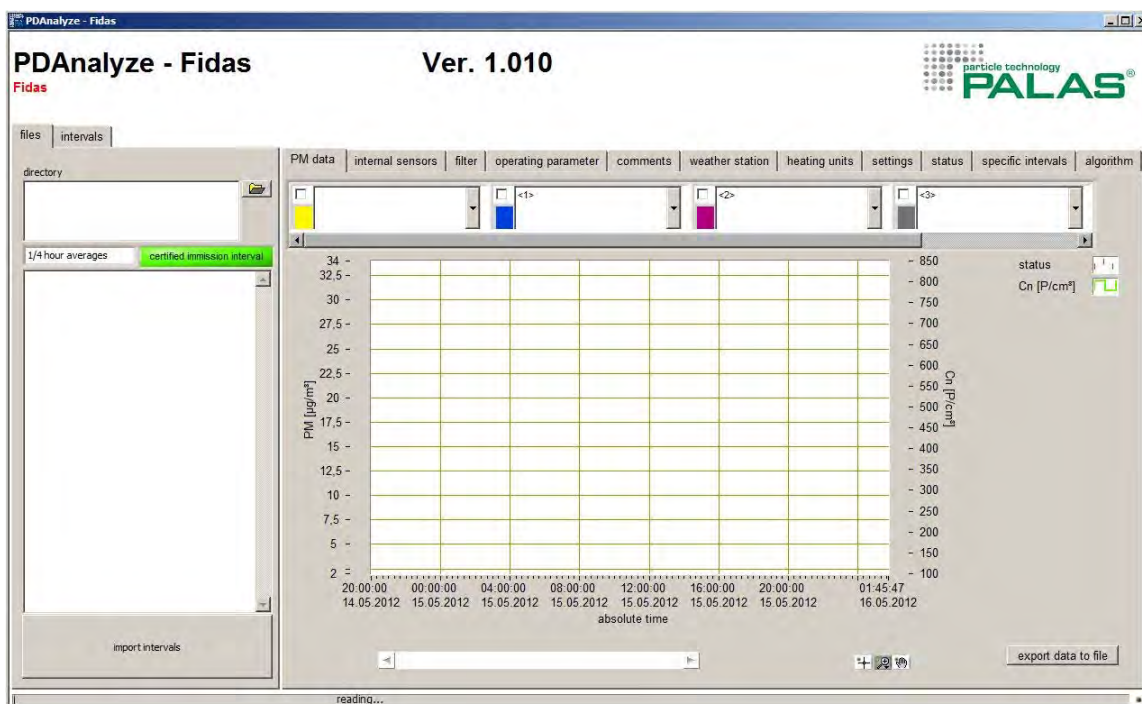


Figure 4: Main screen of the PDAnalyze-Fidas evaluation software

4. Left section of PDAnalyze-Fidas – “files”, “intervals”

4.1 Tab “files”

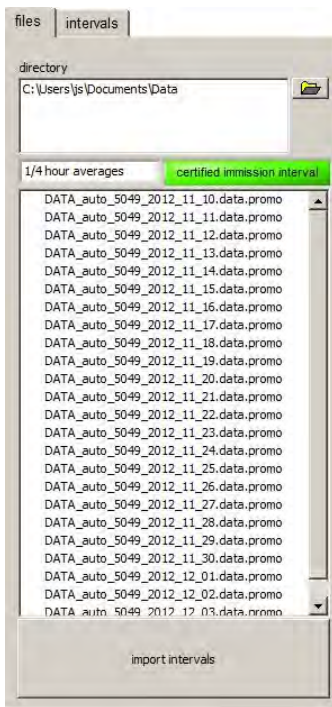


Figure 5: Tab “files”

In the upper section the location where the data files are stored can be selected. Click on the directory symbol and select the directory in which the data files are stored. Acknowledge the selection with “select folder”. The lower part will then list all data files in that directory as shown in figure 5.

By default the evaluation interval is set to 1/4 hour averages which is also the certified immission interval. Only if this one is selected the green message “certified immission interval” is displayed. Figure 6 shows the other possible choices:

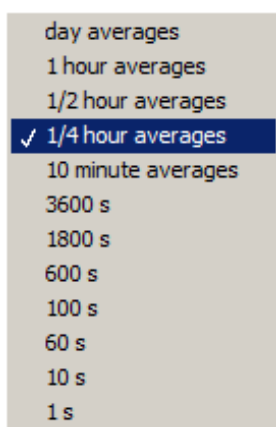


Figure 6: Possible choices for averaging interval

After selecting the averaging interval you then need to select the data files. Select one file by left-clicking on it, select multiple files by ‘Strg’+left-clicking on them.

Once the files are selected press “import intervals” to load the data into the program for evaluation.

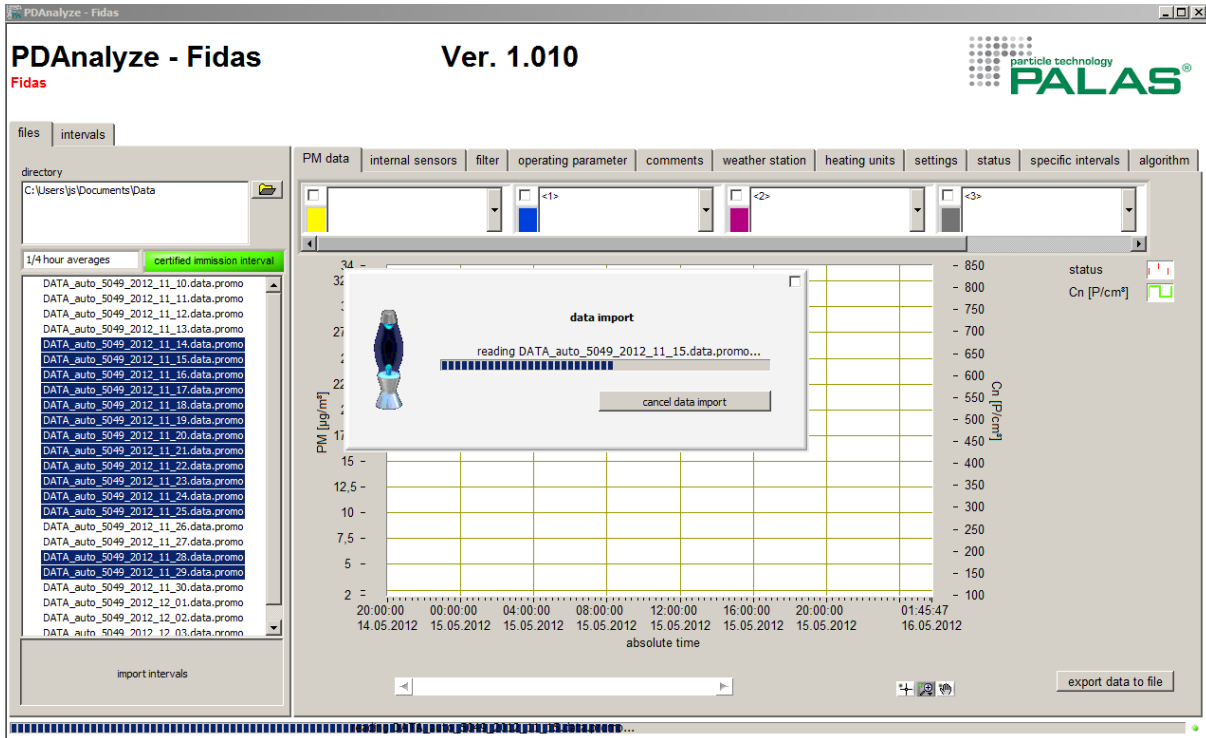


Figure 7: Importing the selected data files with the selected averaging intervals

When all selected data are imported the software will show the following result next to the version number of the software:



Figure 8: Result of importing the data

Note: If you are running the PDAnalyze-Fidas software for the very first time you may be prompted to select an algorithm when you press “import intervals”. Please do so (see section 5.11) and then continue.

4.2 Tab “intervals”



Figure 9: Tab “intervals”

In this tab the files for the following display and analysis options (tabs on right section) are selected.

The intervals are shown in the format:

Date (dd.mm.yyyy) – interval start time – length of interval in seconds / number of original data – instrument status

The instrument status can be:

- | | | |
|---|------------------|---|
| a | auto mode | standard operation mode of the instrument |
| c | calibration mode | during calibration/verification of the instrument the data are automatically flagged as “c” and not used for evaluation |
| i | idle | instrument was switched to idle, i.e. not measuring data |
| m | manual mode | instrument was switched to manual mode |

If the instrument is operated in a high concentration environment and coincidence becomes significant the intervals will show “∅” in front of the interval.

The last line in this list (range first interval -> last interval) includes all intervals and can be selected if all data shall be displayed and evaluated.

5. Right section of PDAnalyze-Fidas – display and evaluation of data

5.1 Tab “PM data”

Please select the data for display. There are several choices:

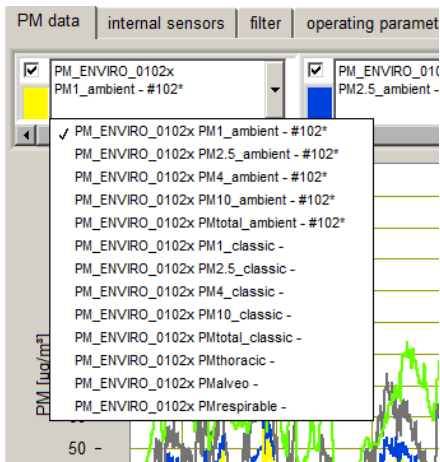


Figure 10: Select what data to display

Note: **PMxxx_ambient** uses a size dependent and weighted conversion algorithm from particle size and number to PM fraction. This conversion is based on many comparison measurements of ambient aerosol at different locations and at different seasons and is currently under evaluation by the TÜV in an equivalency test.

PMxxx_classic uses a fixed density to convert particle size and number to PM fraction. This is best used if evaluating an aerosol that is known (e.g. that is generated using an aerosol generator, please contact Palas® for recommendations about aerosol generators for specific applications).

PMthoracic, **PMalveo**, **PMrespirable** use conversion algorithms from particle size and number to PM fraction that are based on DIN EN 481:1993 “Arbeitsplatzatmosphäre – Festlegung der Teilchengrößenverteilung zur Messung luftgetragener Partikel”.

After the selection is made the data are displayed in the graph below:

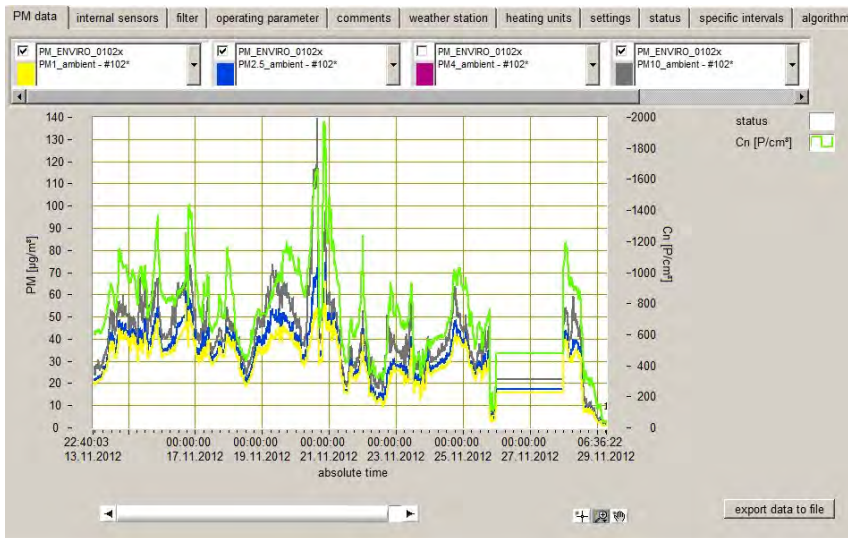


Figure 11: Tab “PM data”

Figure 11 shows the data that are displayed after making the selections in the boxes above the graph. The number concentration is always displayed as well in green color (numbers referring to right axis).

If you would like to remove the curve for number concentration, please right click on the box next to “Cn” [P/cm³], i.e. the one showing the green trail. In the context menu select “Colour” (second item from the top), then select the “T” for transparent colouring (see figure 12). This effectively removes the green curve from the graph.

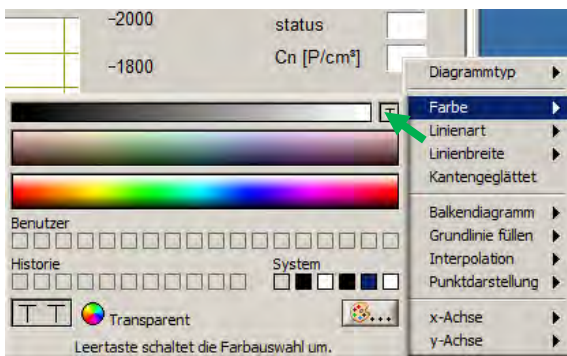


Figure 12: Removing the curve for number concentration “Cn” from the graph

Note: If an error occurred during measurements a red vertical line is drawn in the graph at the time it occurred. If the error persisted, the data display is hidden behind a red curtain. In this case you can remove these multiple red lines the same way you remove for example the curve for number concentration by setting the colour to transparent.

By clicking on the graph and moving the cursor to the left you can zoom into the data. The slider on the bottom of the graph then allows you to scan through the data.

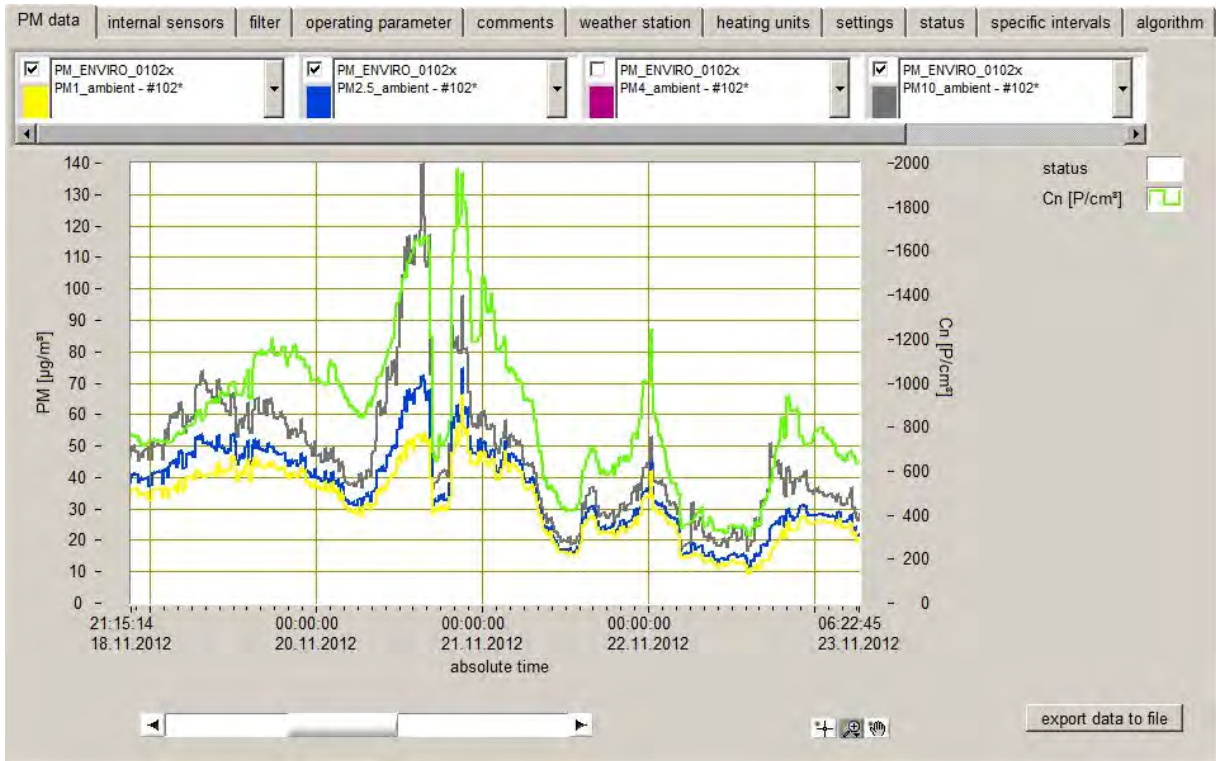


Figure 13: Zooming into the data

With “export data to file” the displayed data (full range) are exported to a tab delimited text file with the following header (example):

```
*
13.11.2012 23:58:47 ___ 29.11.2012 23:46:46
14 file(s)
1343 intervals of 1/4 hour averages
FIDAS®, 0.18 - 18.0 µm #1
date beginning time beginning date end time end date beginning (UTC) time
beginning (UTC) date end (UTC) time end (UTC) relative time [s] status Cn [P/cm³]
PM_ENVIRO_0102x - PM1_ambient - #102* PM_ENVIRO_0102x - PM2.5_ambient - #102*
PM_ENVIRO_0102x - PM4_ambient - #102* PM_ENVIRO_0102x - PM10_ambient - #102*
```

5.2 Tab “internal sensors”

From April 1st, 2013 all Fidas® mobile and Fidas® 100 units are outfitted with internal sensors for ambient pressure, ambient temperature and relative humidity.

Other Fidas® models can be connected to an ambient p, T, rH sensor (Palas® accessory) in addition to the supplied weather station, for example to monitor the temperature inside the environmental enclosure. If such a sensor is present, its data are logged with the particle data and can be displayed with this tab as shown in figure 14.

Note: If no p, T, rH sensor is connected this tab will show no data.

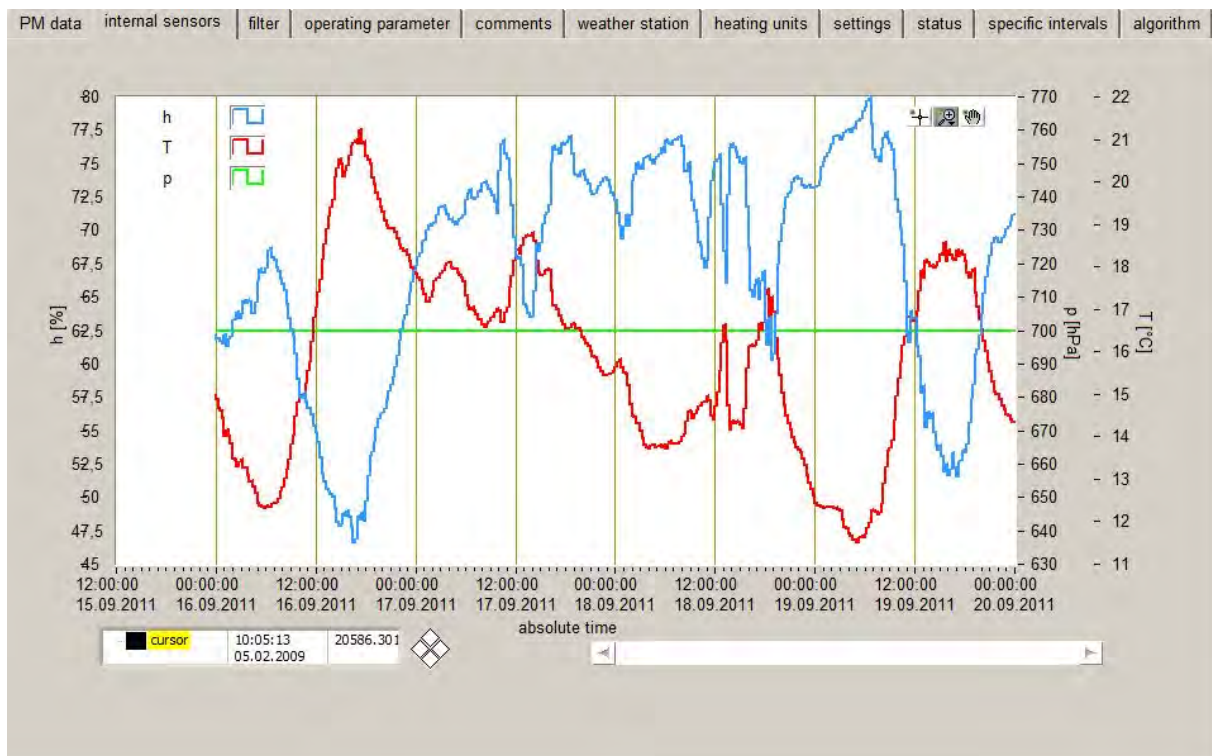


Figure 14: Tab “internal sensors” if a p, T, rH sensor is connected to the instrument

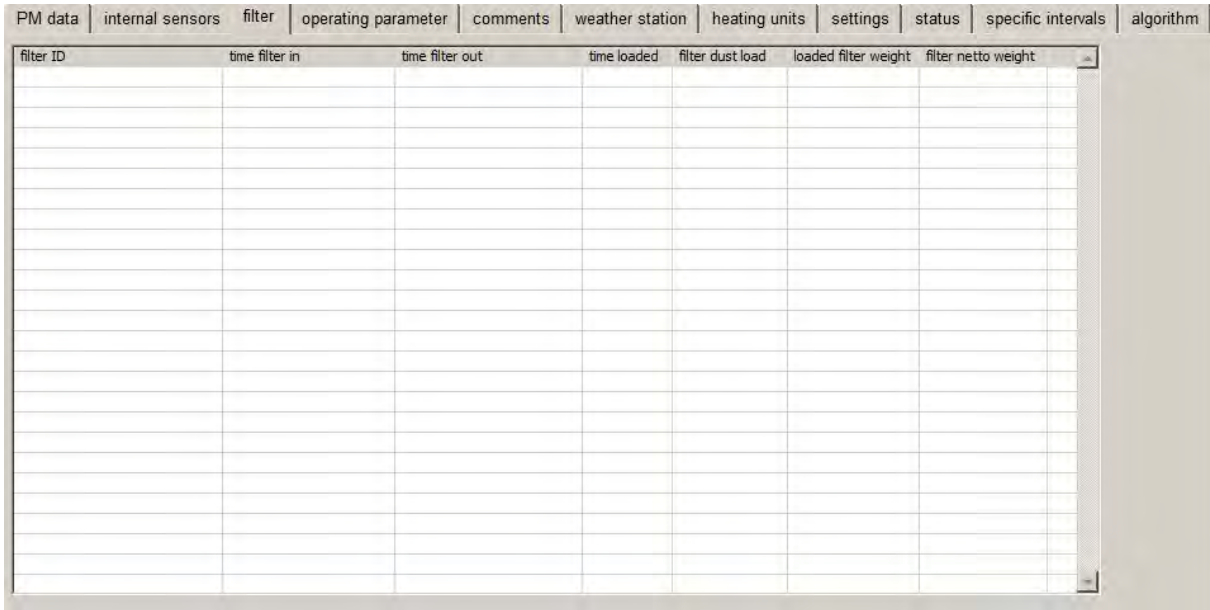
The graph shows the relative humidity (h-blue), temperature (T-red) and ambient pressure (p-green) versus time.

