**TÜV RHEINLAND**
**ENERGIE UND UMWELT GMBH**

Deutsche Akkreditierungsstelle
D-PL-11120-02-00

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

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

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

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

**according to EN ISO/IEC 17025.**

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



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

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

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

**Scope of report:**

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

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# 1. General and certification proposal

## 1.1 General

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

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

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

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

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

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

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

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

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

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

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

6.1 5.3.2 Repeatability standard deviation at zero point

→ no minimum requirement defined

6.1 5.3.3 Repeatability standard deviation at reference point

→ not relevant to particulate measuring systems

6.1 5.3.4 Linearity (lack of fit)

→ not relevant to particulate measuring systems

6.1 5.3.7 Sensitivity coefficient of surrounding temperature

→ no minimum requirement defined

6.1 5.3.8 Sensitivity coefficient of supply voltage

→ no minimum requirement defined

6.1 5.3.11 Standard deviation from paired measurements

→ no minimum requirement defined

6.1 5.3.12 Long-term drift

→ no minimum requirement defined

6.1 5.3.13 Short-term drift

→ not relevant to particulate measuring systems

6.1 5.3.18 Overall uncertainty

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

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

The following procedure was suggested:

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

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

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

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

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

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

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

- VDI Standard 4202, Sheet 1, “Performance criteria for type approval tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants”, September 2010/June 2002
- VDI Standard 4203, Sheet 3, “Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants”, September 2010/August 2004
- Standard EN 12341, “Air quality – Determination of the $PM_{10}$ fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods of equality”, German version EN 12341: 1998
- Standard EN 14907, “Ambient air quality – Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter”, German version EN 14907: 2005
- Guidance document “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of January 2010

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

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

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

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

  The software version published so far depicts now as follows:

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

  100380.0014.0001.0001.0011

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

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

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

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

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

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

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

   Description in chapter 3.3  AMS scope and setup from page 47

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

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

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

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

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

*Table 1: Description of test sites*

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

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

*Table 2: Description of test sites (UK)*

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

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

*Table 3: Results of equivalence tests*

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

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

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

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

## 1.2 Certification proposal

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

**AMS designation:**

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

**Manufacturer:**

PALAS GmbH, Karlsruhe

**Field of application:**

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

**Measuring ranges during type approval testing:**

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

**Software version:**

100380.0014.0001.0001.0011

**Restrictions:**

None

**Notes:**

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

**Test report:**

TÜV Rheinland Energie und Umwelt GmbH, Cologne
Report no.: 936/21227195/C of 12 October 2016

## 1.3 Summary of test results

## Compilation of test results "Initial type approval test"

| Performance criterion | Specification | Test result | Fulfilled | Page |
|---|---|---|---|---|
| 4 Requirements on instrument design | | | | |
| 4.1 General requirements | | | | |
| 4.1.1 Measured value display | Shall be available. | The measuring system provides a display that shows the measured values. | yes | 80 |
| 4.1.2 Easy maintenance | Necessary maintenance of the measuring systems should be possible without larger effort, if possible from outside. | Maintenance work can be carried out from the outside with commonly available tools and reasonable time and effort. | yes | 81 |
| 4.1.3 Functional check | If the operation or the functional check of the measuring system requires particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment. | All functions described in the operator's manual are available, can be activated, and work properly. | yes | 84 |
| 4.1.4 Setup times and warm-up times | Shall be specified in the instruction manual. | Setup and warm-up times were determined. | yes | 86 |
| 4.1.5 Instrument design | Shall be specified in the instruction manual. | The instrument design specifications listed in the operator's manual are complete and correct. | yes | 87 |
| 4.1.6 Unintended adjustment | It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation. | The measuring system is secured against illicit or unintentional adjustments of instrument parameters. Additional protection against unauthorized access is provided by the lockable door of the weatherproof housing. | yes | 88 |
| 4.1.7 Data output | The output signals shall be provided digitally and/or as analogue signals | The test signals are provided digitally (via Ethernet, RS232, and USB). | yes | 89 |

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

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

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

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

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

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

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

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

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

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

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

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

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

# 2. Task definition

## 2.1 Nature of test

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

## 2.2 Objective

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

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

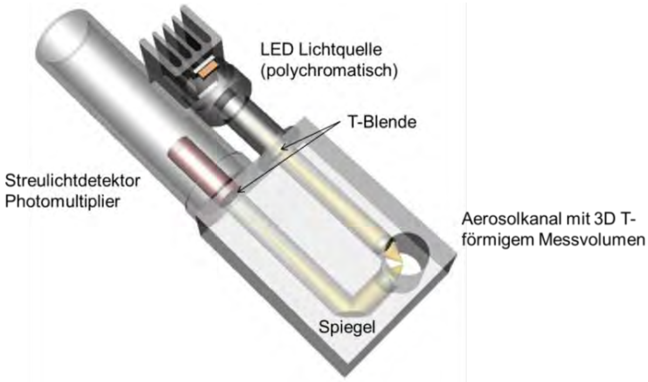
The testing was performed with respect to the following guidelines:

- VDI Standard 4202, Sheet 1, “Performance criteria for type approval tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants”, September 2010/June 2002 [1]
- VDI Standard 4203, Sheet 3, “Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants”, September 2010/August 2004 [2]
- European Standard EN 12341, “Air quality – Determination of the $PM_{10}$ fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods of equality”, German version EN 12341: 1998 [3]
- European Standard EN 14907, “Ambient air quality – Standard gravimetric measurement method for the determination of the $PM_{2,5}$ mass fraction of suspended particulate matter”, German version EN 14907: 2005 [4]
- Guidance document “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English Version: January 2010 [5]

# 3. Description of the AMS tested

## 3.1 Measuring principle

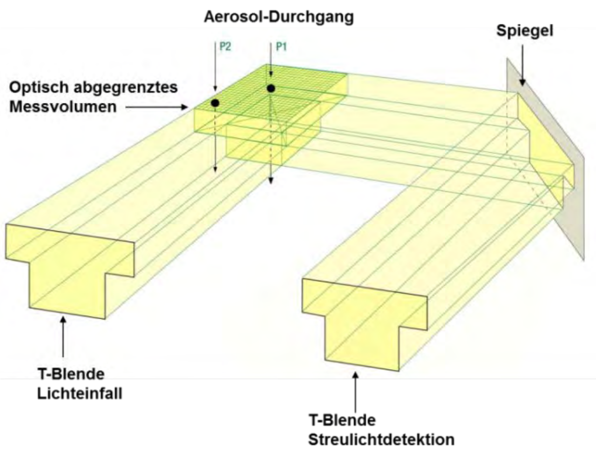
The Fidas® 200 S respectively Fidas® 200 is an optical aerosol spectrometer which determines particle size by means of scattered light analysis according to Lorenz-Mie.




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

*Figure 1: Design of the Fidas® sensor*

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




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

*Figure 2: Graphical representation of the T-aperture*

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

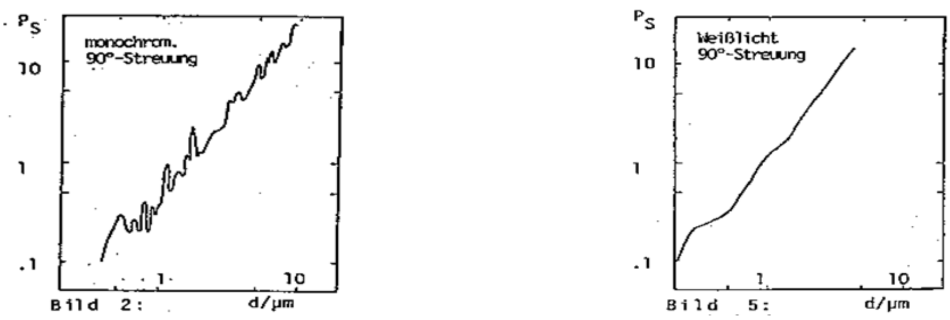



*Figure 3:* *Calibration curve for 90° scattered light detection with monochromatic light source (left) and with polychromatic light source (right)*