Note: These data can not be exported to a text file.

5.3 Tab “filter”

This tab is only applicable to models with a filter holder, i.e. Fidas® 100, Fidas® 200/200 S, Fidas® 300/300 S.

If the user has manually exchanged filters and entered the appropriate data in the instrument, this tab shows a summary.



filter ID	time filter in	time filter out	time loaded	filter dust load	loaded filter weight	filter netto weight	

Figure 15: Tab “filter” showing a summary of filter exchanges

5.4 Tab “operating parameter”



Figure 16: Tab “operating parameter” showing particle velocity, pump performance, LED temperature and flow rate

In the graph under this tab important instrument operating parameters are shown for the whole duration of the imported data files.

u	(blue)	particle velocity through the optical sensing volume
pump performance	(gray)	percentage load of the pump(s) used in the instrument values above 60 % create a warning (see also section 5.9)
LED temperature	(green)	ambient changes in temperature requires that the LED light source is temperature monitored and controlled to ensure constant output
flow rate	(red)	volume flow rate through the instrument regulated to 1,4 l/min for the Fidas® mobile and regulated to 5,0 l/min for Fidas® 100, Fidas® 200/200 S, and Fidas® 300/300 S

With “export to file” the displayed values are exported to a tab delimited text file with the following header (example):

```
FIDAS®, 0.19 - 18.0 µm #1
12.03.2012 16:58:02 ___ 13.03.2012 13:31:40
2 file(s)
41 intervals of 1/2 hour averages
date end      time end      relative time [s]      in sensor particle velocity u [m/s]      pump
performance [%]      LED temperature [°C]      flow rate [l/min]
```

5.5 Tab “comments”

PM data	internal sensors	filter	operating parameter	comments	weather station	heating units	settings	status	specific intervals	algorithm
				time						
				comment						
				20.01.2012 08:56:10						
					BUERO					
				20.01.2012 09:04:30						
					H602H02					
				20.01.2012 09:14:36						
					HDEP HE-PRUEFANLAGE					
				20.01.2012 09:23:30						
					HDEP LOGISTIKPLATZ					
				20.01.2012 09:32:17						
					MDEG					
				20.01.2012 09:40:27						
					PNS Q-PLATZ					
				20.01.2012 14:15:55						
					H602H02					
				20.01.2012 14:23:31						
					HDEP HE-PRUEF					
				20.01.2012 14:28:18						
					HDEP LOGISTIK					
				20.01.2012 14:34:40						
					MDEG					
				20.01.2012 14:42:19						
					PNS Q-PLATZ					
				20.01.2012 16:37:25						
					H602H02					
				20.01.2012 16:45:24						
					HDEP HE-PRUEF					
				20.01.2012 16:51:47						
					HDEP LOG					
				20.01.2012 16:57:37						
					MDEG					
				23.01.2012 08:47:57						
					H602H					
				23.01.2012 08:54:31						
					HDEP HE-PRUEFUNG					
				23.01.2012 08:59:34						
					HDEP LOG					
				23.01.2012 09:07:00						
					MDEG					
				23.01.2012 09:13:28						
					PNS Q					
				23.01.2012 09:26:06						
					ROB					
				23.01.2012 12:57:18						
					H602H					
				23.01.2012 13:05:50						
					HDEP HE					
				23.01.2012 13:14:17						
					HDEP LOG					
				23.01.2012 13:21:15						
					MDEG					
				23.01.2012 13:29:42						
					PNS Q					
				23.01.2012 17:38:32						
					H602H02					
				23.01.2012 17:44:50						
					HDEP HE					

Figure 17: Tab “comments”

If comments were entered during the measurement, for example to discriminate different sampling locations when using the Fidas® mobile, these comments are shown here, listed by their date and time.

Note: These comments also appear as annotations to the graph shown under “PM data” (see section 5.1).

5.6 Tab “weather station”

If the instrument was connected to a Lufft weather station (standard for Fidas® 200/200 S and Fidas® 300/300 S) the weather station data are displayed under this tab.

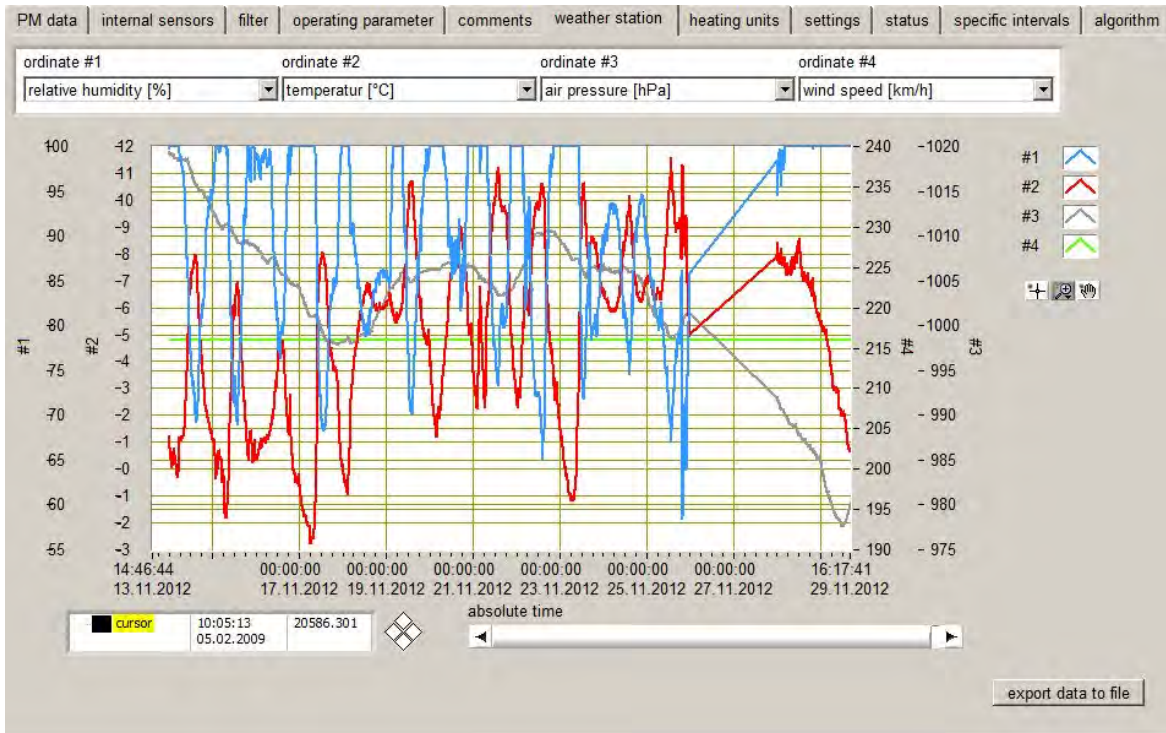


Figure 18: Tab “weather station” displaying weather station data

Depending on the weather station that is connected, e.g. WS-300-UMB (p, T, rH) or WS-600-UMB (p, T, rH, wind speed, wind direction etc.) different values can be displayed.

Figure 19 shows the choices currently implemented in the software:

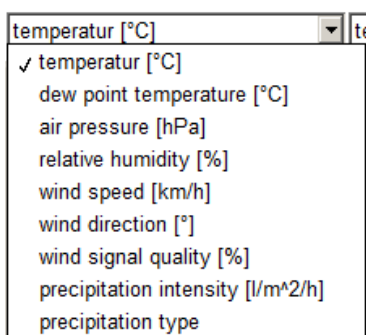


Figure 19: Choice of values to be displayed if available by connected weather station

With “export data to file” the displayed values are exported to a tab delimited text file with the following header (example):

```
FIDAS®, 0.19 - 18.0 µm #1
12.03.2012 16:58:02 ___ 13.03.2012 13:31:40
2 file(s)
41 intervals of 1/2 hour averages
date   time   relative time [s] humidity [%]   wind speed [km/h]   wind direction [°]
      precipitation intensity [l/m²/h]   precipitation type   dew point temperature [°C]   air
pressure [hPa]   wind signal quality [%]   temperature [°C]
```

5.7 Tab “heating units”

The Fidas® mobile and Fidas® 100 don’t contain heating elements, so this tab is not applicable to them. In Fidas® 200/200 S, 300/300 S systems the heating units refer to the heating used in the intelligent aerosol drying system (IADS).

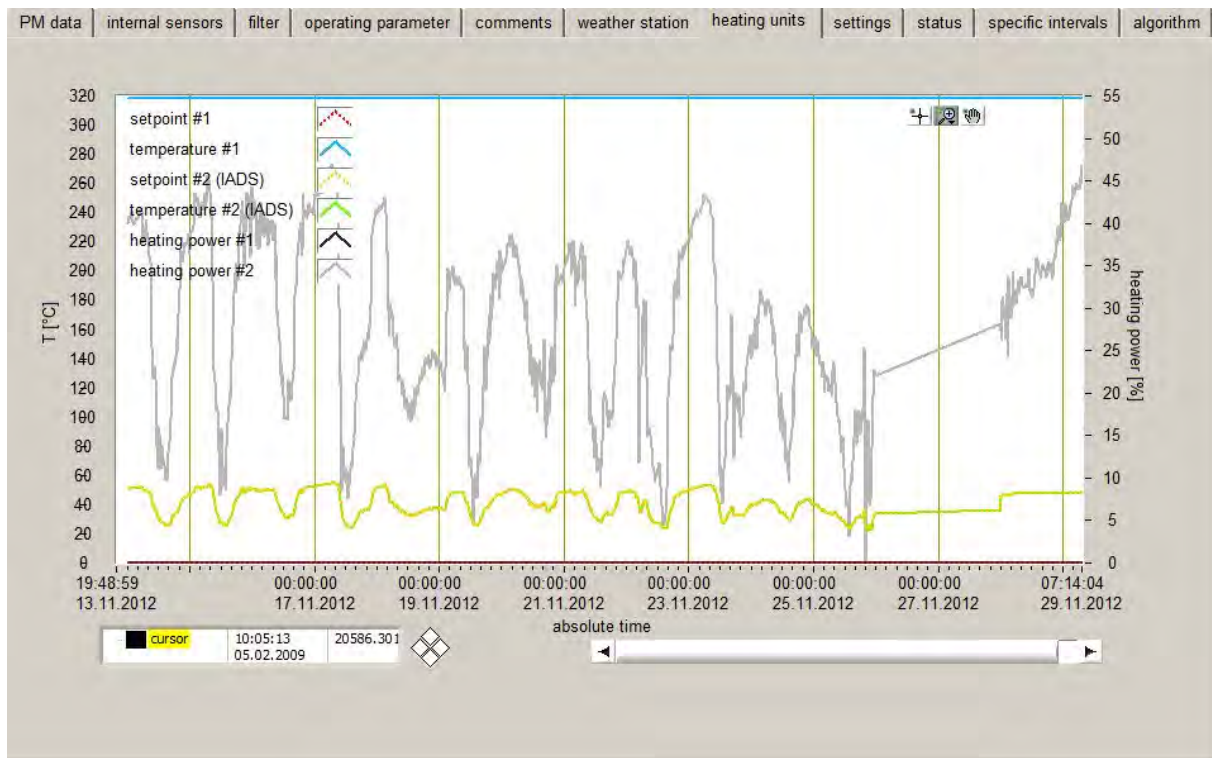


Figure 20: Overview of heating units in the Fidas® 200/200 S, 300/300 S

This tab displays an overview of the heating units that are used in the Fidas® 200/200 S, 300/300 S systems.

Note: Although “setpoint #1”, “temperature #1” and “heating power #1” are listed in the graph, they are not used currently and only added for future expansion possibilities.

- setpoint #2 (IADS) displays the setpoint temperature for the IADS that is used on the instrument. Depending on the mode of operation this can be a fixed value or a value that is continuously changing based on ambient conditions (see “Description Fidas Firmware” manual for more information)
- temperature (IADS) actual measured temperature of the IADS heating unit. This temperature should follow closely the set temperature.
- heating power #2 load in percent of the IADS heating unit (right axis). If this value is at 99 % the heating unit has reached its capacity limit. Please contact Palas® if this is the case!

5.8 Tab “settings”

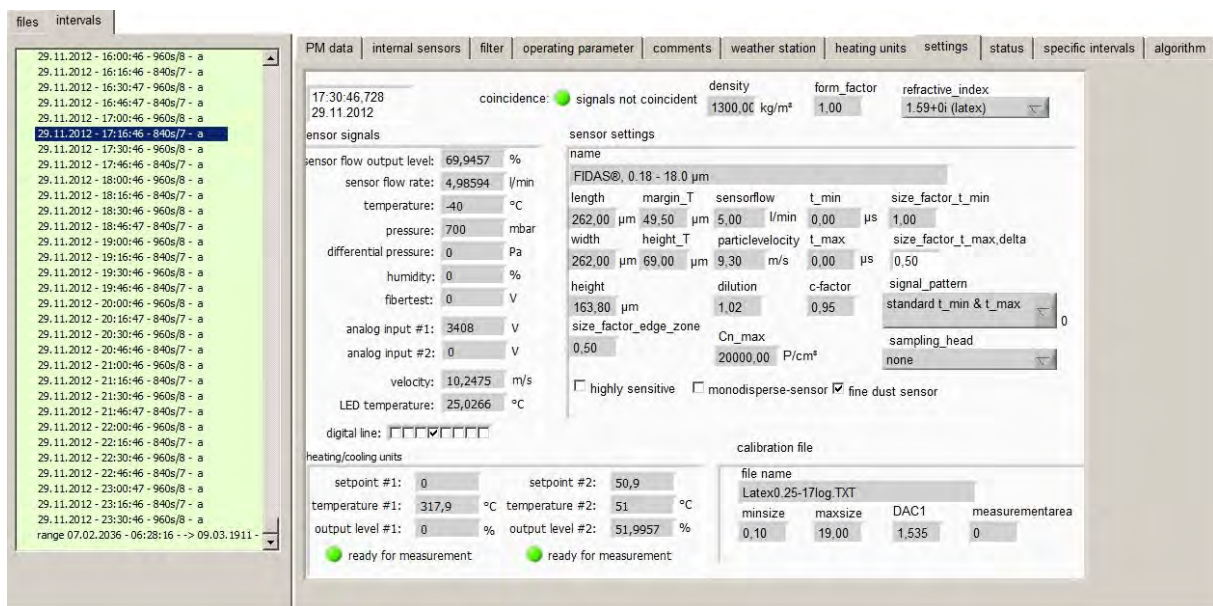


Figure 21: Instrument settings for the measurement

For each measurement interval the instrument settings are saved with the data and can be displayed by selecting the interval of interest.

In the top left section it shows time and date, whether signals were above the coincidence limit (see section 5.9) and the used particle characteristics (density, form factor and refractive index)

Note: if “fine dust monitor” is selected (at bottom of center section) the particle characteristics that are shown are not used, instead a size dependent measurement conversion algorithm is applied (see section 5.11).

The center section shows sensor specific information (e.g. dimensions of the T-aperture) that a service technician might want to see.

The bottom section contains information on the IADS heating unit (see section 5.7) and calibration information (e.g. voltage of the photomultiplier, used calibration file).

5.9 Tab “status”

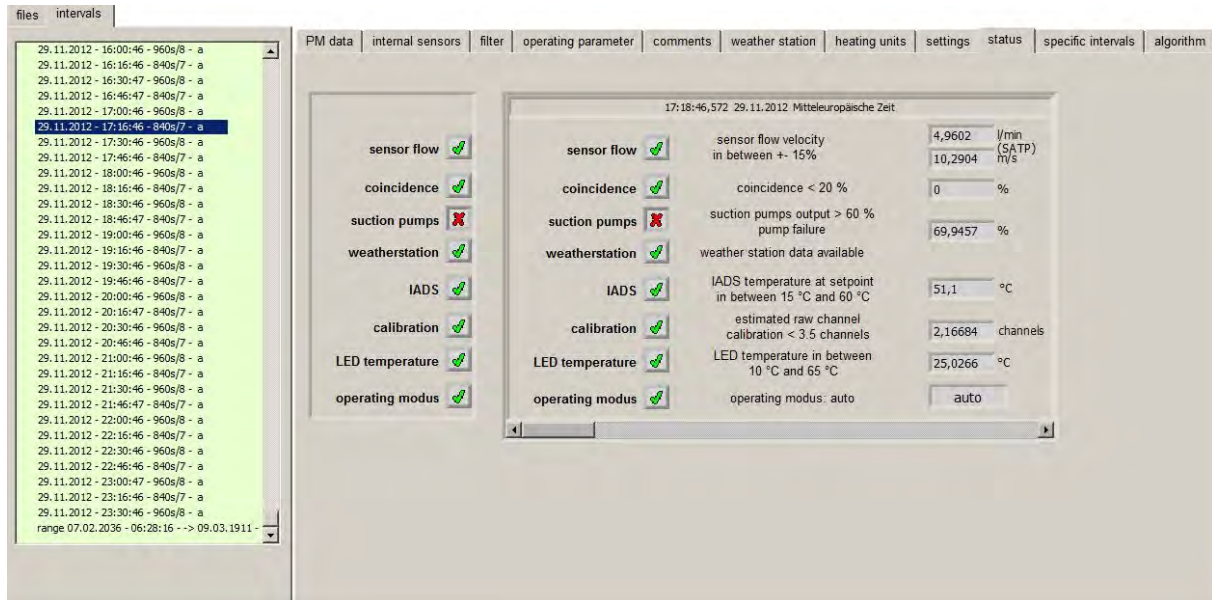


Figure 22: Tab “status” with status information about the instrument

This tab shows a copy of the instrument status screen for the selected interval.

If a performance parameter is not within set limits a red cross indicates a problem that requires attention and the data are flagged (see also sections 5.1 and 5.4).

The monitored performance parameters are:

sensor flow	<p>volume flow of the sensor, two values are monitored independently:</p> <ol style="list-style-type: none"> 1. Volume flow by mass flow meter incorporating T & p from weather station or internal sensor displayed as standard atmospheric temperature (25°C) and pressure (1013 mbar) - (SATP) 2. Velocity of particles through optical detection volume in m/s. <p>If these values divert from the factory calibrated set points or from each other by more than 15 % the green check mark changes to a red cross</p>
coincidence	detects if more than one particle was in the optical volume during the measurement and alerts if this happens more than 20 % of the time
suction pumps	monitors load of integrated pump(s) and can be used to monitor ageing of the pump(s). Alert is issued when load exceeds 60 %. Note: The Fidas® mobile has one pump, the Fidas® 100, 200/200 S, 300/300 S has two pumps working in parallel
weather station	checks if weather station is properly connected and data are available
IADS	checks if intelligent aerosol drying system (IADS) is properly connected and measured temperature is at setpoint and in between 15°C and 60°C

- calibration uses a patented algorithm to monitor whether it appears as if the sensor starts drifting.
Note: If the channel deviation is > 3.5 for a longer period please check calibration of the instrument using CalDust 1100 (for more information consult the instruments operation manual). No action is generally required if it only periodically exceeds the value.
- LED temperature ambient changes in temperature requires that the LED light source is temperature monitored and controlled to ensure constant output. The actual value of the temperature control is displayed and it is verified that it is between the set limits.
- operating modus this should be set to auto at all times

5.10 Tab “specific intervals”

If the data of the Fidas® instrument are compared to gravimetric data it can happen that the interval of the gravimetric sampler is not from midnight (0:00 o'clock) to midnight. In that case it can be very cumbersome to correlate the data.

For this purpose in this tab you can specify arbitrary evaluation intervals for your data.

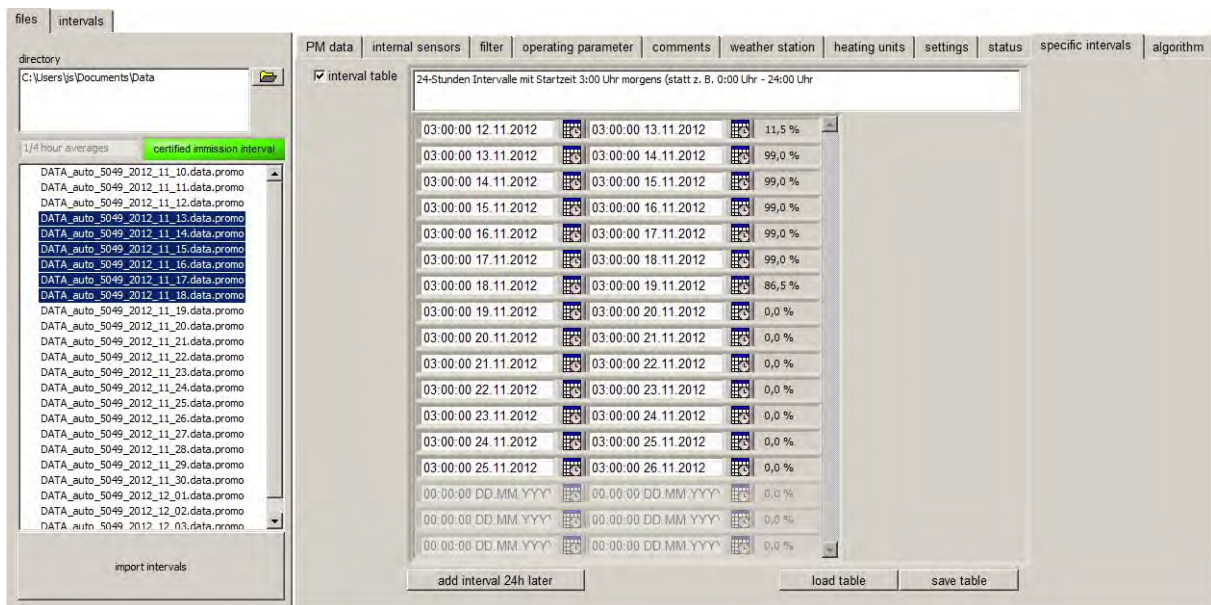


Figure 23: Specifying arbitrary evaluation intervals for data using the interval table

First enter the start time & date of the interval or select it from the calendar, then enter the end time & date of the interval. If you would like to repeat this pattern the next day just press “add interval 24h later”. In the white area above this table you can enter a comment.

After you have entered all intervals you can save this table by pressing “save table”. Previously generated specific interval tables can be loaded by pressing “load table”.