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

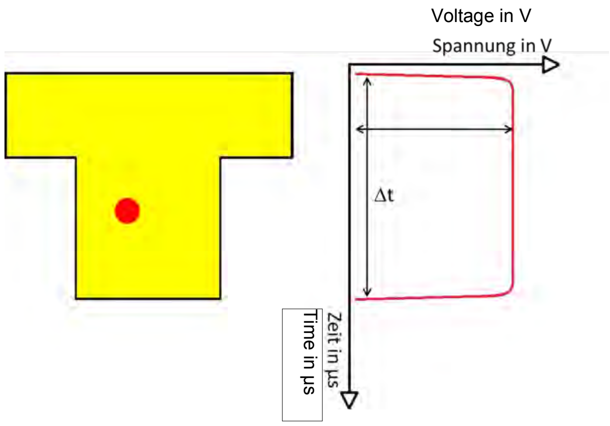



*Figure 4:* *Measurement of scattered light signal at one single particle. Amplitude and signal length are being measured*

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

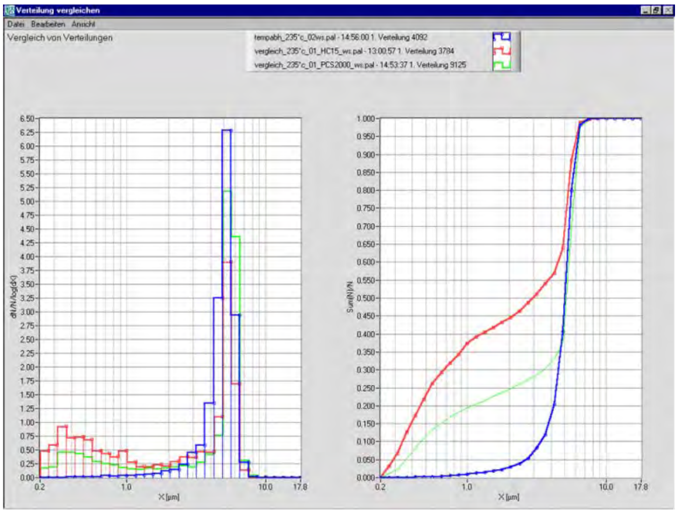



*Figure 5: Comparison of an optical light scattering spectrometer with rectangular aperture (HC15, red) with an optical scattering light spectrometer with T-aperture (welas®, blue) upon application of monodisperse 5 µm particles*

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

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

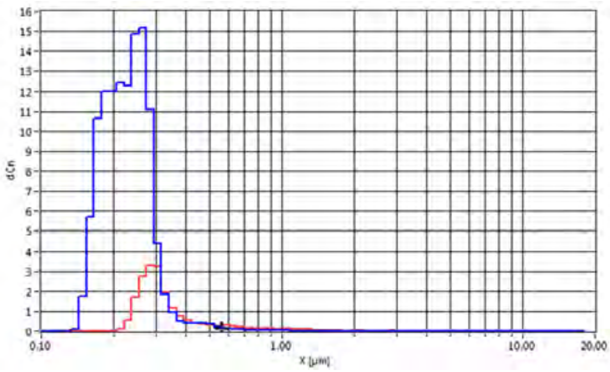



*Figure 6: Comparison of results of a measurement carried out in close proximity to a street between the Fidas® measuring system (size range from 0.18 µm, blue curve) and another optical measuring system (size range from 0.25 µm, red curve)*

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

The described features

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

yield the following advantages

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

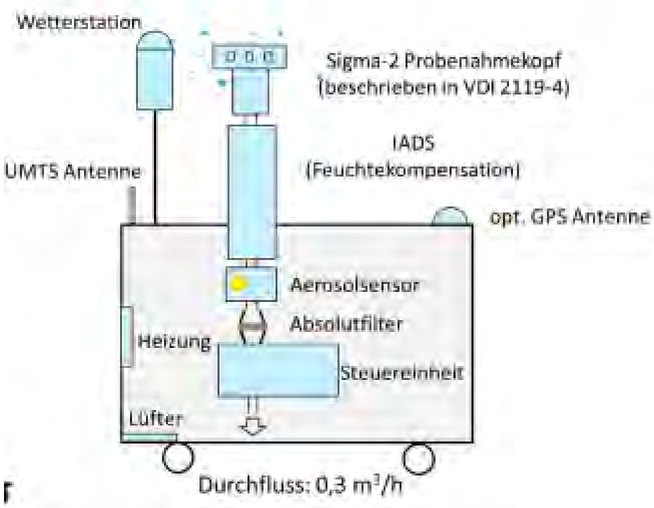
In addition to the continuous and simultaneous measurement of PM fractions, information on measured particle number concentration and particle size distribution is provided in high size resolution as well.

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

## 3.2 Principle of operation

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

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




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

Durchfluss/flow rate: 0.3 $m^3$/h

*Figure 7: Schematic view of the Fidas® 200 S*

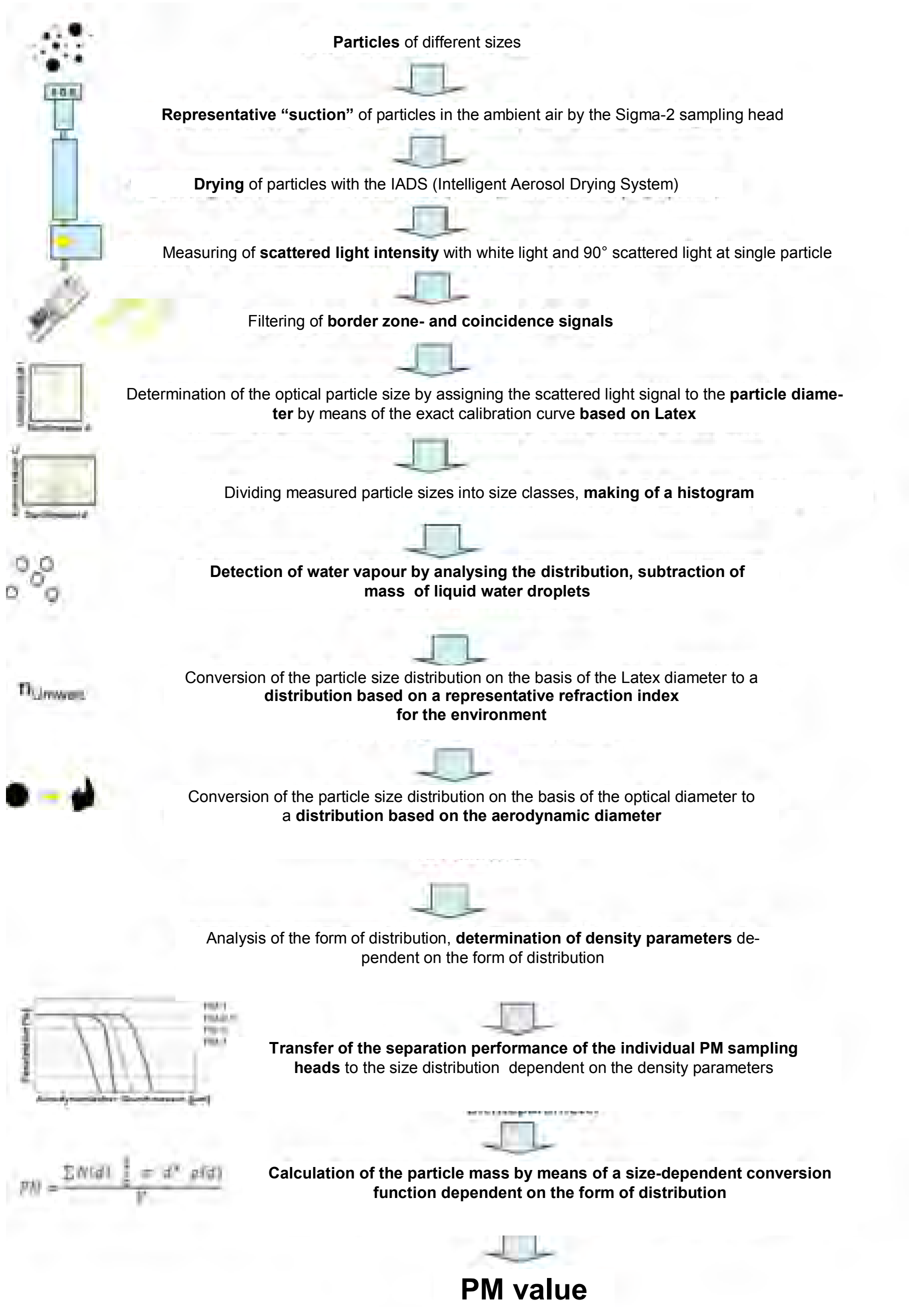