Note: If you use this table to set arbitrary evaluation intervals the interval length (left section) is fixed at 1/4 hour averages.

After the data are imported the percentage after the interval shows how much of the measured data lie within the specified interval.

5.11 Tab “algorithm”

The Fidas® instruments save the data in raw format with extensive additional information. It is therefore possible to evaluate data at a late time with a different algorithm. This may be used to:

- compare data with standard algorithm to the same data with customized algorithm, that e.g. takes particular sampling location better into consideration (e.g. placement of instrument next to a steel mill)
- optimize on-site correlation to gravimetric data.

Please contact Palas® to obtain more information about this feature.

In order to evaluate the data obtained with your instrument it is necessary that an algorithm is selected. The proper algorithm should be selected by default, if not please select the algorithm with the highest number (if there is a choice offered).

IMPORTANT: You need to select an algorithm else no data evaluation can be performed. If you don't see any algorithm being listed, check whether you have read/write/delete rights in the directory you copied the PDAnalyze-Fidas program files into. If you continue having this problem please contact Palas®.

In order to select the proper algorithm, first select your instrument:

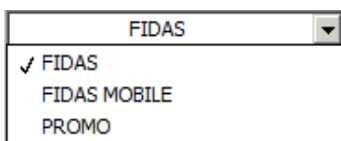


Figure 24: Selecting the instrument

Then select the algorithm:



Figure 25: Selecting the algorithm to use for the evaluation of the data

Note: Although not explicitly shown, the algorithm contains the information for all possible evaluation modes (see section 5.1).

6. Reader's comments sheet

In order to improve our manuals continuously we kindly ask you to fill in this questionnaire and to return it to Palas®. Thank you for your cooperation.

How to contact us:

Address: Greschbachstraße 3 b, 76229 Karlsruhe, Germany

Phone: +49 721 96213-0

Fax: +49 721 96213-33

E-mail: mail@palas.de

This evaluation concerns: PDAnalyze Fidas® Software, V0010413

Please inform us about your contact data:

Company: _____

Name: _____

Address: _____

Telephone or e-mail: _____

Were the procedures clearly written and easy to understand?

yes

no

If not, please explain: _____

Did you miss some information?

yes

no

If yes, please explain: _____

Have you been satisfied with the structure of the manual? Did you quickly find the required information?

yes

no

If not, please explain: _____

In case of technical problems, have you been satisfied with the telephone support?

yes

no

If not, please explain: _____

Please feel free to add any comments you may find necessary or helpful:

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User Manual

Fidas® Firmware

Fidas® mobile

Fidas® 100

Fidas® 200/200 S/200E

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1 Important information on switching-on and switching-off Fidas®

Since the firmware of Fidas® runs on a dynamic operating system which is based on Windows XPembedded for industrial applications, **Fidas® should never be switched off at the power switch.**

For the switching off of Fidas® the button "shut down" should be used. Only after the operating system has automatically shut down, the power switch should be operated!

Attention:

If you do not use the firmware shutdown button and just turn off the main power of the instrument you can lose data!

Fidas® is a high-capacity optical aerosol spectrometer and dust monitor with a 1.7 GHz Intel® Atom™ processor. Thus it is able to evaluate measured particle size information in real time. The dust monitor starts automatically after switching it on at the power button.

After turning on the Fidas® the Windows operating system is booted first. Then, the Fidas® startup-manager is starting up automatically. The latest revision (highest number) of the firmware is selected and started unless the user selects an older version.

Note: Selecting "Ver.exe" will bring the user straight to the Windows operating system.

This screen also displays the Palas® contact details.



Figure 1: Screen of the startup-manager

During the startup process, the aerosol pump is turned on (maximum throughput) and then regulated to a volume flow of 4.8 l/min. Then the Fidas® starts measuring and saving the data to the internal memory automatically.

After completing the startup process the main menu of the user interface is displayed (figure 2).

2 Fidas® user interface

2.1 Main menu

The main menu is displayed automatically after startup or by pressing “menu” in the status bar from any screen.

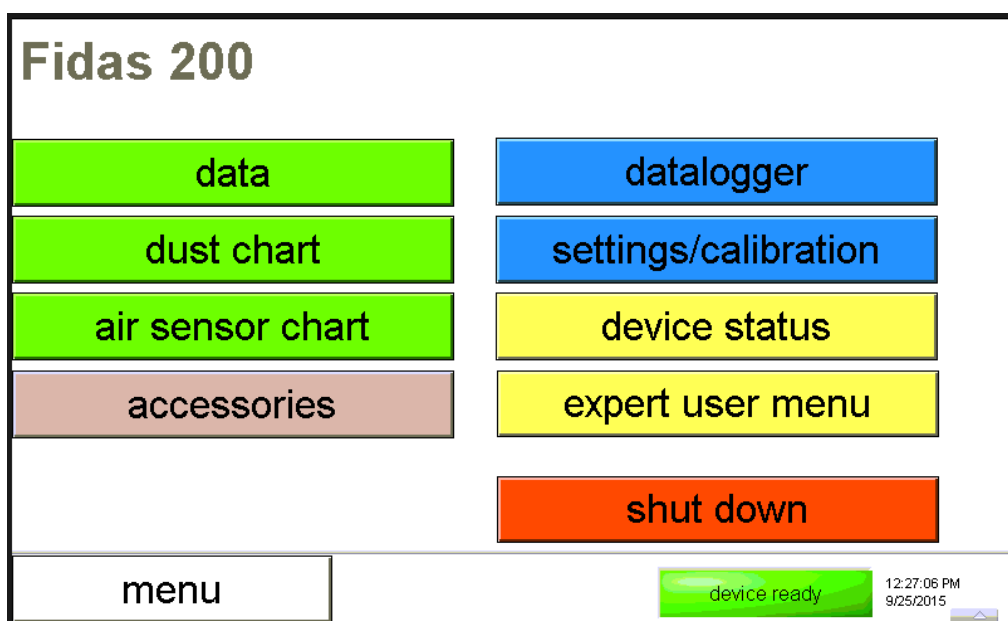


Figure 2: Main menu of the Fidas® user interface

The main menu is structured as follows:

The green buttons deal with the measured data:

data	shows the data overview with the currently measured values for PM ₁ , PM _{2.5} , PM ₄ , PM ₁₀ , PM _{tot} (TSP) and particle number concentration Cn. Additionally, the measured values from the weather station for relative humidity, ambient temperature and ambient pressure are displayed.
dust chart	graph that displays the measured values of PM-fractions and number concentration over time
air sensor chart	graph that displays the measured values from the weather station over time

The grey button contains additional information and capabilities:

accessories	contains further screens, i.e. IADS, weather station, nano sizer/counter, filter system, particle size distributions, alarms
-------------	--

The blue buttons relate to data logging and data quality

datalogger	allows entering a comment to the data that are saved internally or transmitted through a communication protocol. Additionally, the internally saved data can be exported to an USB-stick. It also enables text file data logging and entering a comment to this text file
------------	--

settings/calibration allows the validation of the calibration of the Fidas® with MonoDust 1500. Additionally, displays an online-calibration feedback and whether the calibration is within an allowed range

The yellow buttons deal with the hardware of the Fidas®:

device status overview of important system parameters, i.e. sensor flow, coincidence, suction pumps, weather station, IADS, calibration, LED temperature and operating mode

expert user menu access to the expert user interface.
Note: This is password protected to ensure only trained personnel have access to the advanced functions of this system.

The red button ends the measurement:

shut down shuts down the Fidas® and Windows® user interface.
This is the recommended way to turn-off the system
Note: For access to the Windows user interface go to “expert user menu” ->“system”->“exit to OS”

Attention:

If you do not use the shutdown button and just turn off the main power of the instrument you can lose data!

In the upper left the product name and model is displayed. In the upper right is the Palas® logo.

At the bottom is the status bar:

On the left is the “menu” button that can be activated from any screen and will bring you to the main menu. On the right is the device status (green: „device ready“ or red: „check device status“), and the system time and date. Time and date can be changed under Windows.

2.2 „data“ overview

Here one can see all measured PM-values and the particle number concentration.

Additionally, the measured values for relative humidity, ambient temperature and pressure of the air sensor are shown.

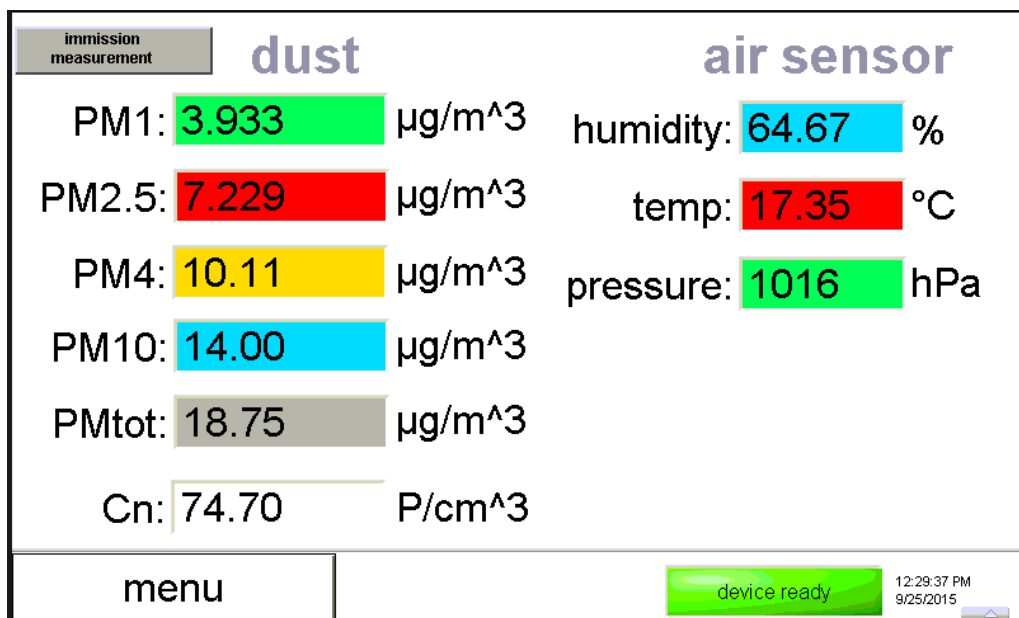


Figure 3: "data" overview

The particle number concentration is displayed in real time. The measurement value of the PM-fractions is based on a sliding average with a time constant of 900 seconds (entry in the promo.ini file), updated every 30 seconds. The data from the weather station are displayed with a time resolution of 1 minute.

All data are saved with a time resolution of typically 1 minute (or as set in the data logger in the expert user menu).

The grey field in the upper left corner shows "immission measurement". In this case the size dependent and TÜV verified (TÜV report 936/21218896/A) conversion algorithm is used to transform the measured particle size and number concentration to PM-fractions.

Further information to the measurement technology can be found in the Fidas® manual.

2.3 „dust chart“ – measured values over time

This chart shows all measured PM-values (coloured, right axis) and the particle number concentration (white line, left axis) over time.

“clear charts” will restart the chart.

Note: This has no effect on the saved data, so no data are lost by restarting this display.

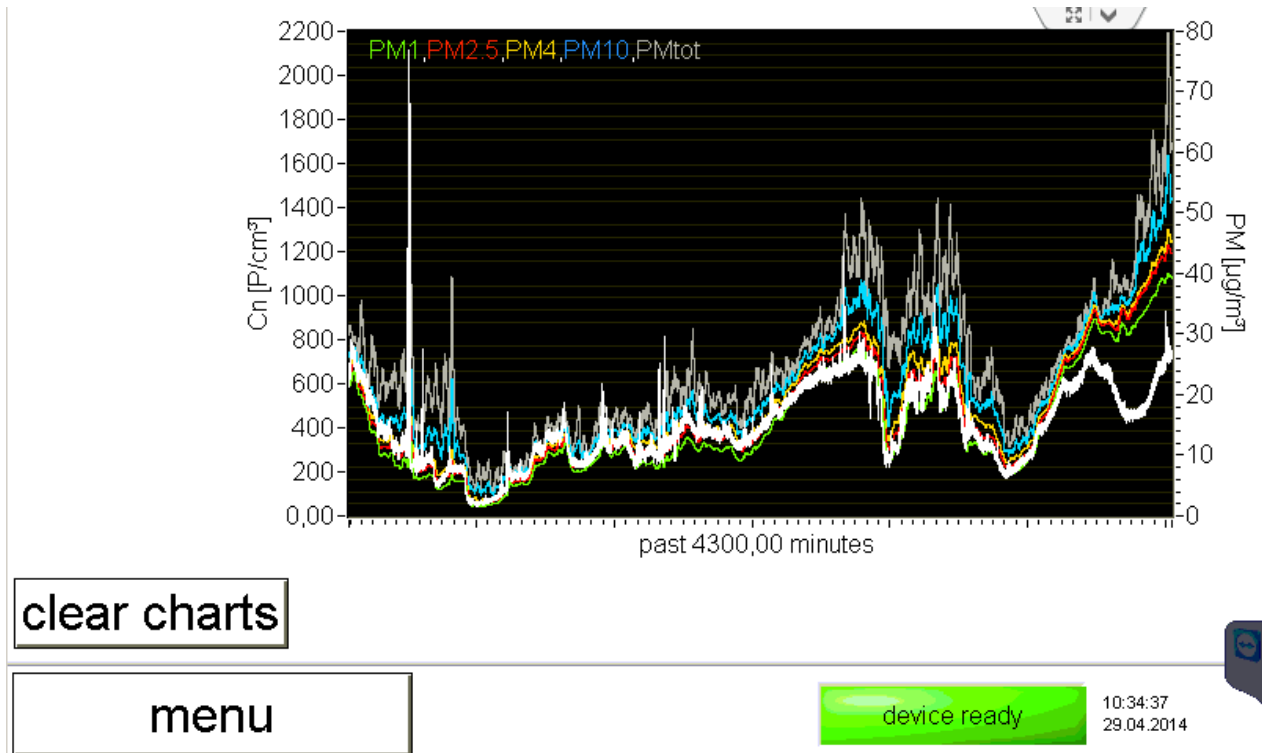


Figure 4: “dust chart” – measured values over time

2.4 „Air sensor chart“ – data from the weather station over time

This chart displays the measured relative humidity h [%], ambient temperature T [°C] and ambient pressure p [hPa]. The chart is updated every minute and shows a time-period of approximately one week.

Blue	relative humidity	left axis
Red	ambient temperature	right axis
Green	ambient pressure	right axis

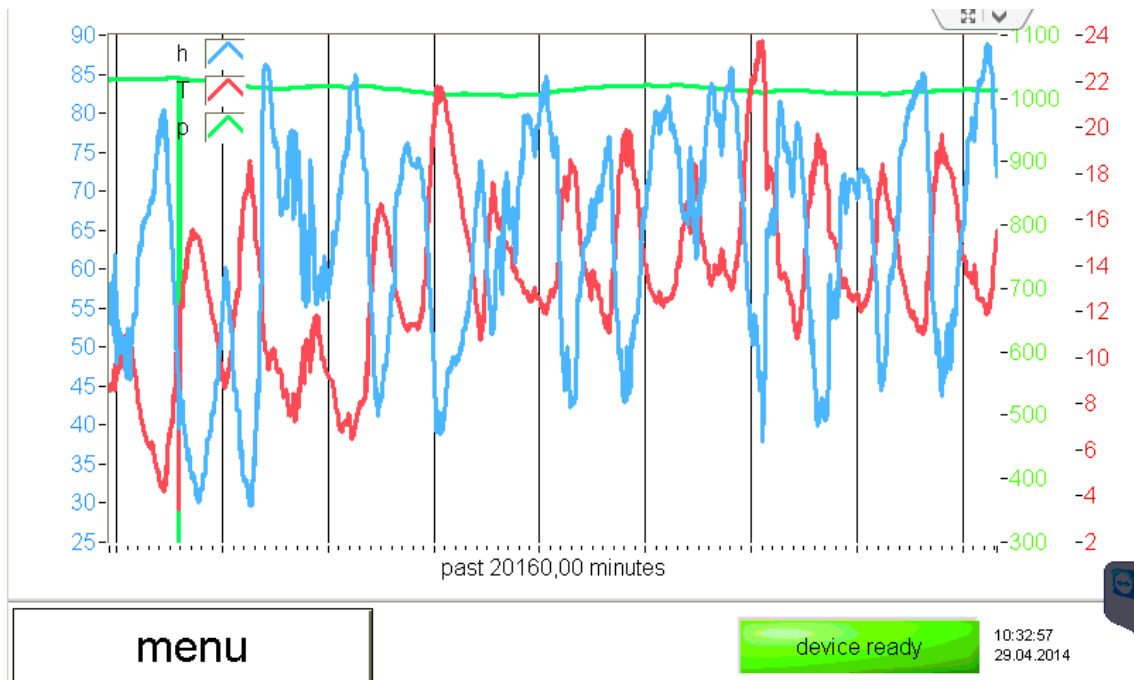


Figure 5: „air sensor chart“ – data from the weather station over time

Note: If the weather station (e.g. Lufft WS 600-UMB) reports additional values, for example amount of precipitation, wind direction and wind speed, then these values are also saved. They can be viewed under “accessories”->“weather station”.

2.5 „Accessories“

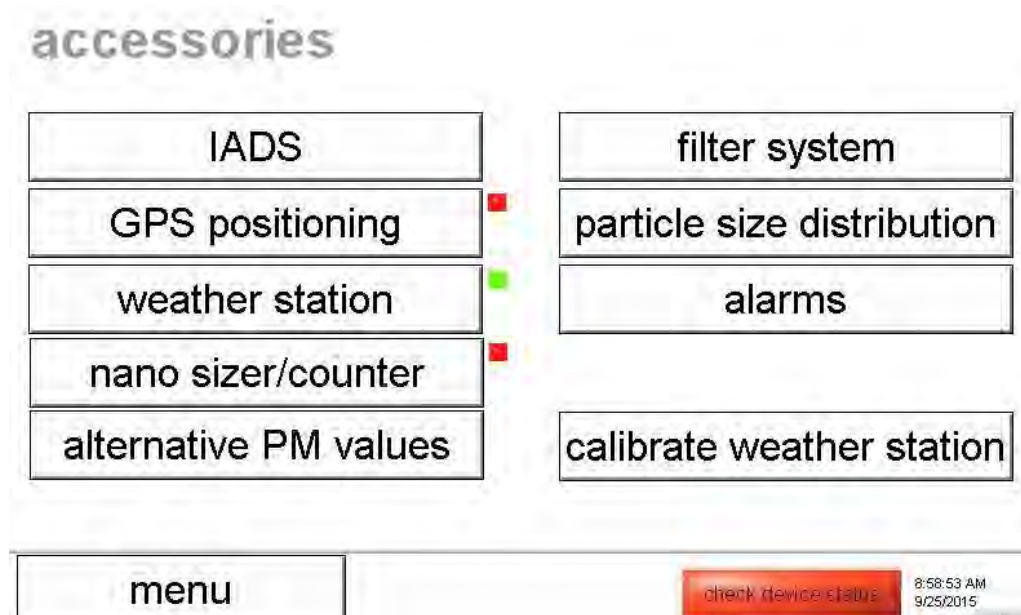


Figure 6: accessories

This menu contains the following sub menus that offer additional information and capabilities:

IADS	abbreviation for “intelligent aerosol drying system” and stands for the regulated heating in the sampling probe. Here, the basic setting of the IADS can be changed.
GPS positioning	if a GPS mouse is connected through the backside USB port, its coordinates are displayed here <u>Note:</u> this is no longer actively supported by Palas!
Weather station	displays all values from the weather station. The graph displays wind speed, wind direction and precipitation amount over time if these values are reported by the weather station (e.g. Lufft weather station WS 600-UMB).
Nano sizer/counter	if a DiSCmini from Matter/Testo is connected through the USB port, its data are displayed here and automatically attached to the saved data.
Alternative PM values	lists PM-values and algorithm (e.g. PM2.5_ambient #11) that was used to obtain these (same PM-values as shown under “data”), followed by PM-values (e.g. PM2.5_classic) as obtained if using the density that is entered under “expert user menu”->“???”, followed by PM-values (e.g. PMthoracic) based on EN 481 that are more relevant for indoor measurements
Filter system	assists the user for a filter exchange. The time and date when the filter is inserted and removed as well as the weight of the filter before and after the measurement can be entered and logged.

Particle size distribution	this shows two graphs. The upper graph shows the particle size distribution by number concentration, the bottom graph shows the particle size distribution by mass concentration. Red is the discrete, blue is the cumulative distribution.
Alarms	if activated an e-mail is sent to the entered e-mail address whenever one of the status parameters (see "device status") is out of range. In the bottom section a limit value for a PM-fraction can be defined (the value is defined in the promo.ini file). When this value is surpassed a digital alarm (at the digital out connector) is triggered.
Calibrate weather station	Since firmware version 100389, the sensors of the weather station for temperature, ambient pressure and rel. humidity can be adjusted.

2.5.1 “IADS” – settings of the intelligent aerosol drying system

The intelligent aerosol drying system is used to remove moisture from the aerosol, so particles are measured and sized at their original size. Further, fog droplets should not be interpreted as particles and are therefore removed. The IADS needs a weather station for operation as it uses the measured ambient temperature and humidity to dynamically adjust the heating that is integrated in the sampling tube. The IADS has three different settings:

“off”: The IADS is switched off, however the internal tube of the IADS is heated to +1 K related to the ambient temperature to avoid condensation within the IADS and the optical sensor.

“remove volatile / moisture compensation”: The IADS removes volatile particles (water droplets) and compensates the condensation of water and the related particle growth if the relative humidity is larger than 60 %. The setpoint temperature is dynamically adjusted in dependence of the ambient temperature and humidity.

“remove volatile and semi-volatile”: The IADS removes volatile and semi-volatile particles (water droplets, hydro-carbon droplets) and compensates the influence of moisture on the particle size. The internal heating of the IADS is set to a constant temperature of 75°C.

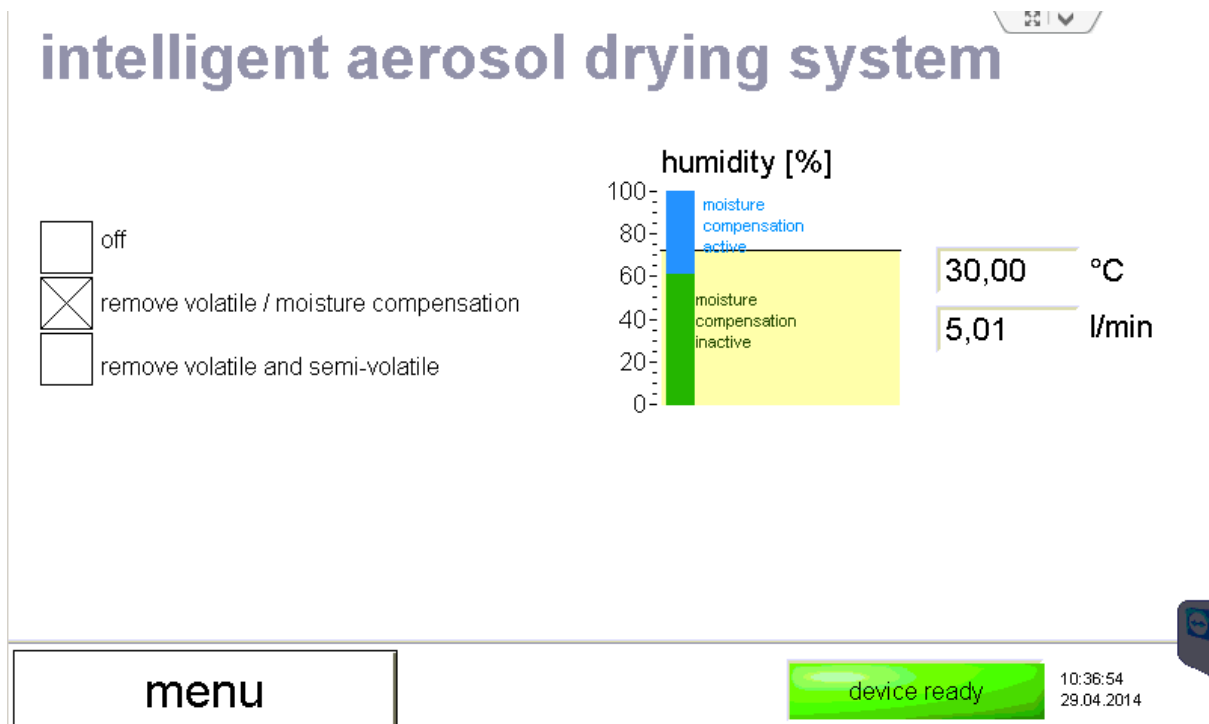


Figure 7: “IADS” – settings of the intelligent aerosol drying system

2.5.2 “GPS positioning” – coordinates of the GPS mouse

If a GPS mouse is connected to the USB slot in the back of the instrument, its data are displayed automatically.

Note: this is no longer actively supported by Palas!

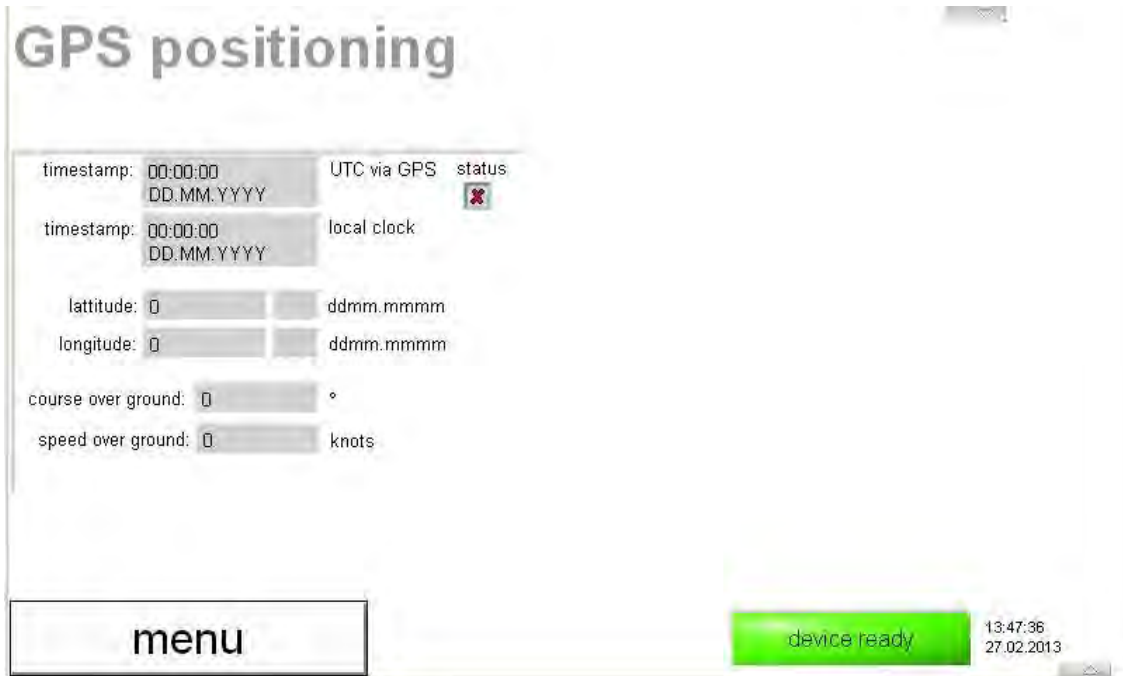


Figure 8: “GPS positioning”

2.5.3 “weather station”

If a weather station is connected to the Fidas® the measured values are displayed here. The graph displays wind speed, wind direction and precipitation amount over time if these values are reported by the weather station (e.g. Lufft weather station WS 600-UMB).

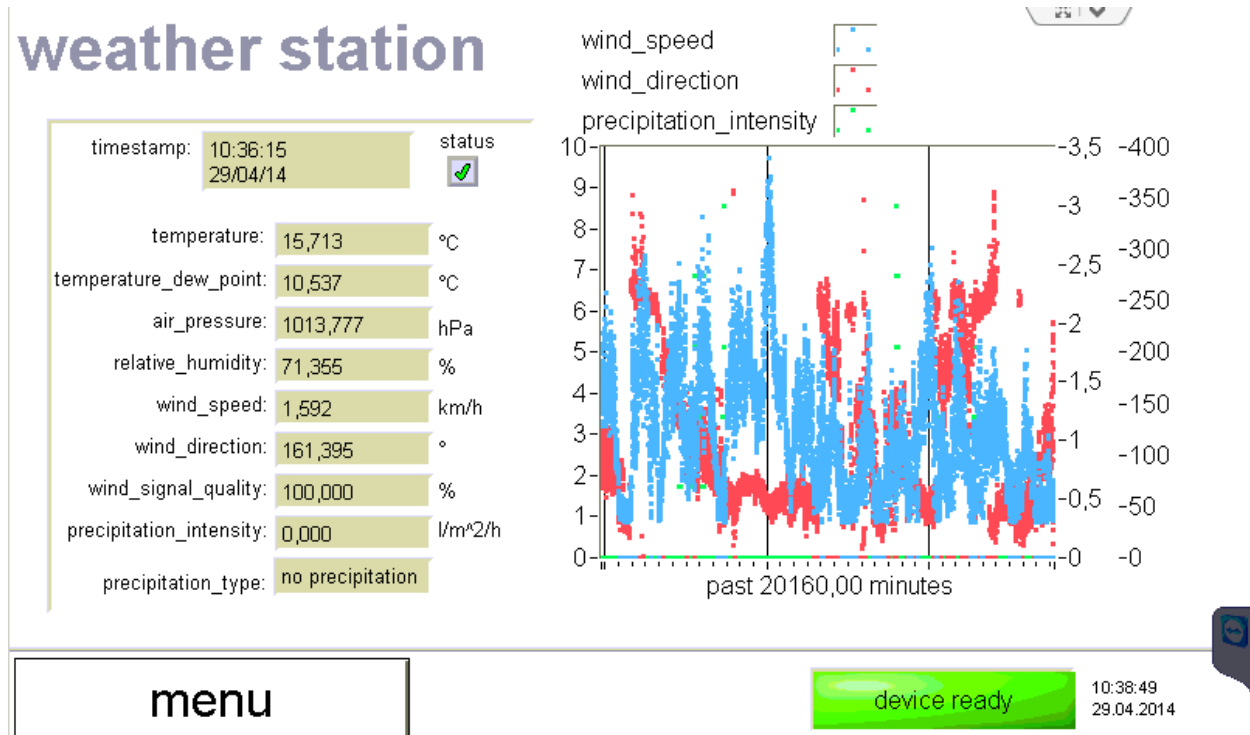


Figure 9: “weather station” – all data of the connected weather station

2.5.4 „nano sizer/counter“ – additional information on nanoparticles

If a DiSCmini from Matter/Testo is connected through the USB port, its data are displayed here. The data are also automatically saved (attached to the other saved data).

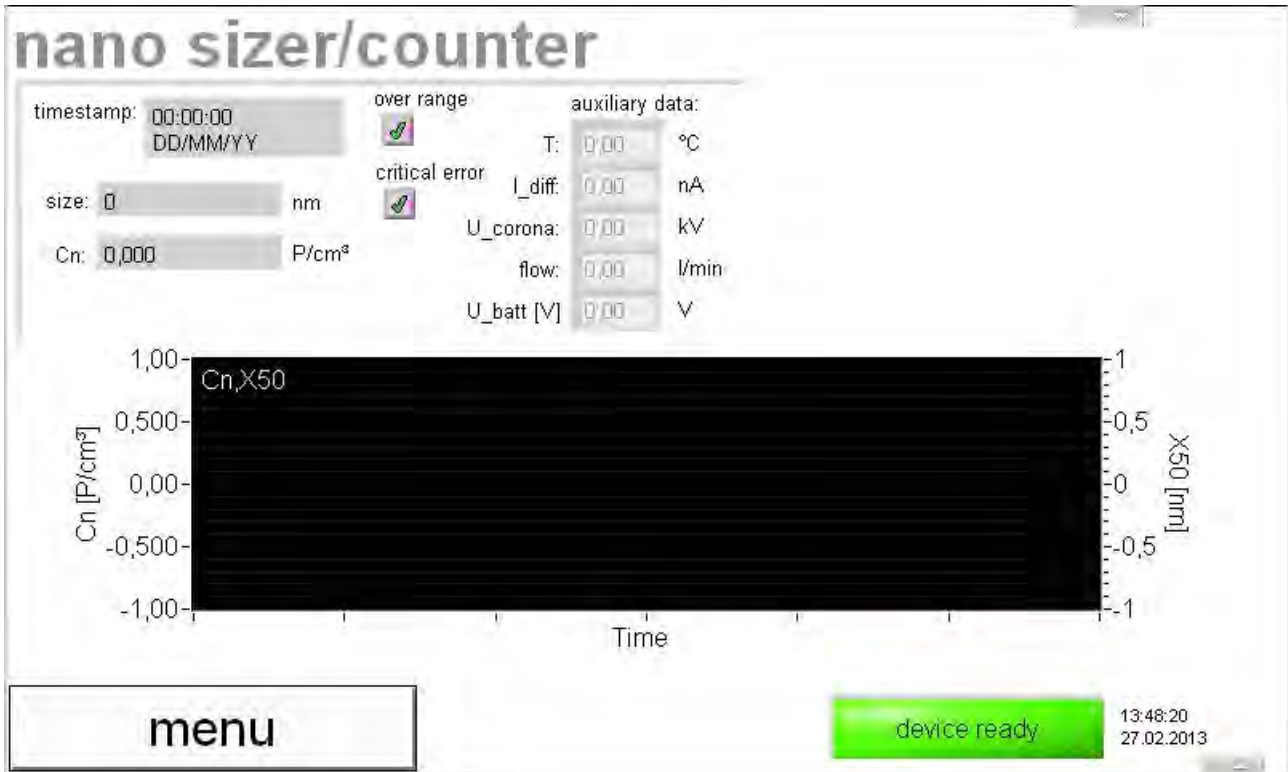


Figure 10: “nano sizer/counter” – additional information on nanoparticles

Note: It can be necessary to manually change the Com-port under Windows, if the USB-converter selected an improper com-port.

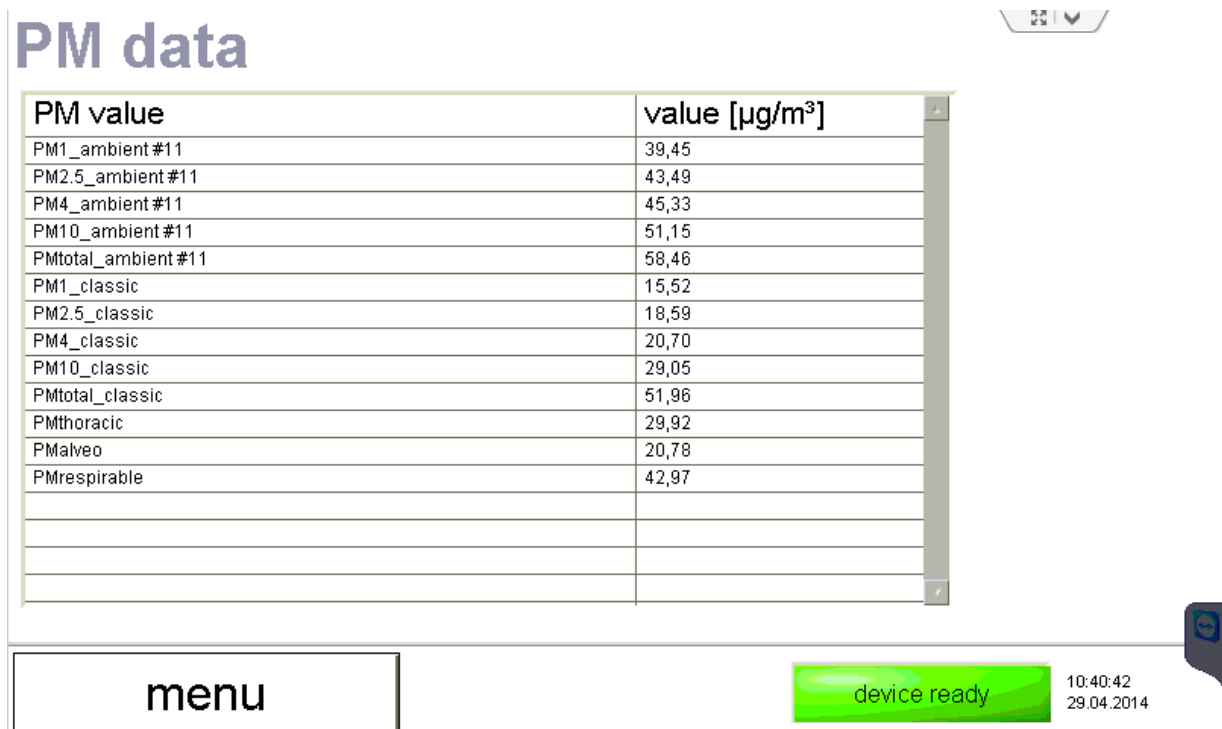
2.5.5 “alternative PM values”

Lists PM-values and the algorithm (e.g. PM2.5_ambient #11) that was used to obtain these. In this case algorithm 11 is used, this is the same algorithm that is TÜV certified.

The PM-values are the same that are shown under “data”.

Next are PM-values (e.g. PM2.5_classic) that are based on a constant density. It uses the density value that is entered under “expert user menu”->“???”.

Last are PM-values (e.g. PMthoracic) that are based on the definitions in EN 481 that are typically more relevant for indoor measurements.



The screenshot displays the 'PM data' menu. At the top left, the title 'PM data' is shown in a large blue font. Below it is a table with two columns: 'PM value' and 'value [µg/m³]'. The table lists various PM metrics and their corresponding values. At the bottom of the screen, there is a 'menu' button on the left, a green 'device ready' indicator in the center, and the time '10:40:42' and date '29.04.2014' on the right.

PM value	value [µg/m³]
PM1_ambient #11	39,45
PM2.5_ambient #11	43,49
PM4_ambient #11	45,33
PM10_ambient #11	51,15
PMtotal_ambient #11	58,46
PM1_classic	15,52
PM2.5_classic	18,59
PM4_classic	20,70
PM10_classic	29,05
PMtotal_classic	51,96
PMthoracic	29,92
PMalveo	20,78
PMrespirable	42,97

Figure 11: “alternative PM values”

2.5.6 “filter system”

Provides assistance in case of a manual filter exchange, specifically when a filter is inserted for a gravimetric measurement. The user can set the time when a filter is inserted and can enter its weight. Upon removal of the filter the user can set the time when the filter is removed and enter the weight of the filter after the measurement.

When all entries are completed a new button “save to datalogger” appears and the data can be saved to file.

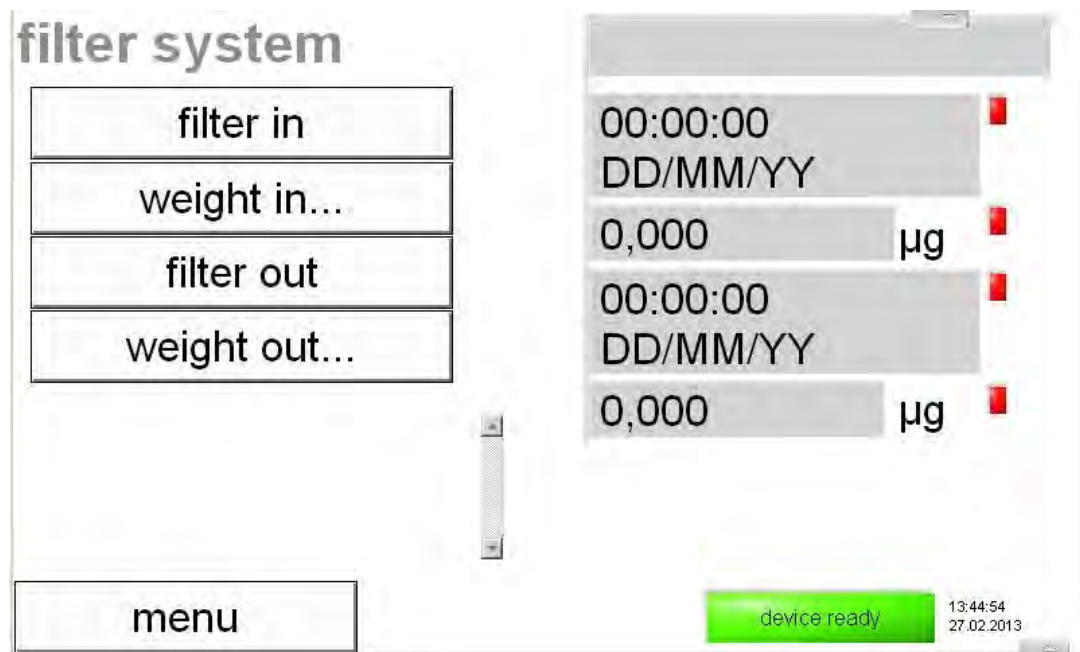


Figure 12: “filter system”

The entries are:

filter in	The current time is taken as the time the filter is inserted. Additionally, a filter-identification-number (FID) is created and displayed.
weight in...	A popup window appears in which the weight of the empty filter can be entered. It is implied that the entered weight correlates to the „filter in“ time and date.
filter out	The current time is taken as the time the filter is removed.
weight out...	A popup window appears in which the weight of the full filter can be entered. It is implied that the entered weight correlates to the „filter out“ time and date.
save to datalogger	The entered data are saved to file and are available when the data are analyzed using PDAalyze.

2.5.7 “particle size distribution”

Displayed here are two graphs. The upper graph shows the particle size distribution by number concentration, the bottom graph shows the particle size distribution by mass concentration. Red is the discrete, blue is the cumulative distribution.

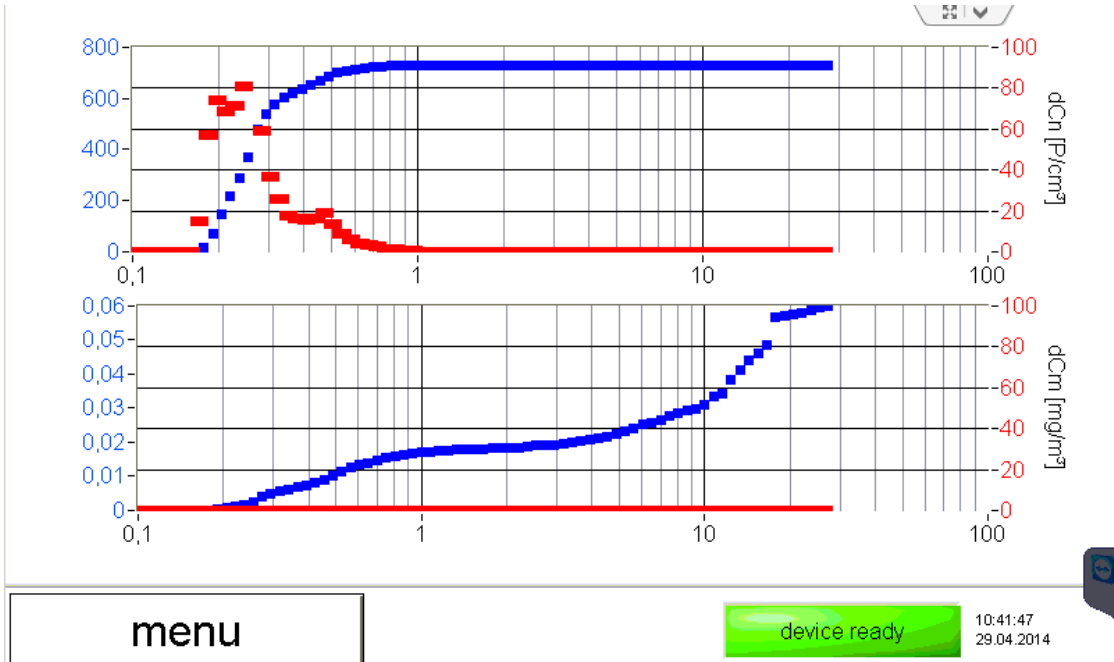


Figure 13: “particle size distribution”

2.5.8 „alarms“ – e-mail notification in case of warnings/errors

If activated an e-mail is sent to the entered e-mail address whenever one of the status parameters (see “device status”) is out of range.

In the bottom section a limit value for a PM-fraction can be defined (the value is defined in the promo.ini file). When this value is surpassed a digital alarm (at the digital out connector) is triggered and can be used to control a warning light or other warning signal.

alarms

E-mail alarm by status error

E-mail address:

digital out alarm by PM threshold

PM threshold: µg/m³

PM10 0,000 µg/m³

menu

device ready 13:04:24 09.04.2014

Figure 14: “alarms” – e-mail notification in case of warnings/errors

The following entry needs to be in the promo.ini file:

In the [Fidas] section:

alarm_threshold=50 (or any other value)

alarm_value=PM10 (or e.g. PM2.5)

2.5.9 „calibrate weather station“ – Adjustment of weather station

Since firmware version 100389, the sensors for temperature, ambient pressure and rel. humidity of the connected weather station (WS300-UMB or WS600-UMB) can be adjusted by comparing the measured values with the measured values of a transfer standard and by determining respective factors by linear equation.

weatherstation calibration

	scale	offset
temperature:	1.00	0.00
pressure:	1.00	0.00
relative humidity:	1.00	0.00

$$\text{value} = \text{scale} \times \text{measured_value} + \text{offset}$$

Changes take effect after restart only!