*Figure 8: Overview of the measurement steps of the Fidas® 200 S / Fidas® 200*

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

## 3.3 AMS scope and setup

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

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

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

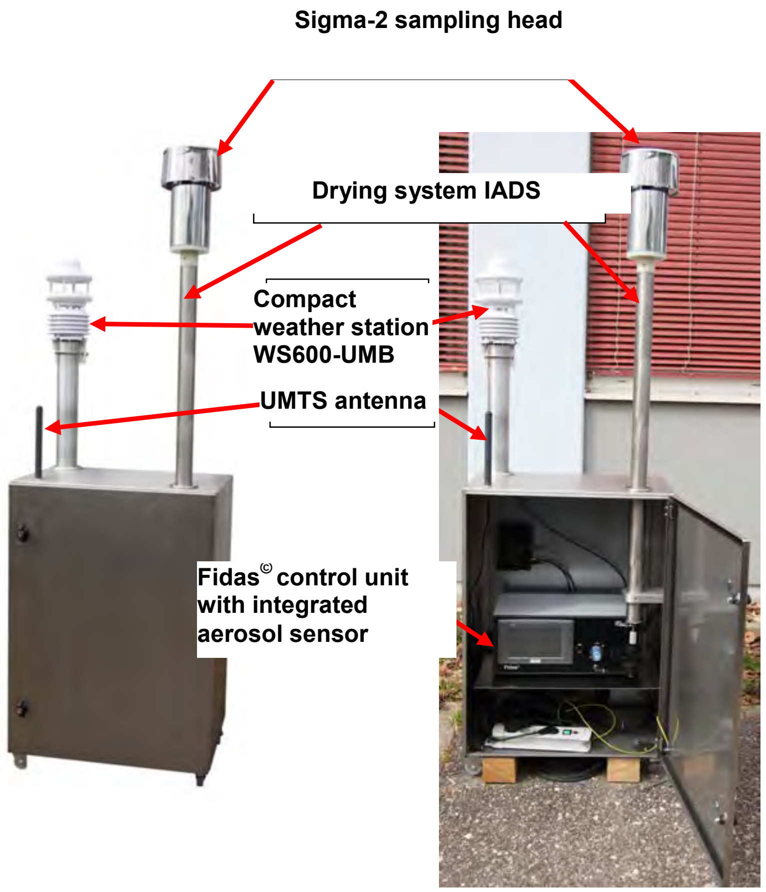



*Figure 9 Overview Fidas® 200 S complete system (=Fidas® 200 in weatherproof housing)*


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


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

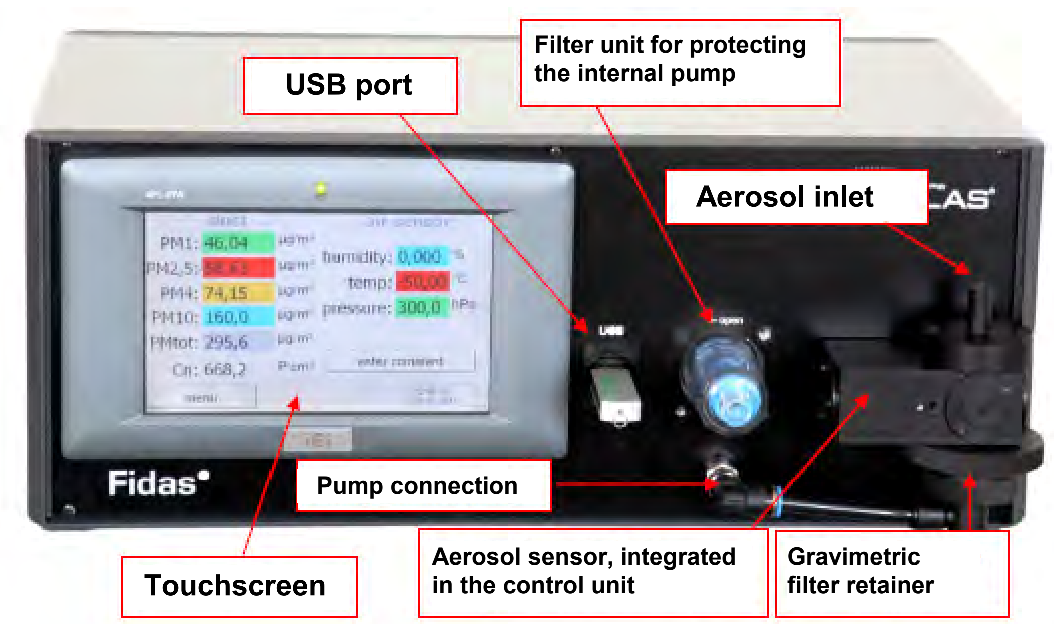



*Figure 12: Control unit of the Fidas® 200 S / Fidas® 200*

*Figure 13: Weather station WS600-UMB*

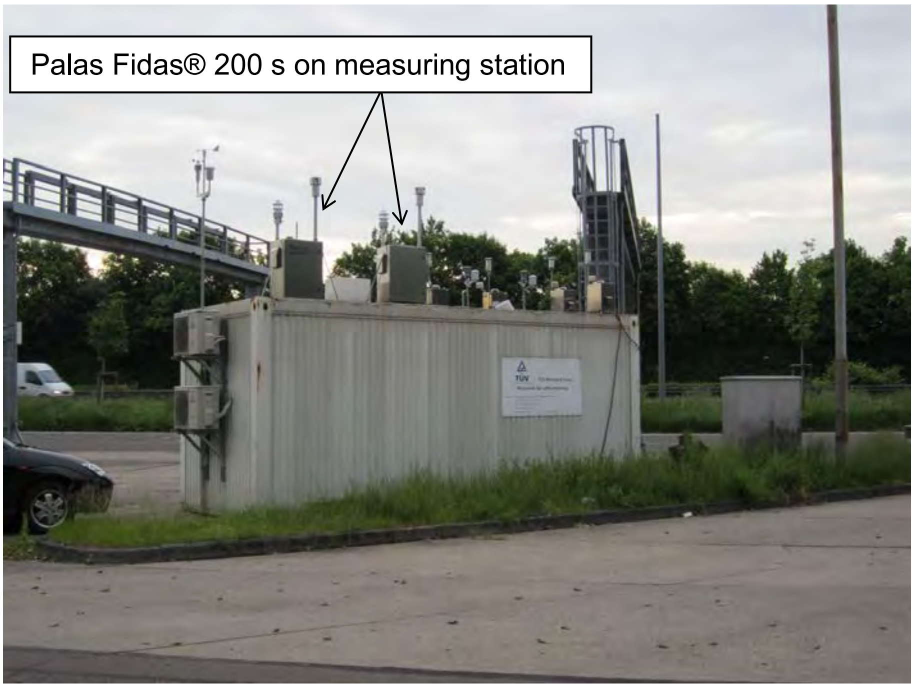



*Figure 14: Fidas® 200 S measuring systems on measuring station*

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

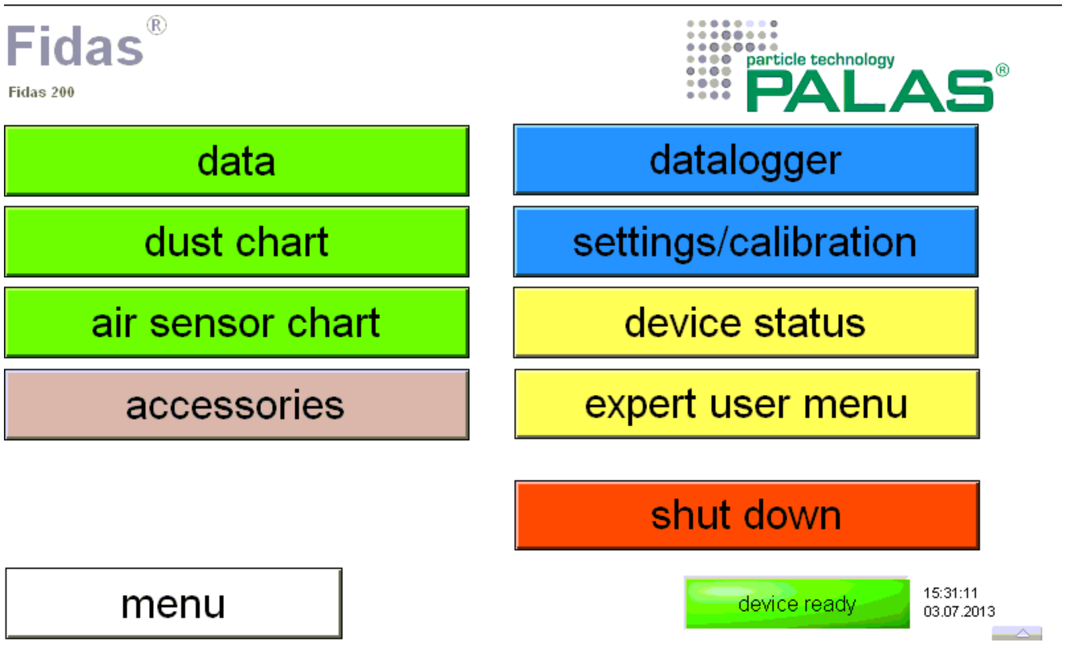



*Figure 15: Main menu*

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

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

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

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

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

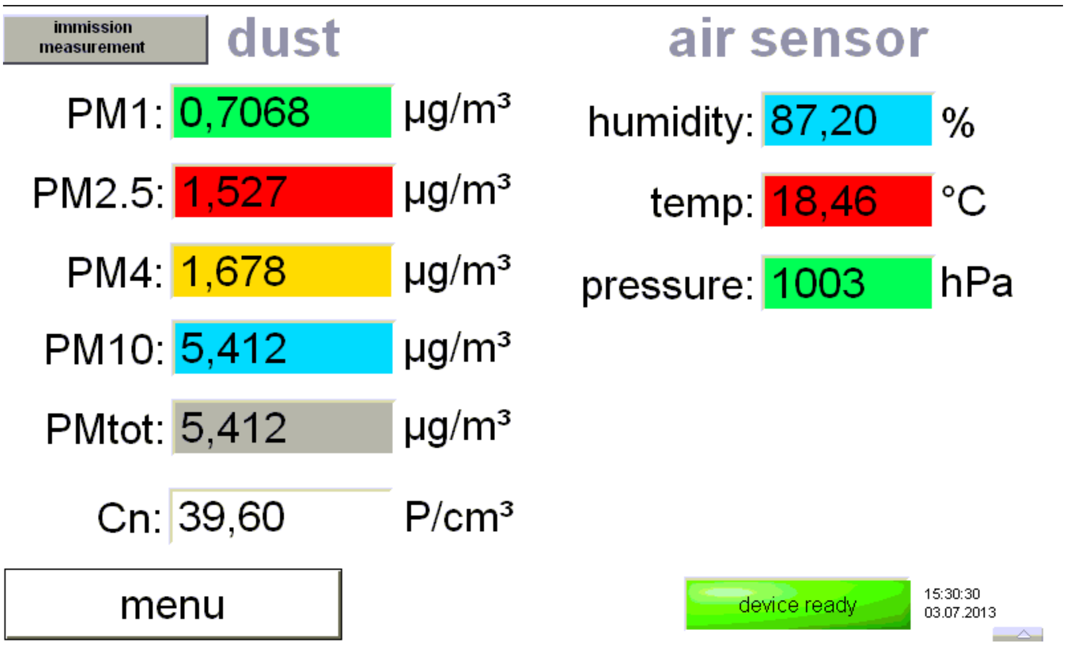



*Figure 16: “data” menu*

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

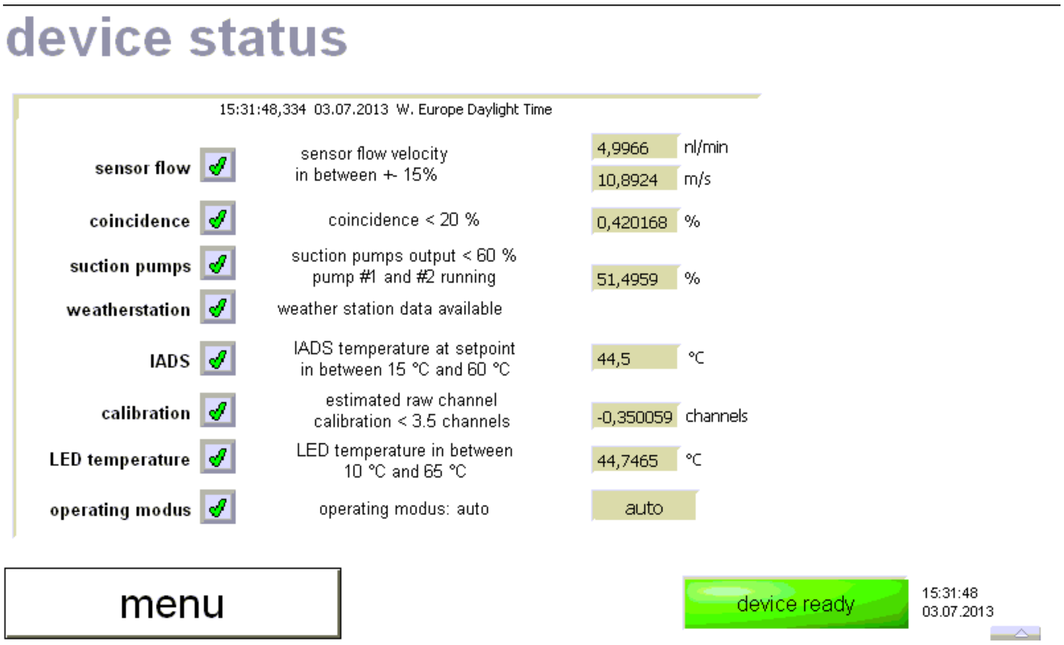



*Figure 17: “device status” menu*

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

The following parameters are monitored continuously:

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

Coincidence — Detection of more than one particle within the optical detection volume.
An error message is displayed if this occurs at a rate of more than 20 %.

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

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

The following options are available:

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