Figure 15: „calibrate weather station“ – Adjustment of the weather station

Note: Changes take effect after system restart only.

2.6 „datalogger“ – saving data to internal memory or text file

Fidas® continuously saves the measured data to a file. Fidas® generates a new file each day. The files can be transferred to a USB stick (copy datafiles to D:\).

If a USB-stick is connected to the Fidas®, it automatically copies the data files to the USB-stick at midnight.

copy datafiles to D:\	Copies the datafiles from internal memory to an USB-stick (drive D:\ is the front USB port).
-----------------------	--

At any time a comment can be entered that is saved along with every saved measurement data. The same comment is saved until the comment is deleted or changed.



Figure 16: “datalogger” – saving data to internal memory or text file

Additionally, text file datalogging can be activated so that data are continuously saved to a text file in text format. The time resolution is typically 1 minute (value taken from “expert user menu” ->“datalogger”). The name of this text file is „dustmonitor_serial number_year_month.txt (Example: dustmonitor_0117_2014_04.txt).

If measuring continuously a new text file is created every month.

The columns of this text file are:

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

PMthoracic	PMalveo	PMrespirable

Columns AI-AO

Numerical values for status parameters						
Flowrate	Velocity	Coincidence	Pump_output	IADS_temperature	Raw channel deviation	LED temperature

The device status is a numeric and coded as follows:

Mode: Scope	0
Auto	1
Manual	2
Idle	3
Calib	4
Offset	5
PDControl	6

Note: only the bold ones are likely to be seen with the Fidas® system. Note: if the text file is moved or deleted, the Fidas® will automatically create a new text file for the current month. If a text file for the current month exists, Fidas® will append the data.

2.7 „settings/calibration“

The calibration of the Fidas® is monitored online through a patented analysis of the measured signal in the graph “immission estimated channel deviation – trend 40h”.

If the calibration starts to drift it can be seen by a downward progression of dots between two red horizontal lines. The dots are based on a ½ hour measurement. If the average deviation over a period of 40 hours is more than 3.5 raw data channels an error flag is set and the Fidas® should be checked with MonoDust 1500.

Note: Individual dots might be outside the limit values, this happens occasionally and is no reason for concern, the calibration is also valid for these occurrences.

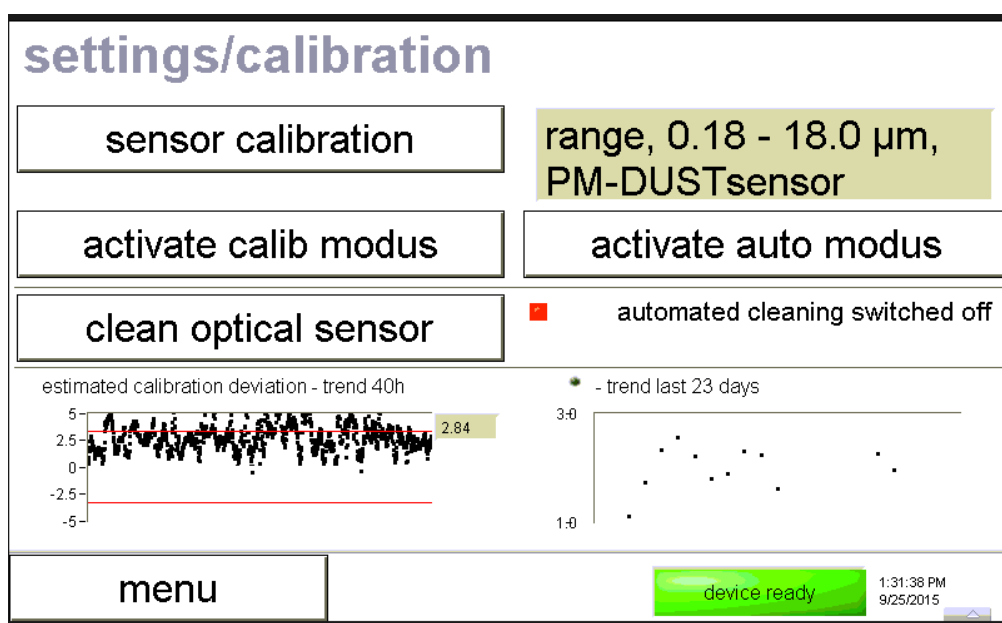


Figure 17: “settings/calibration”

In order to calibrate the Fidas® activate “sensor calibration”.

Further information on how to proceed with the calibration can be found in the Fidas® manual.

“activate calib modus” flags all data as obtained during calibration and they will not be used for evaluation unless specifically chosen in PDAalyze. This button can also be used during maintenance of the Fidas® to ensure data are omitted for evaluation during these activities.

Note: if activated manually, auto mode needs to be turned on (“activate auto modus”) manually after work is finished, otherwise the unit will show “device not ready” as in device status, “auto mode” would then not be shown.

“clean optical sensor” starts an automatic cleaning procedure in which the IADS is heated up to 75 °C and the pumps alternate between 0 l/min and maximum flow. The intention is to loosen and remove possible material in the flow path.

If desired, an automated schedule can be activated in the promo.ini file.

Note: Unless there is a real problem at a specific site with material or insects entering the sampling system frequently it is not advised to turn on an automated schedule for the cleaning procedure as it puts extra strain on the pumps.

2.8 “device status”

The “device status” status overview shows the different sensor information, which is necessary for a correct operation of the Fidas®. This information is saved in form of an error byte with every data record.

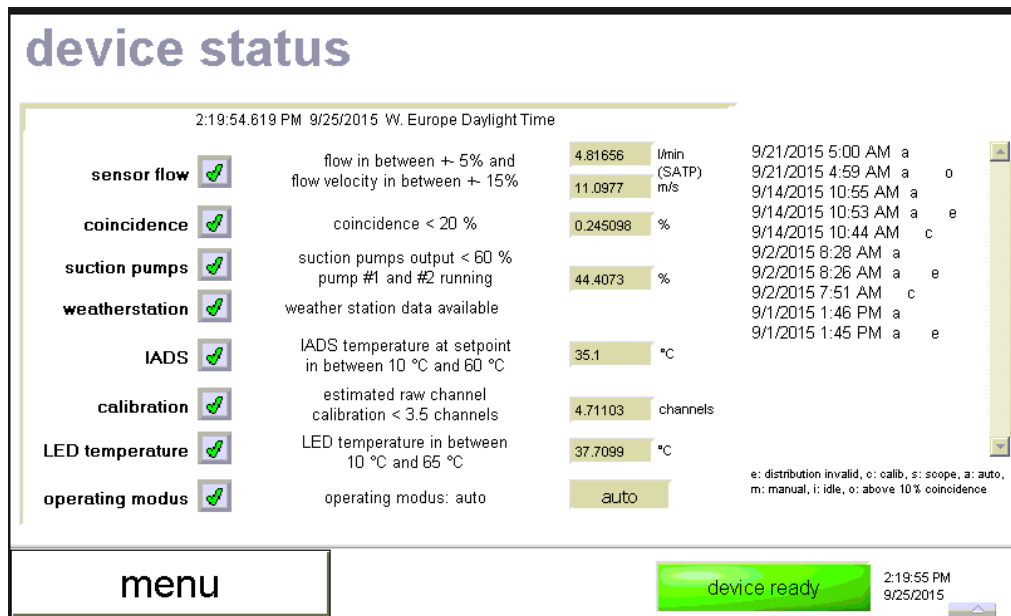


Figure 18: “device status”

In detail:

Sensor flow a feedback circuit with a mass flow meter and including the measured values for temperature and ambient pressure is used to regulate the volume flow through the Fidas® 100 or 200. The flow is regulated to 4.8 l/min. The volume flow is then standardized to „standard atmospheric temperature and pressure (SATP)“, i.e. with regard to 25°C & 1013 hPa. An error is set if the flow deviates more than 5 % from the set value.

Note: In some older models the flow was regulated to 5,0 l/min.

The second value shows the particle velocity through the optical detection volume. An error occurs, if the volume flow differs more than 15 % from the set value or if the particle velocity differs too much from the regulated volume flow.

Coincidence	Detection of more than one particle in the optical detection volume. Error output if it occurs with a frequency of more than 20 %.
Suction pumps	In Fidas® 100 und 200 two pumps (connected in parallel) provide the volume flow. If one pump fails, the other one can take over, but then the input is higher which leads to an error. If both pumps consistently age, an error occurs if they increase 60 %. It is important to know that the device continues to measure correctly, but the user has to change the pumps soon.
Weatherstation	Shows that the weather station is connected correctly and provides values
IADS	Shows that the IADS is connected correctly and the temperature corresponds to the given set point
Calibration	monitors the calibration online, if it differs for more than 3.5 raw data channels, an error occurs.
Note: In some cases this value can be outside the measurement, however the device will function properly. Need for action (i.e. a field calibration with calibration dust) is only necessary, if a long-term trend (>40 hours) can be seen.	
LED temperature	The LED light source is temperature controlled. If there is a problem in this control loop an error bit is set.
Operating modus	The operation mode should be set to „auto“, otherwise the data are not saved correctly or the device does not start independently after a blackout.

The status log keeps track of activities performed with the Fidas®. The abbreviations are:

a	auto mode	Standard operating mode of the Fidas®
c	calibration mode	during calibration all data are marked with „c“ and are not included in the evaluation
i	idle	the Fidas® is running idle, i.e. no measurements are performed
m	manual mode	the Fidas® was switched to manual mode
s	scope mode	the Fidas® was switched to scope mode. This is an electronic oscilloscope where the individual signals can be analyzed
e	distribution invalid	the measured distribution is invalid
o	above 10% coincidence	concentration was so high that more than 10% of the measured data were in coincidence, i.e. during measurement more than one particle was in the detection volume more than 10% of the time

2.8.1 Differences for the Fidas® mobile

The “device status” screen of the Fidas® mobile is simplified (e.g. no IADS or weather station) and the error checkboxes are removed as shown in figure 18a.

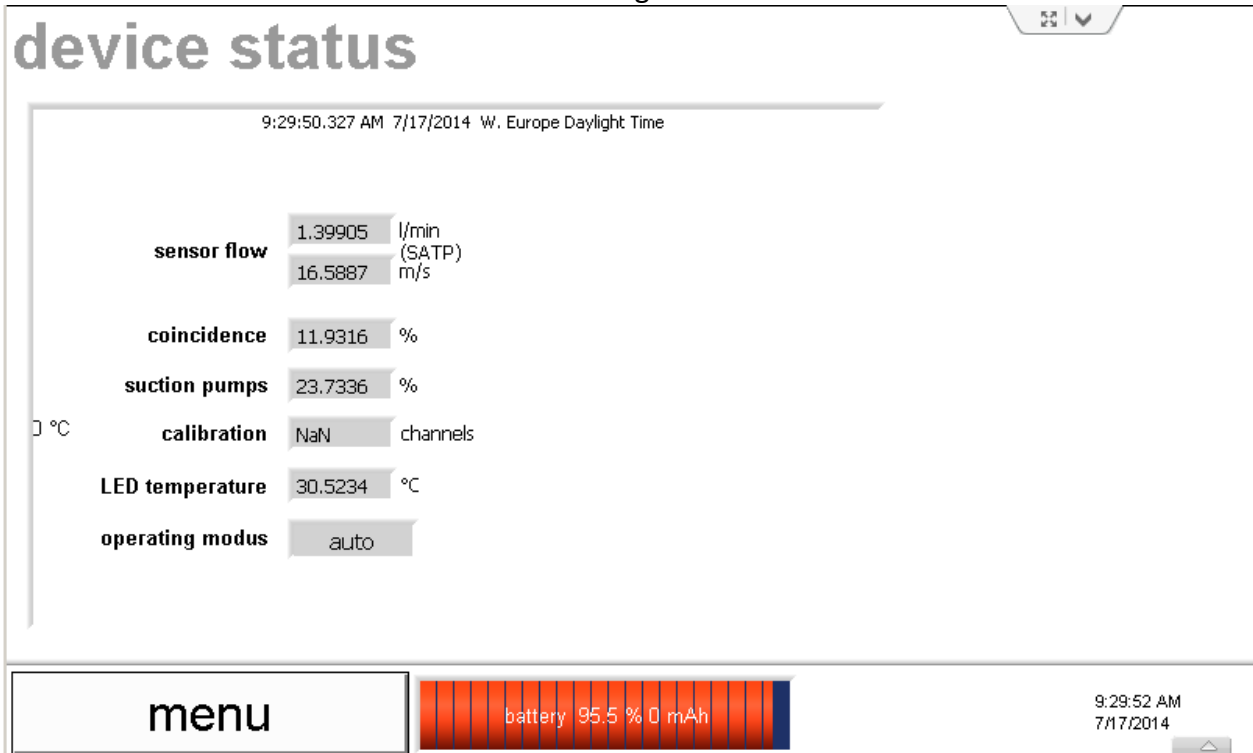


Figure 18a: Simplified “device status” screen for the Fidas® mobile

2.9 “expert user menu”

Advanced functions and information can be accessed through the expert user menu. In order to access this menu a code needs to be entered to ensure that only trained personnel can access this. The code is “1” followed by “-” followed by “accept” (figure 18).

Note: It is possible to set the password differently. In order to do that the following needs to be entered in section [Fidas] in the promo.ini file:

password_service=-1 (-1 is the default password, if desired change this to a different password)

Further information to the expert user mode can be found in the manual to the expert user mode.

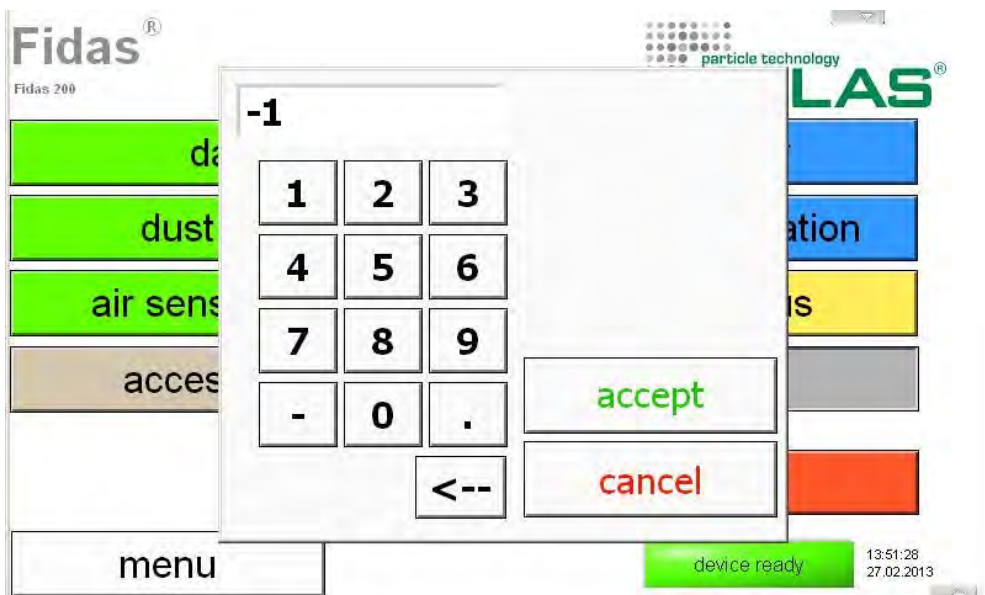


Figure 18: „expert user menu“ – changing into the expert user mode



Figure 19: „expert user menu“ – main menu

Note: The firmware version string is composed as follows:

Position 1:	100396	Firmware version of the panel PC (Touchscreen)
Position 2:	0014	Firmware version of the SCA board
Position 3:	0001	Firmware version of the MIO board
Position 4:	0001	Firmware version of the Pt100 board
Position 5:	0011	Method

2.10 “shut down” - shutting down the Fidas® Firmware

We recommend using “shut down” to turn off the Fidas®.

Since the Fidas® firmware is running on a dynamic operating system that is based on Windows XPembedded for industrial applications, the Fidas® should not be turned off by just flipping the power switch. This could result in a corruption of the file system.

If the “shut down” is initiated, the following popup will appear on the screen:



The Fidas® Firmware is now shut down properly. After this procedure is finished and the touch screen monitor is off (green indicator light is off), the Fidas® can be turned off by pressing the on/off button on the backside of the instrument. It's recommended to do so, else the internal fan will keep running.

Compact Weather Station

WS200-UMB

WS300-UMB

WS301-UMB

WS302-UMB

WS303-UMB

WS304-UMB

WS400-UMB

WS401-UMB

WS500-UMB

WS501-UMB

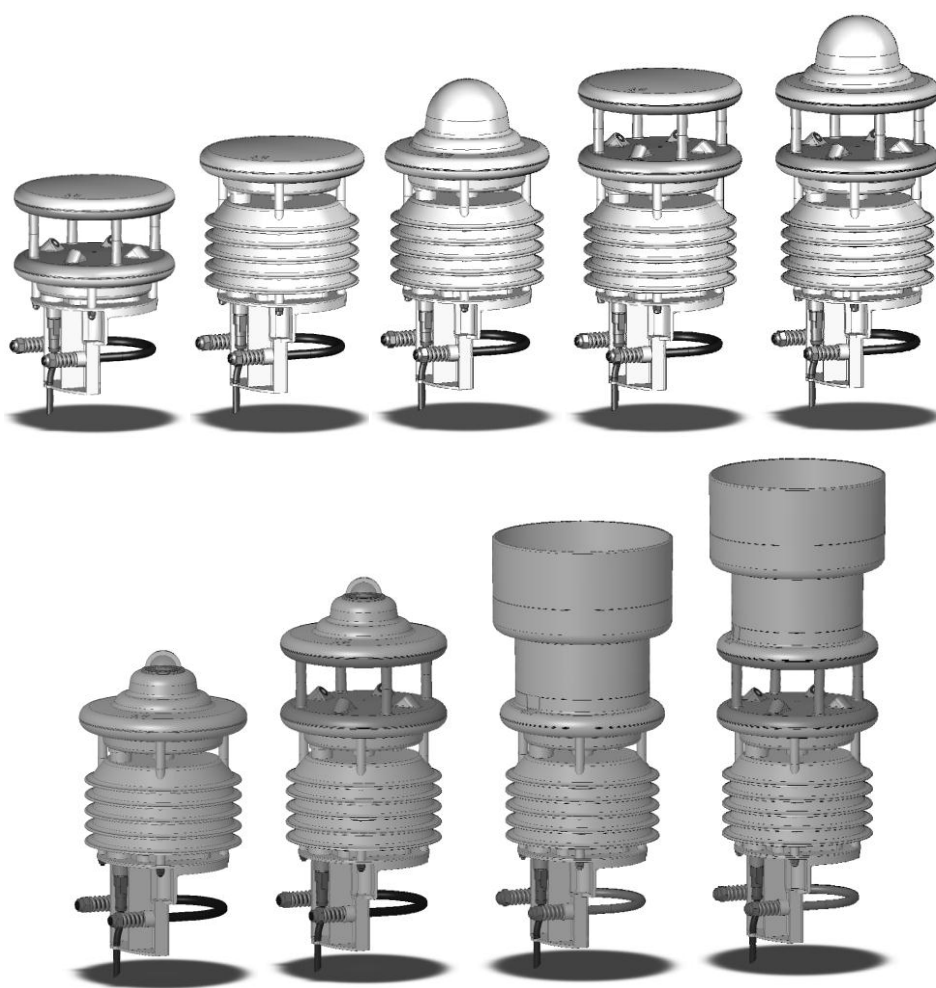
WS502-UMB

WS503-UMB

WS504-UMB

WS600-UMB

WS601-UMB



CE

UMB

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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

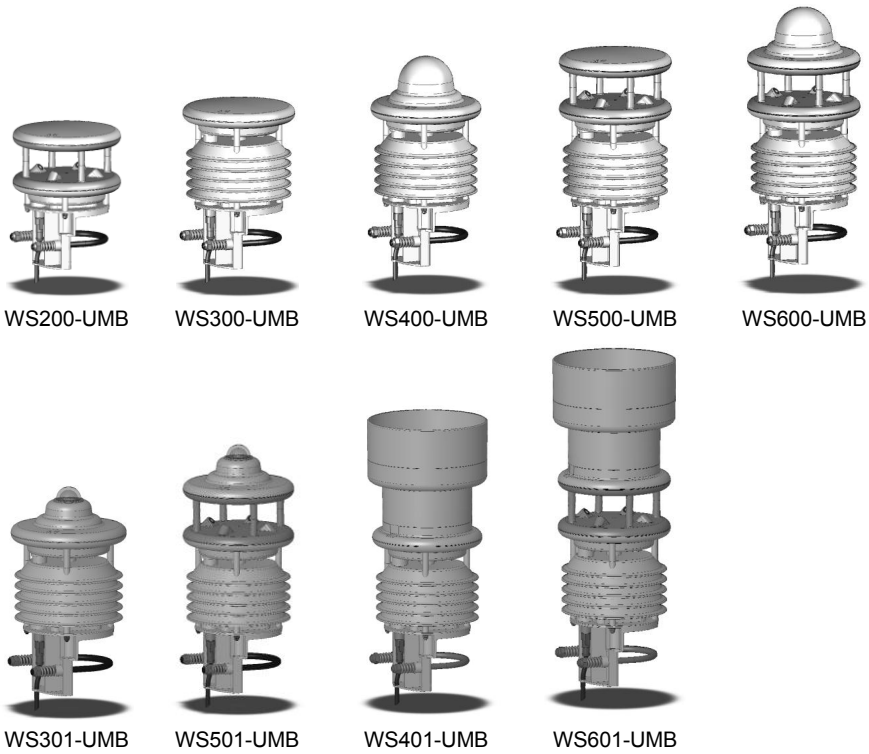
The guarantee period is 12 months from the date of delivery. The guarantee is forfeited if the designated use is violated.

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



- 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)

8369.U02 (UK)

- Precipitation Radar
- 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
- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass

8370.U02 (UK)**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	<ul style="list-style-type: none">• This document
UMB-Config-Tool	<ul style="list-style-type: none">• Windows® software for testing, firmware updates and configuration of UMB devices
UMB Protocol	<ul style="list-style-type: none">• Communications protocol for UMB devices
Firmware	<ul style="list-style-type: none">• 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)

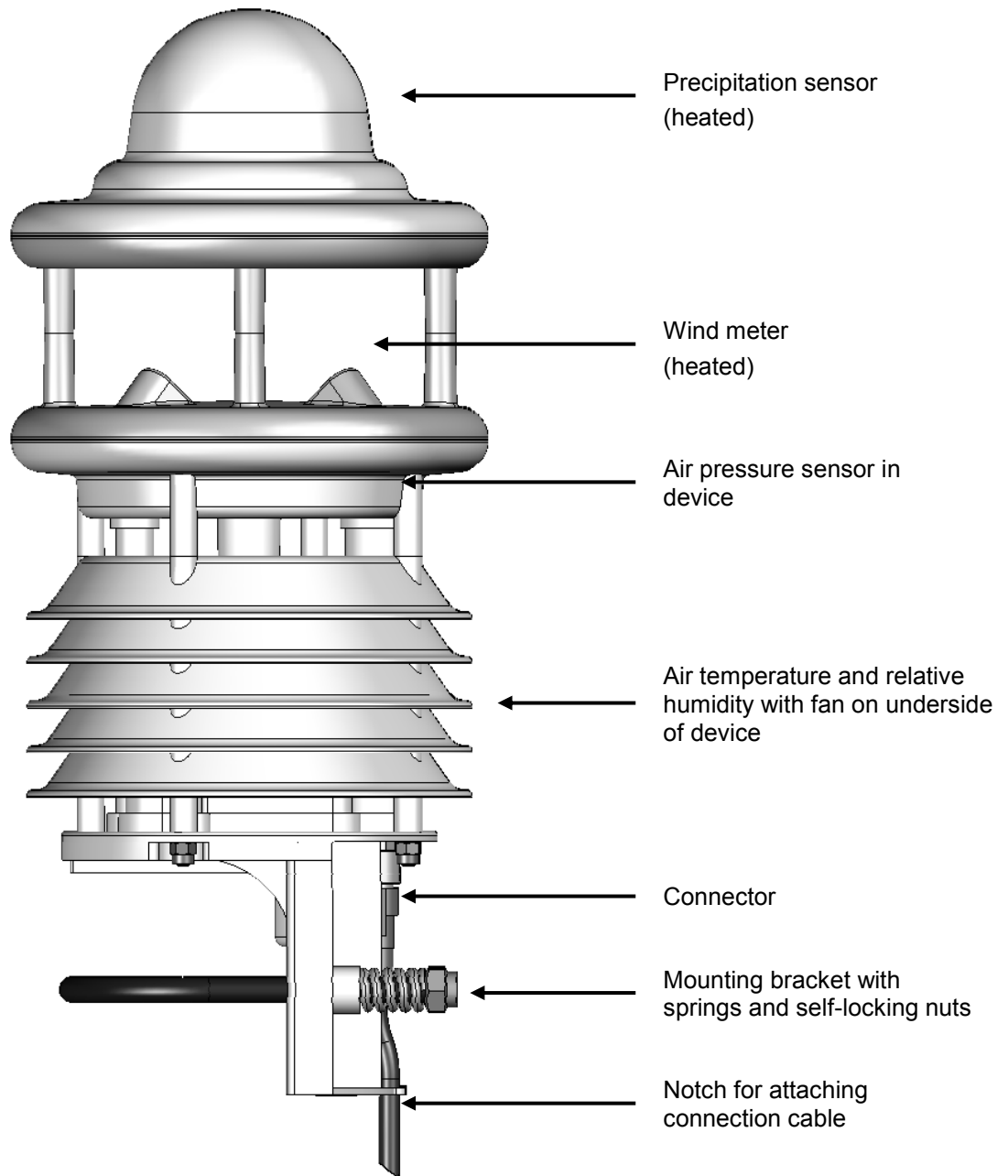


Figure 1: Sensor Technology

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				Measurement Variable (float32)	Measuring Range		
act	min	max	avg		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				Measurement Variable (float32)	Measuring Range		
act	min	max	avg		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				Measurement Variable (float32)	Measuring Range		
act	min	max	avg		min	max	unit
200	220	240	260	Relative humidity	0.0	100.0	%
205	225	245	265	Absolute humidity	0.0	1000.0	g/m ³
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				Measurement Variable (float32)	Measuring Range		
act	min	max	avg		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/m ³

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					Measurement Variable (float32)	Measuring Range		
act	min	max	avg	vct		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					Measurement Variable (float32)	Measuring Range		
act	min	max	avg	vct		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					Measurement Variable (float32)	Measuring Range		
act	min	max	avg	vct		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					Measurement Variable (float)	Measuring Range		
act	min	max	avg	vct		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/m ²
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/m ²
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/m ² /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				Measurement Variable (float32)	Measuring Range		
act	min	max	avg		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				Measurement Variable (float32)	Measuring Range		
act	min	max	avg		min	max	unit
900	920	940	960	Global Radiation	0.0	1400.0	W/m ²

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				Measurement Variable (float32)	Measuring Range		
act	min	max	avg		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

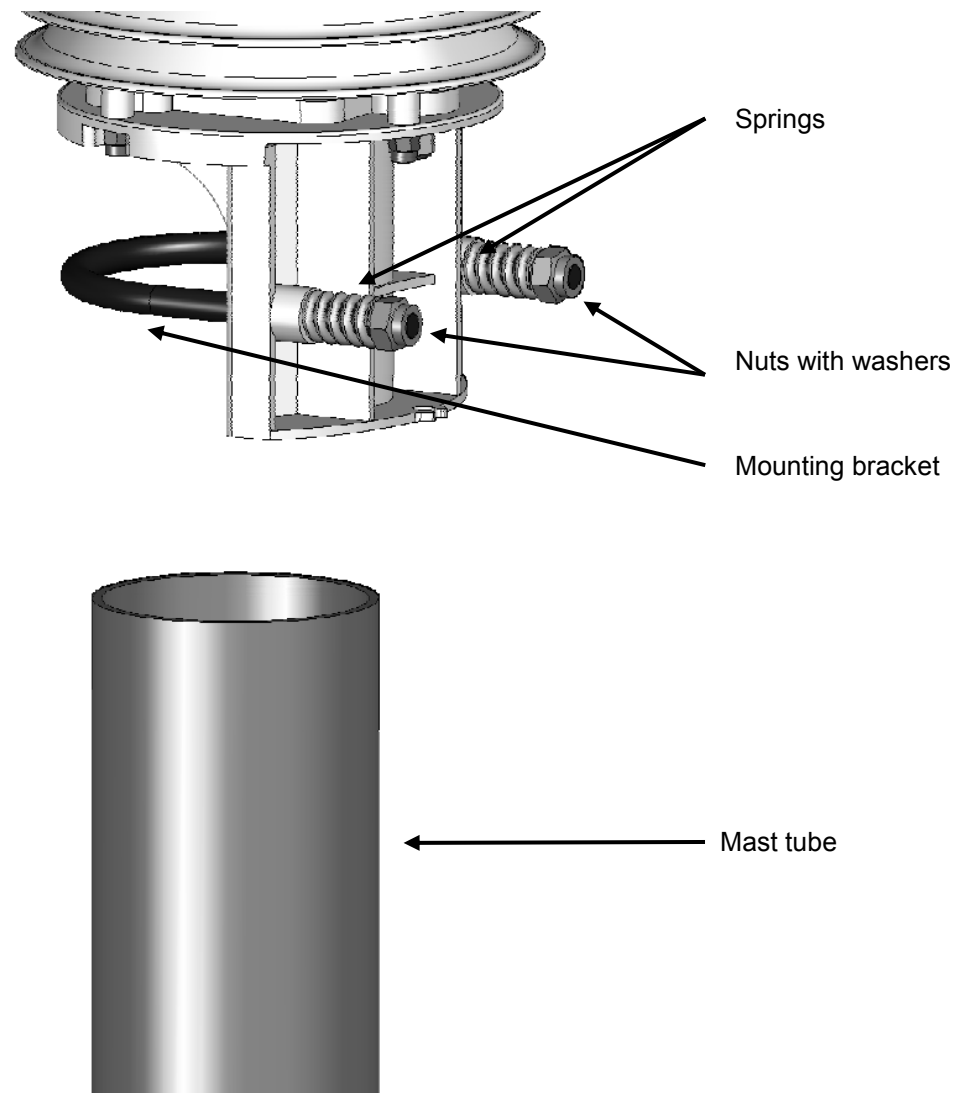


Figure 2: Fastening to the Mast

- 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.

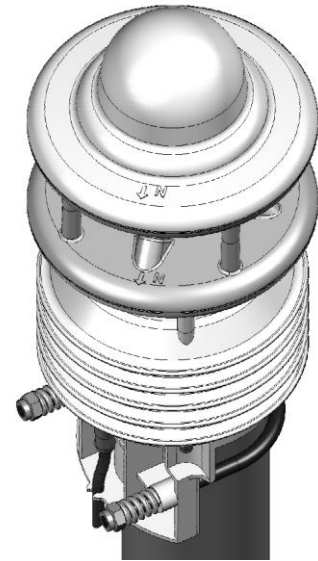
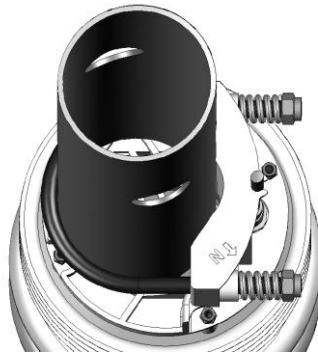


Figure 3: North Markings

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

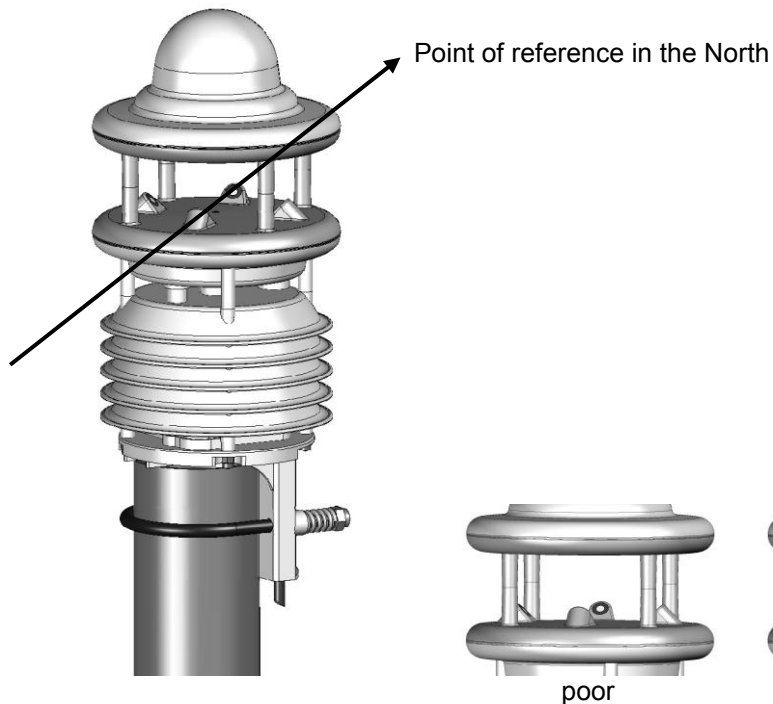


Figure 4: Alignment to North



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:

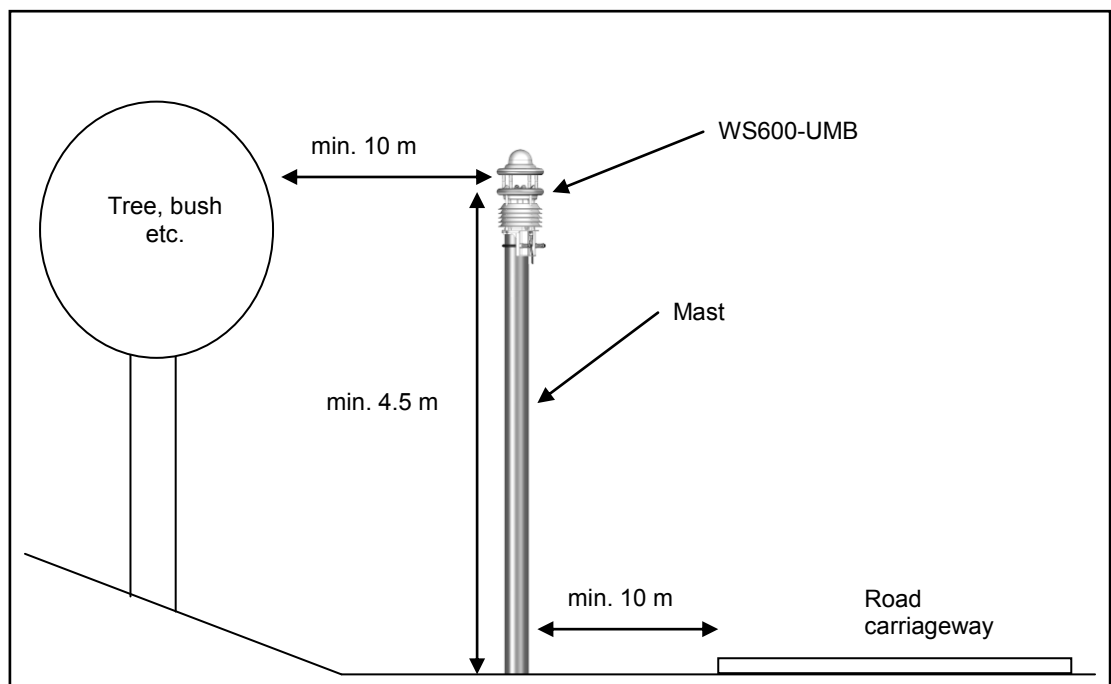


Figure 5: Installation Sketch

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:

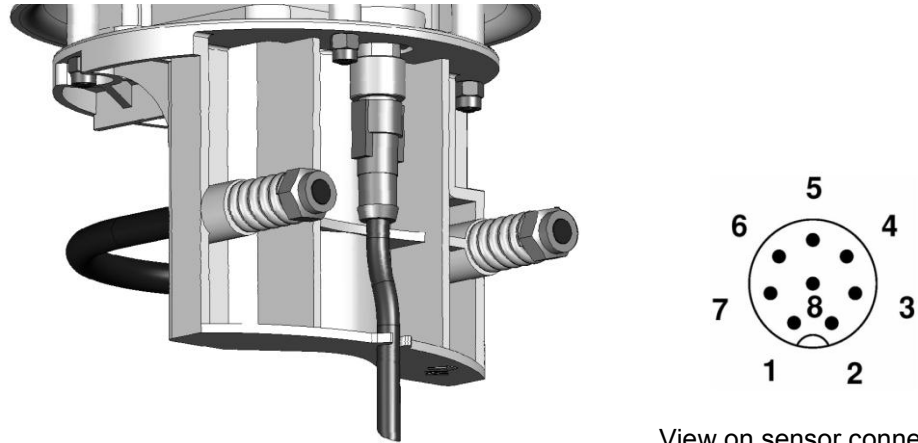


Figure 6: Connections

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)

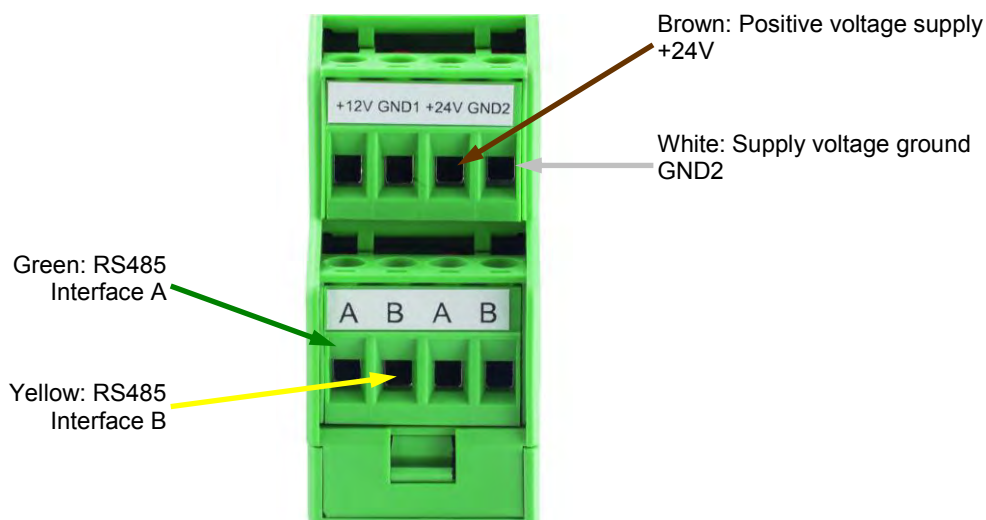


Figure 7: Connection to ISOCON-UMB



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 Chapter 18.

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 17 and 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).

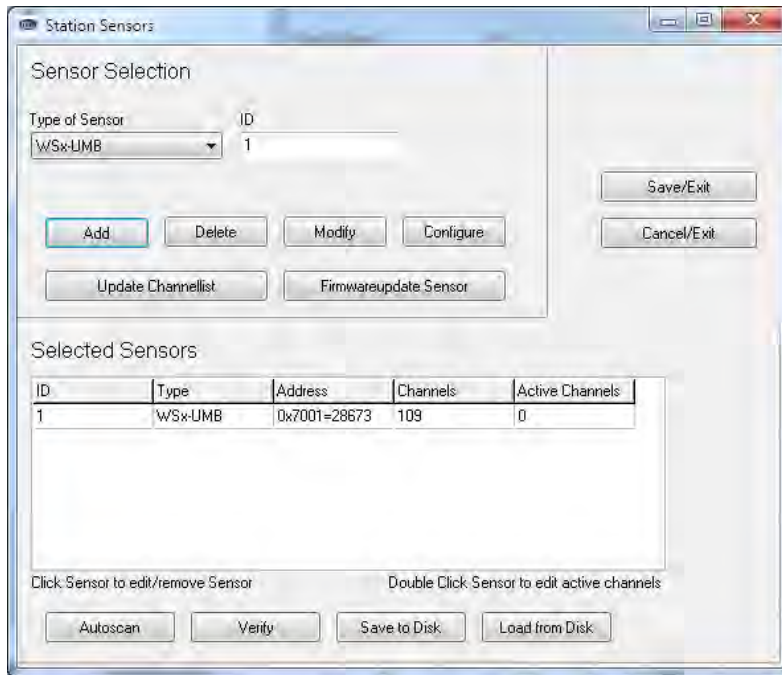


Figure 8: Sensor Selection



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

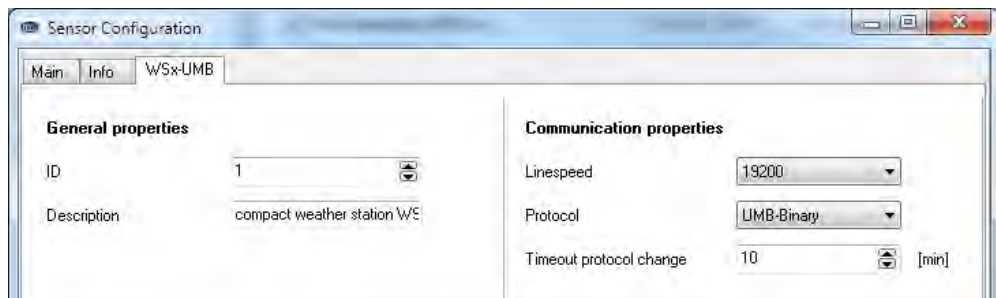


Figure 9: General Settings

- 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

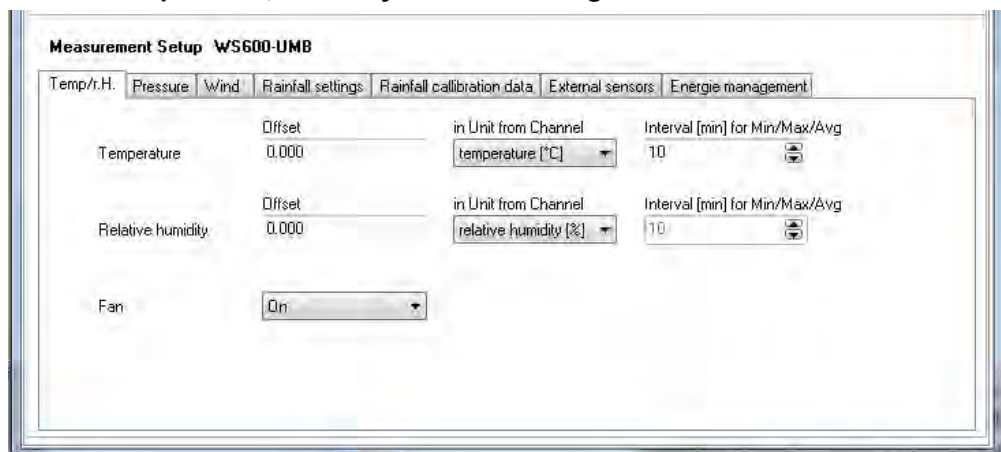


Figure 10: Temperature, Humidity and Fan Settings

- 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,

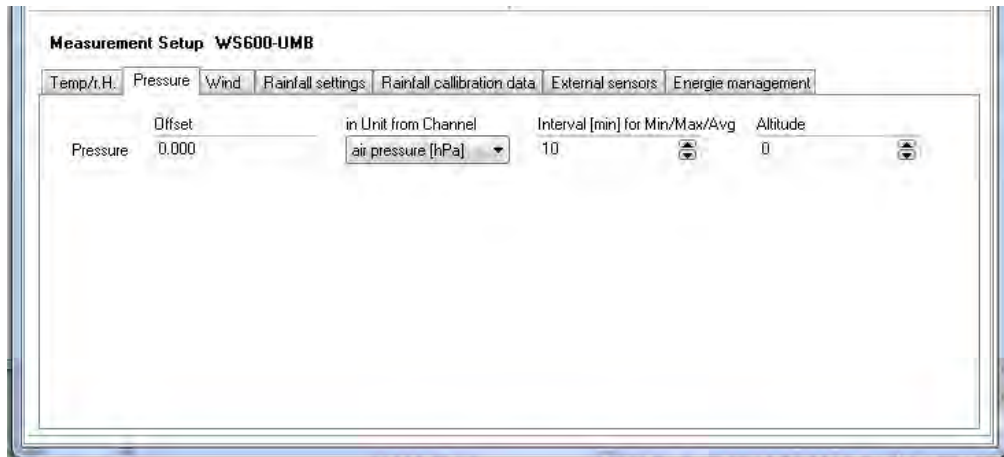


Figure 11: Pressure Settings

- 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

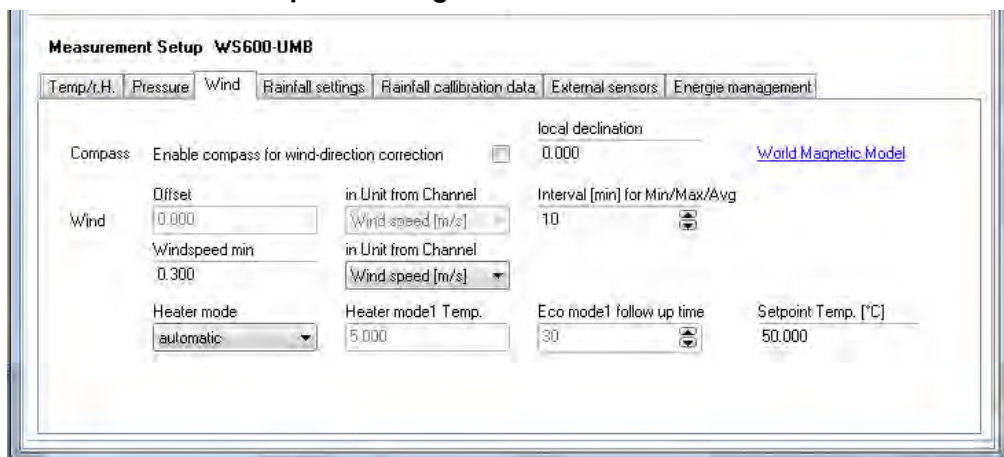


Figure 12: Wind Settings

- 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.



10.2.9 Energy Management

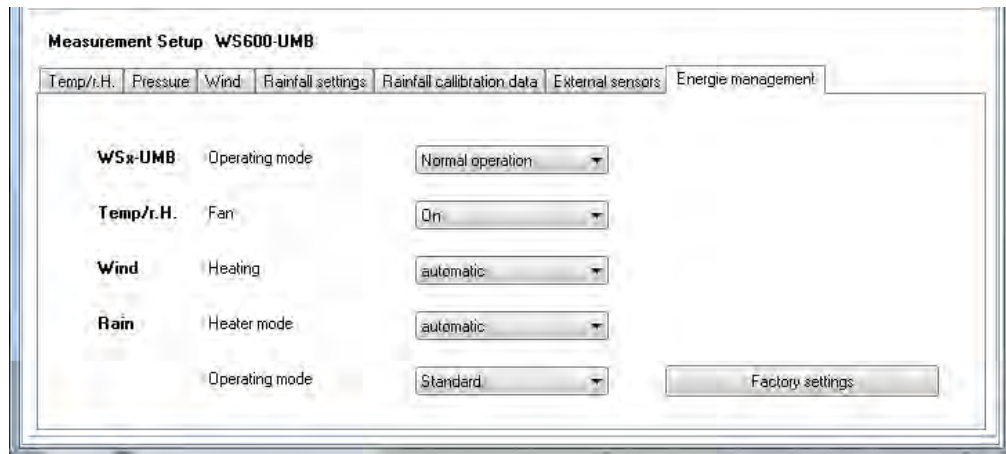


Figure 15: Energy Management Settings

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

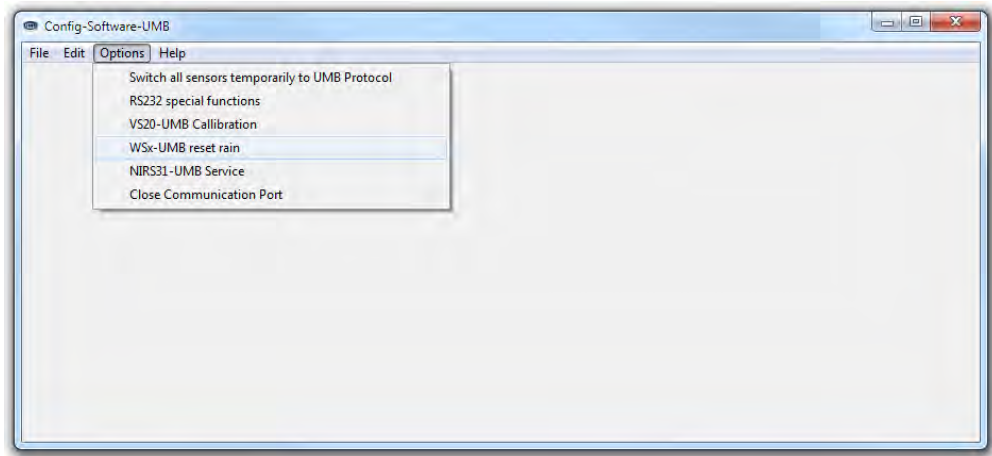
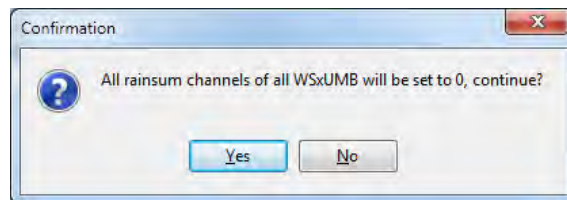


Figure 16: Reset Precipitation Quantity

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.

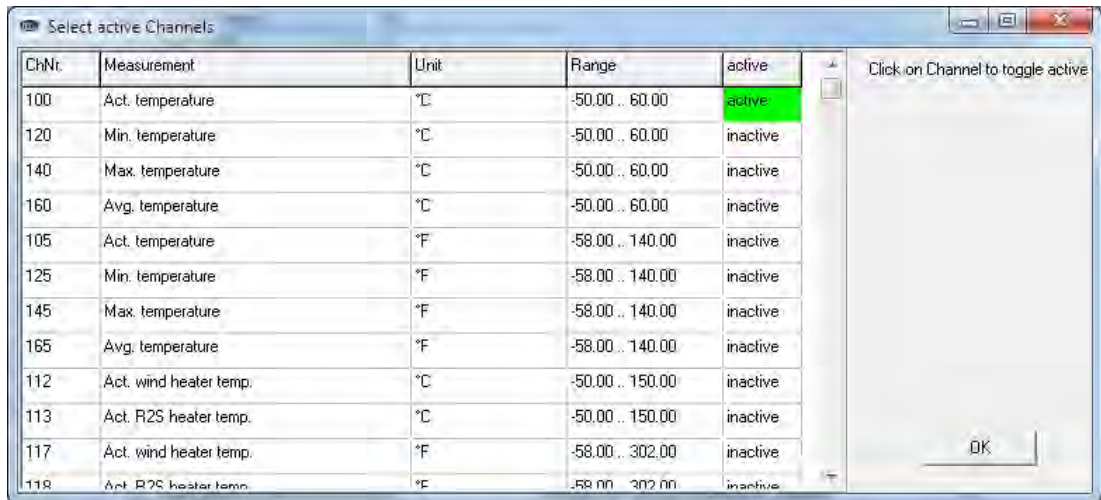


Figure 17 Measurement Polling Channels

10.3.2 Example of Measurement Polling

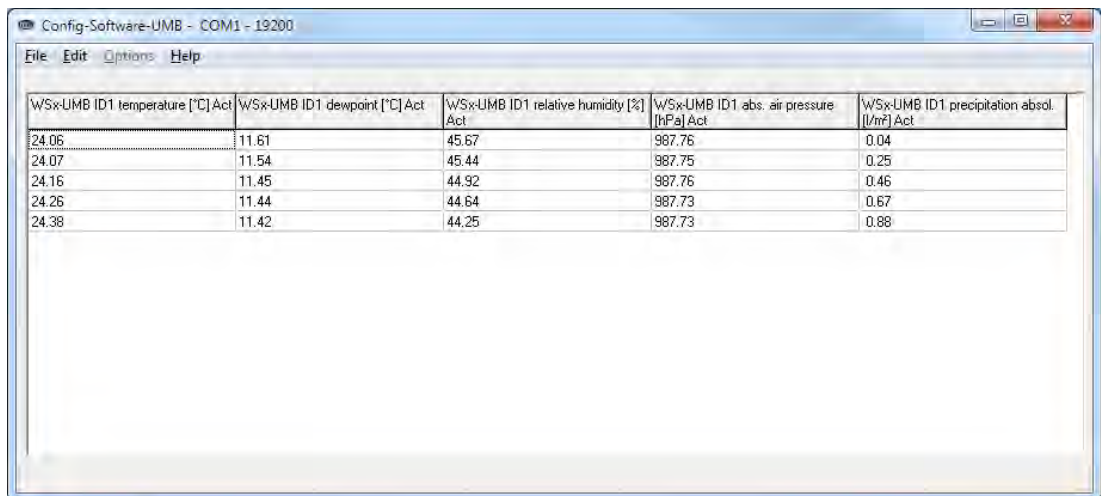


Figure 18 Example of Measurement Polling



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 be 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 the 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.

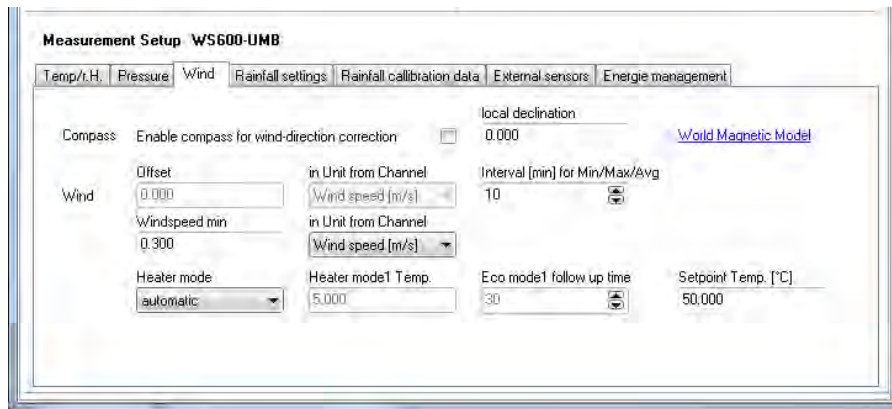


Figure 19: Operating Modes for Equipment Heating

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.

Heater mode	Heater mode1 Temp.	Eco mode1 follow up time	Setpoint Temp. [°C]
Eco-Mode 1	5.000	30	50.000

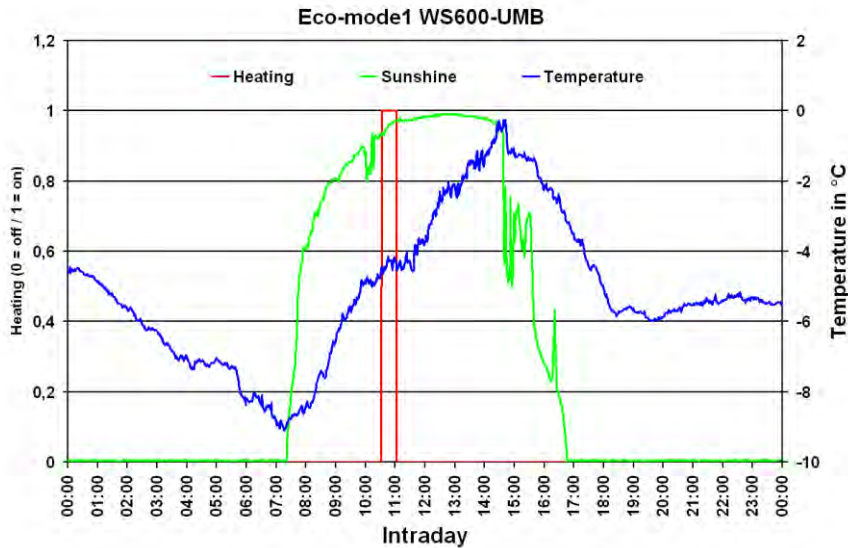
Setpoint Temp.: The heating controls at this temperature (in °C)

Heating mode1 Temp.: Threshold temperature (in °C) with effect from which heating is enabled

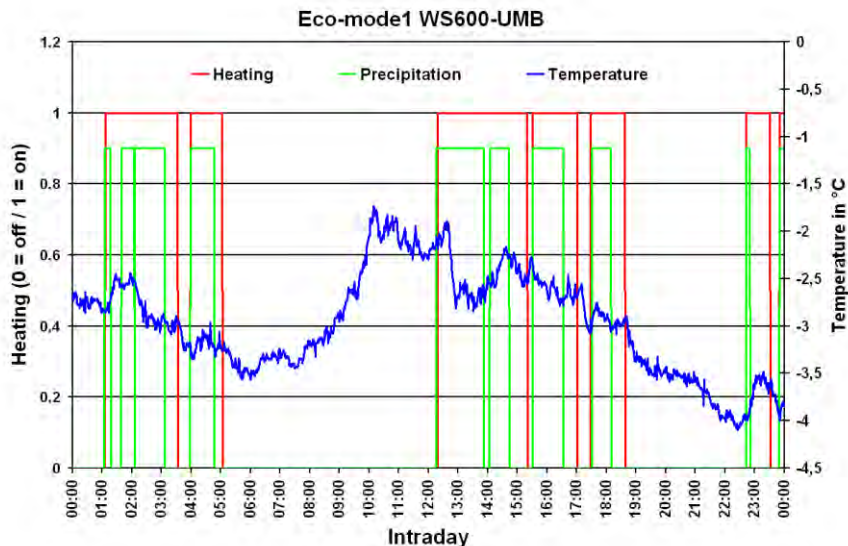
Eco mode1 follow-up time: Follow-up time (in minutes)

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).

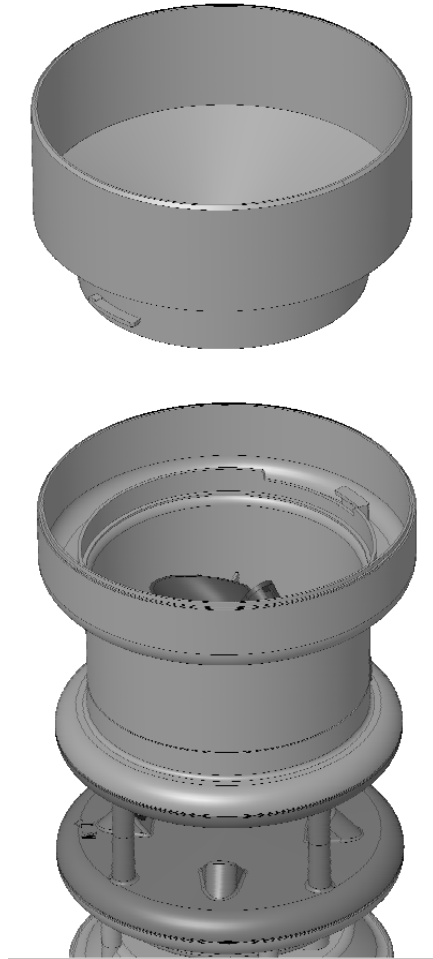


Figure 20: WS601-UMB
with removed funnel

- 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 Supply	Standard		Power Saving Mode 1		Power Saving Mode 2	
	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	135 mA	70 mA	8 mA	8 mA	4 mA	2 mA
WS302-UMB						
WS303-UMB						
WS304-UMB						
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	145 mA	85 mA	16 mA	25 mA	4 mA	2 mA
WS502-UMB						
WS503-UMB						
WS504-UMB						
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	833 mA / 20VA at 24VDC
WS503-UMB, WS504-UMB	
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, 19200³, 28800, 57600

(In SDI-12 mode, the interface is changed to meet the requirements of the standard.)

Housing: Plastic (PC)

³Factory 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/m ³ ; 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/m ²
Resolution	< 1W/m ²
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/m ²)	<1%
Directional error (at 80° with 1000 W/m ²)	<20 W/m ²
Temperature dependence of sensitivity	<5% (-10 to +40°C)
Tilt error (at 1000 W/m ²)	<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

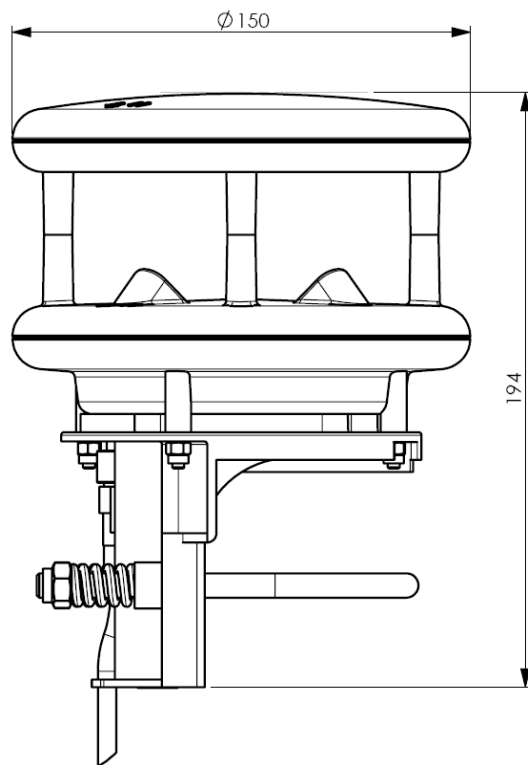


Figure 21: WS200-UMB

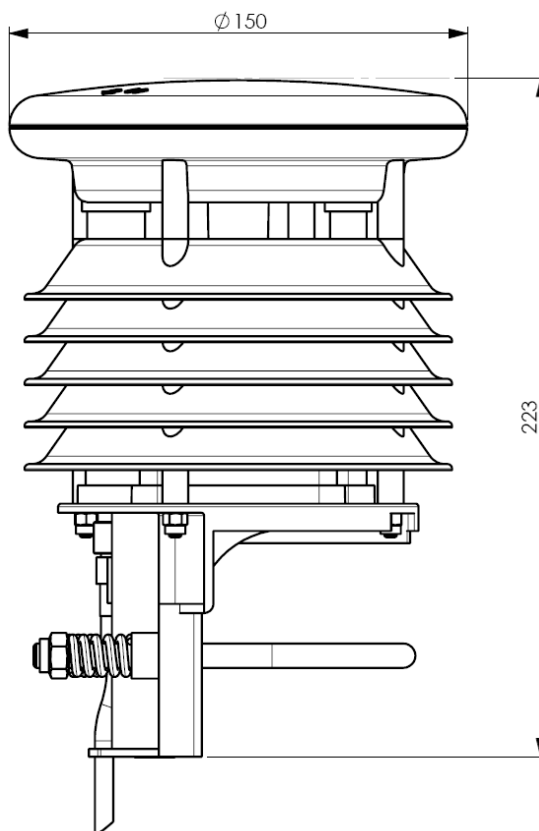


Figure 22: WS300-UMB

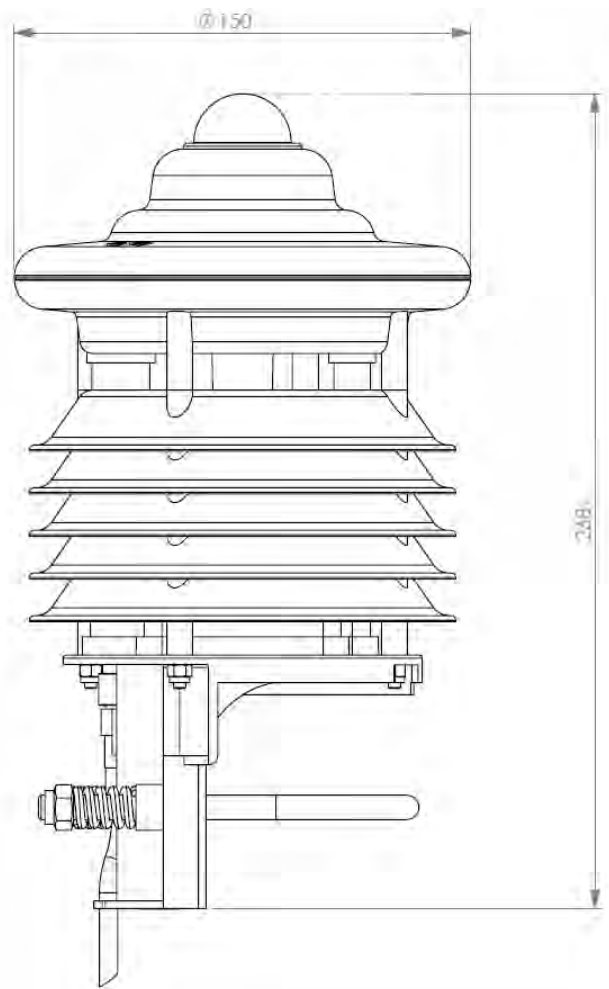


Figure 23: WS301-UMB

WS302-UMB, WS303-UMB und WS304-UMB are similar.

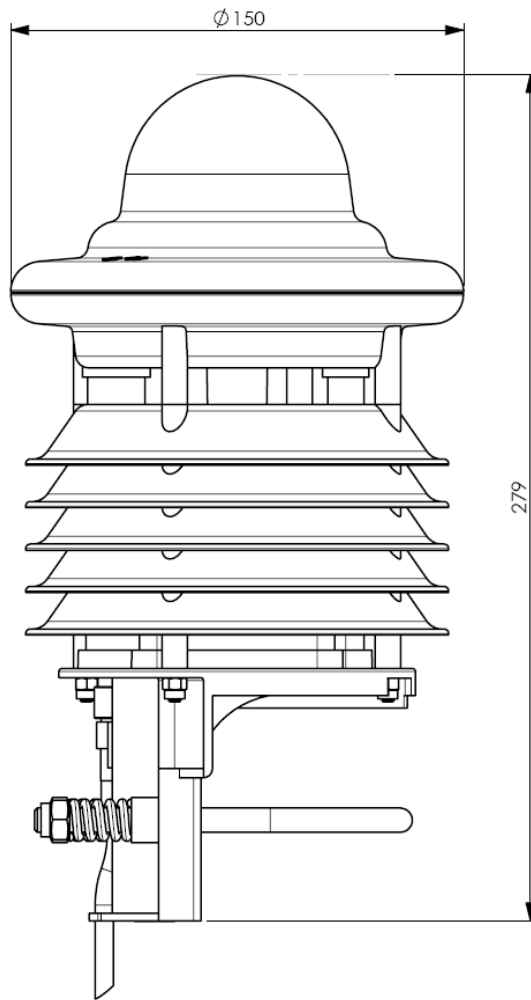


Figure 24: WS400-UMB

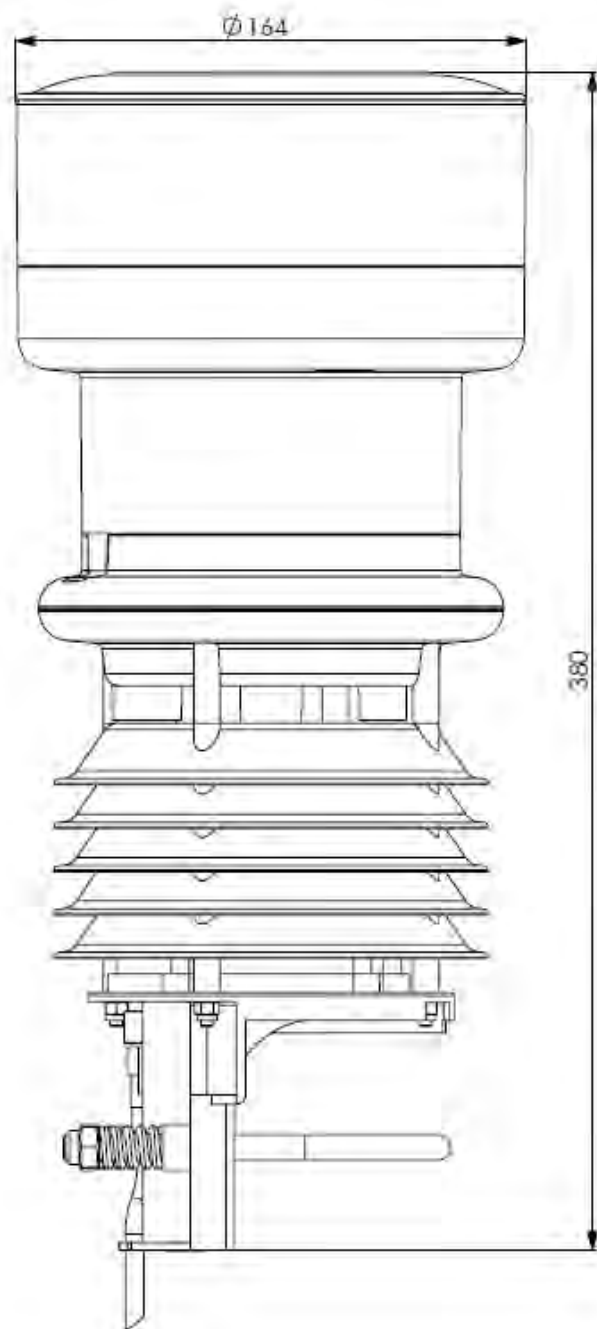


Figure 25: WS401-UMB

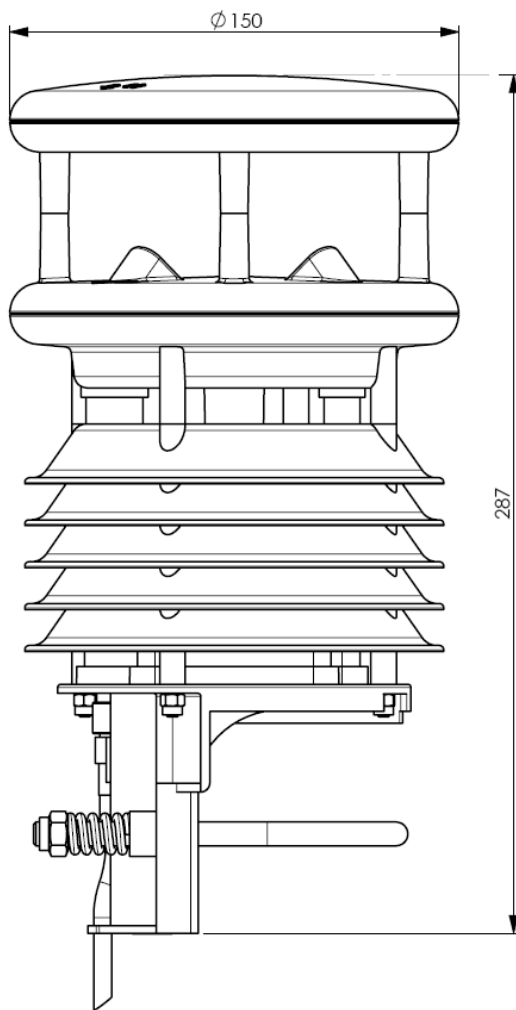


Figure 26: WS500-UMB

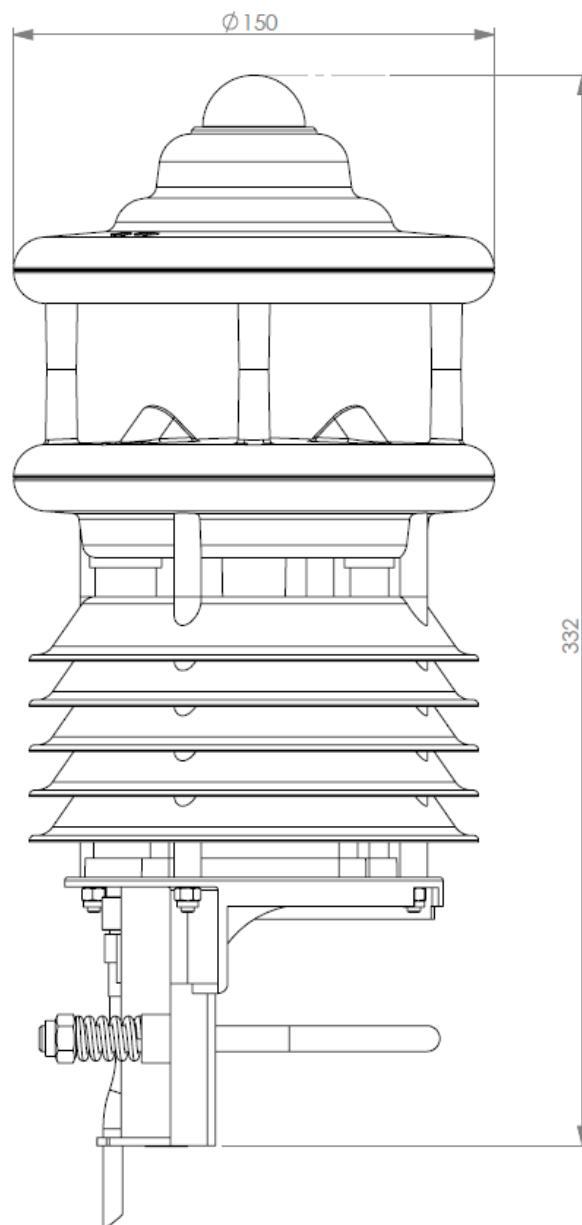


Figure 27: WS501-UMB

WS502-UMB, WS503-UMB und WS504-UMB are similar.

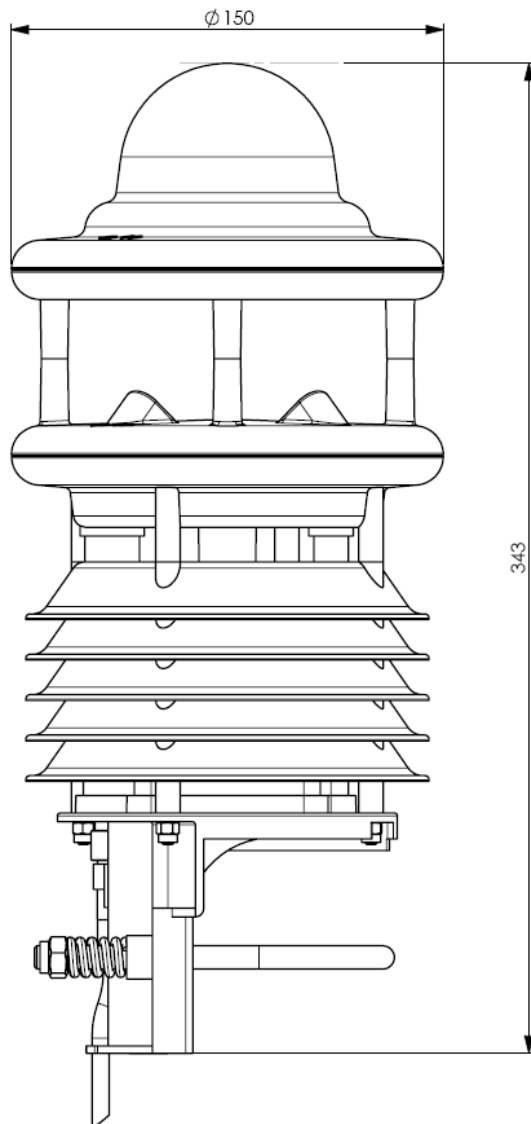


Figure 28: WS600-UMB

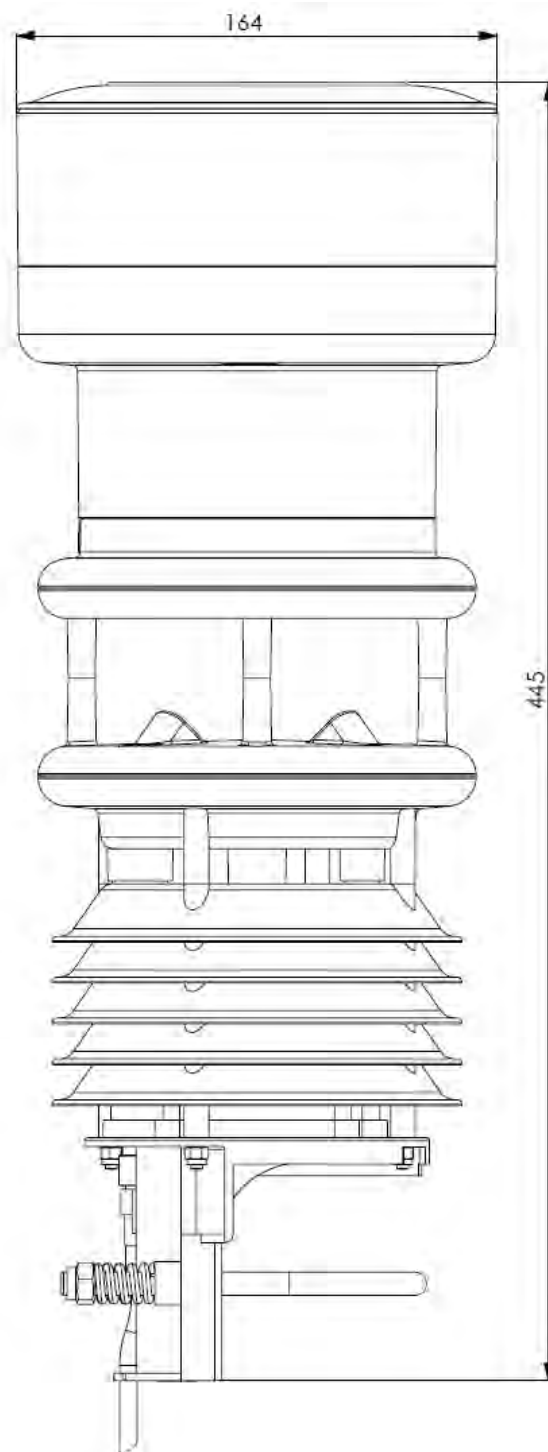


Figure 29: WS601-UMB

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	<ul style="list-style-type: none"> - 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	<p>The device is unable to execute a valid measurement due to the ambient conditions. This may be due to the following reasons:</p> <ul style="list-style-type: none"> - 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 always 100%	<p>In normal operation the device should always transmit 90 – 100%. Values up to 50% do not represent a general problem.</p> <p>When the error value 55h (85d) is transmitted this value is 0%.</p> <p>If the device permanently transmits values below 50% this may mean that there is a fault.</p>
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 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.

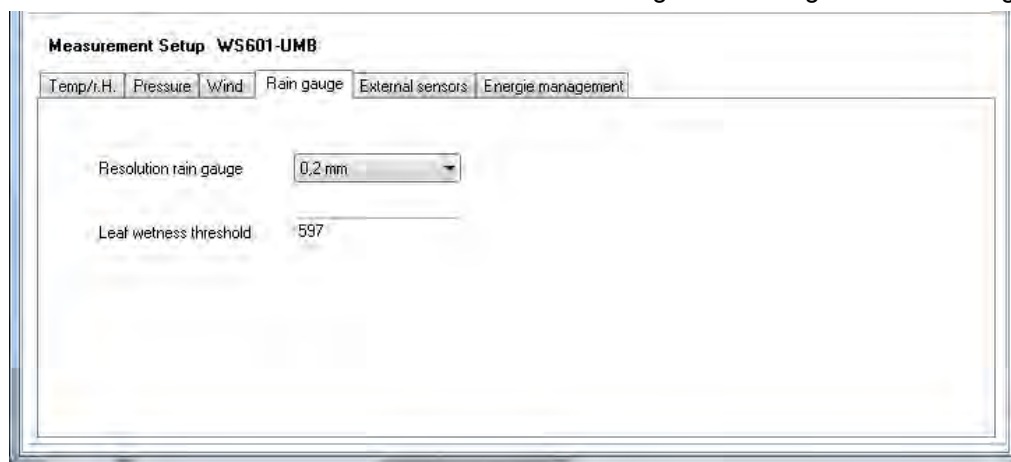


Figure 31: Setting the Leaf Wetness Threshold



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.

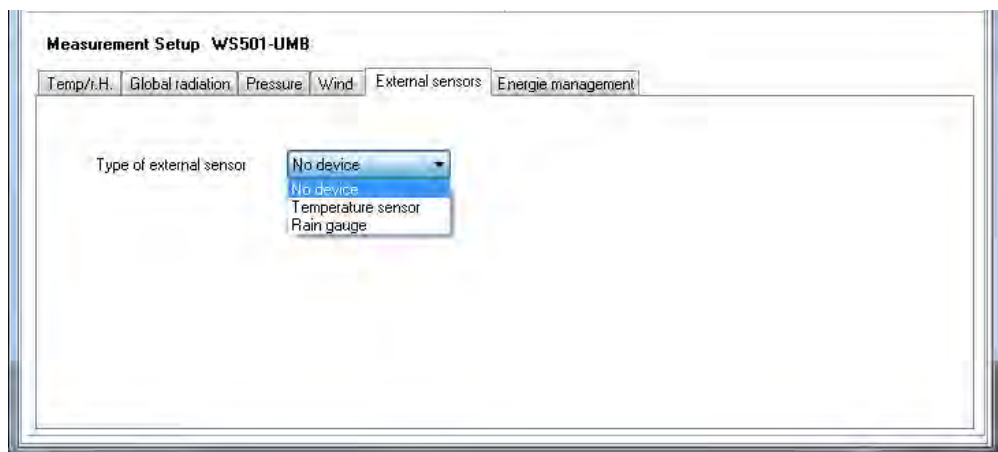


Figure 32: Setting type of external sensor

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 WTB100 can 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:

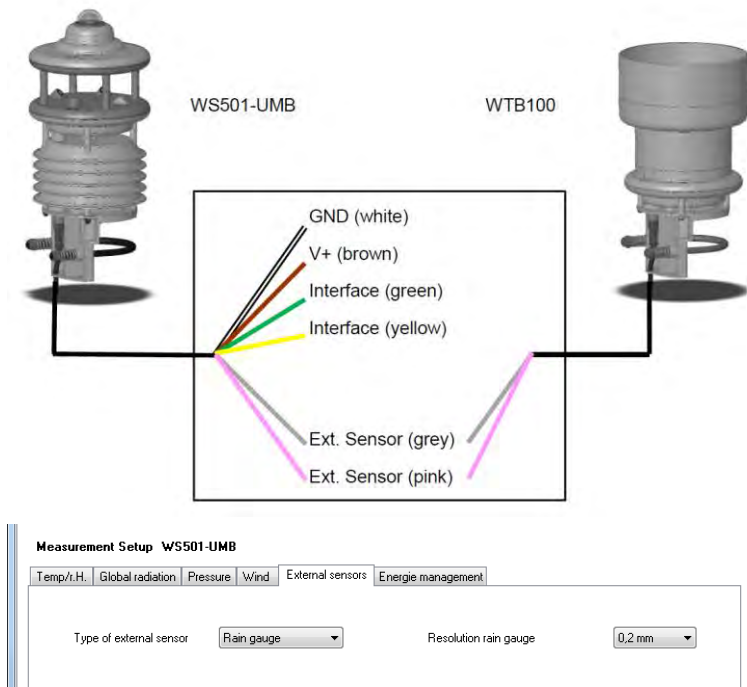


Figure 33: Example WS501-UMB and WTB100

19 Appendix

19.1 Channel List Summary

The channel assignment applies to online data requests in binary and ASCII protocol.

UMB Channel				special	Measurement Variable (float32)	Measuring Range		
act	min	max	avg			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/m ³
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/m ³
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/m ²			
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/m ²			
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/m ² /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/m ²
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 $[+60^{\circ}\text{C} - (-50^{\circ}\text{C})] / 65520 * 34785 + (-50^{\circ}\text{C}) = 8.4^{\circ}\text{C}$

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	-50.0	60.0	°C
Dew point	-58.0	140.0	°F
Wet Bulb Temperature	-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	0.0	1000.0	g/m ³
Mixing ratio	0.0	1000.0	g/kg
Specific Enthalpy	-100.0	1000.0	kJ/kg
Pressure			
Relative air pressure	300.0	1200.0	hPa
Absolute air pressure	300.0	1200.0	hPa
Air Density			
air density	0.0	3.0	kg/m ³
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 / m ²
	0.0	6552.0	mm
	0.0	257.9	inches
	0.0	257952.7	mil
Quantity since last request	0.0	655.2	litres / m ²
	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/m ² /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/m ²
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/m ²	Ga	W	(Channel 900)
	Min. Global Radiation in W/m ²	Gn	W	(Channel 920)
	Max. Global Radiation in W/m ²	Gx	W	(Channel 940)
	Avg. Global Radiation in W/m ²	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)
E5<CR>	Act. Air Density in kg/m ³	Ad	G	(Channel 310)
	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	
Mx<CR>	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.

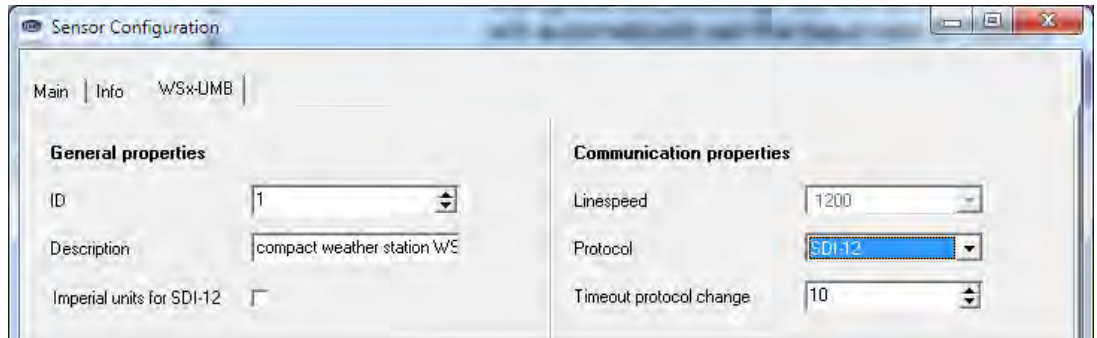


Figure 34: Sensor Configuration SDI-12

Measurement data can be transmitted alternatively in metric or US units. The selection is done by the UMB Config Tool.

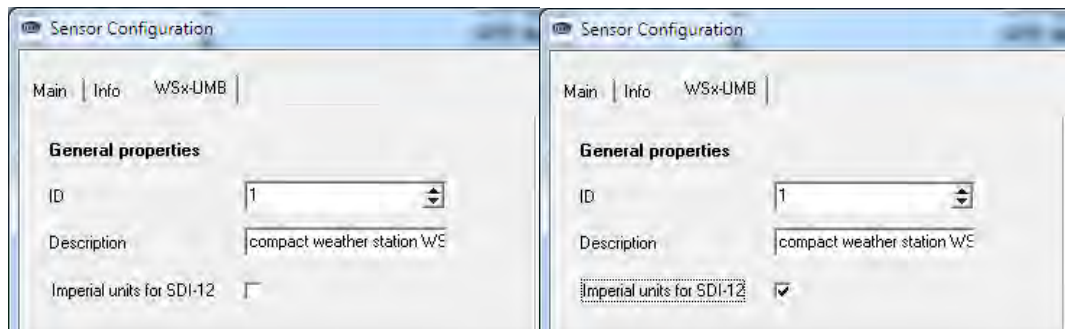


Figure 35: Sensor Configuration SDI-12 Units

Metric units

US 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?
al!	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 v! 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 l-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 enthalpy 29,3kJ/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/m ³
Abs. Humidity (max)	245	0.0	1000.0	g/m ³
Abs. Humidity (avg)	265	0.0	1000.0	g/m ³
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/m ³
Abs. Humidity (max)	245	0.0	1000.0	g/m ³
Abs. Humidity (avg)	265	0.0	1000.0	g/m ³
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/m ²
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/m ²
Global Radiation (max)	940	0.0	1400.0	W/m ²
Global Radiation (avg)	960	0.0	1400.0	W/m ²

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/m ²
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/m ²
Global Radiation (max)	940	0.0	1400.0	W/m ²
Global Radiation (avg)	960	0.0	1400.0	W/m ²

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/m ²
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/m ³
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/m ²
Global Radiation (max)	940	0.0	1400.0	W/m ²
Global Radiation (avg)	960	0.0	1400.0	W/m ²

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/m ²
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/m ³
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/m ²
Global Radiation (max)	940	0.0	1400.0	W/m ²
Global Radiation (avg)	960	0.0	1400.0	W/m ²

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/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)	114	-50.0	60.0	°C
Specific Enthalpy (act)	215	-100.0	1000.0	kJ/kg
Air Density	310	0.000	3.000	kg/m ³
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 speed 1.8m/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/m ³
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/m ³
Abs. Humidity (min)	225	0.0	1000.0	g/m ³
Abs. Humidity (max)	245	0.0	1000.0	g/m ³
Abs. Humidity (avg)	265	0.0	1000.0	g/m ³
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/m ²
Global Radiation (min)	920	0.0	1400.0	W/m ²
Global Radiation (max)	940	0.0	1400.0	W/m ²
Global Radiation (avg)	960	0.0	1400.0	W/m ²

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 ≥ 10 sec. Anyway for most of the weather data significant changes have to be 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 see 19.7.3.1

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 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
Temperatur e-Buffer	Temperatur e	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
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