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

*Figure 18: Zero filter*

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

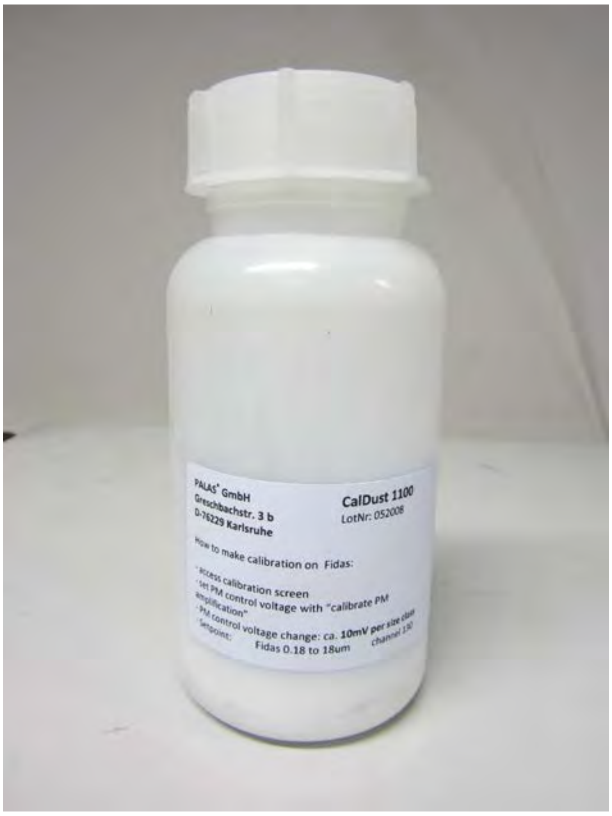



*Figure 19: CalDust 1100 for verification / calibration of sensitivity*

**Test standard MonoDust1500**

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

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

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

The following results have been obtained:

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

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

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

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

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

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

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

# 4. Test programme

## 4.1 General

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

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

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

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

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

## 4.2 Laboratory test

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

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

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

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

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

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

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

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

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

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

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

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

## 4.3 Field test

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

| | |
|---|---|
| System 1: | SN 0111 |
| System 2: | SN 0112 |

The following performance criteria were tested in the field:

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

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

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

The following auxiliary devices were used during the field test:

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

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

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

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

**Measuring sites and AMS placement**

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

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

*Table 6: Field test sites*

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

*Table 7: Additonal field test sites (UK)*

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

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

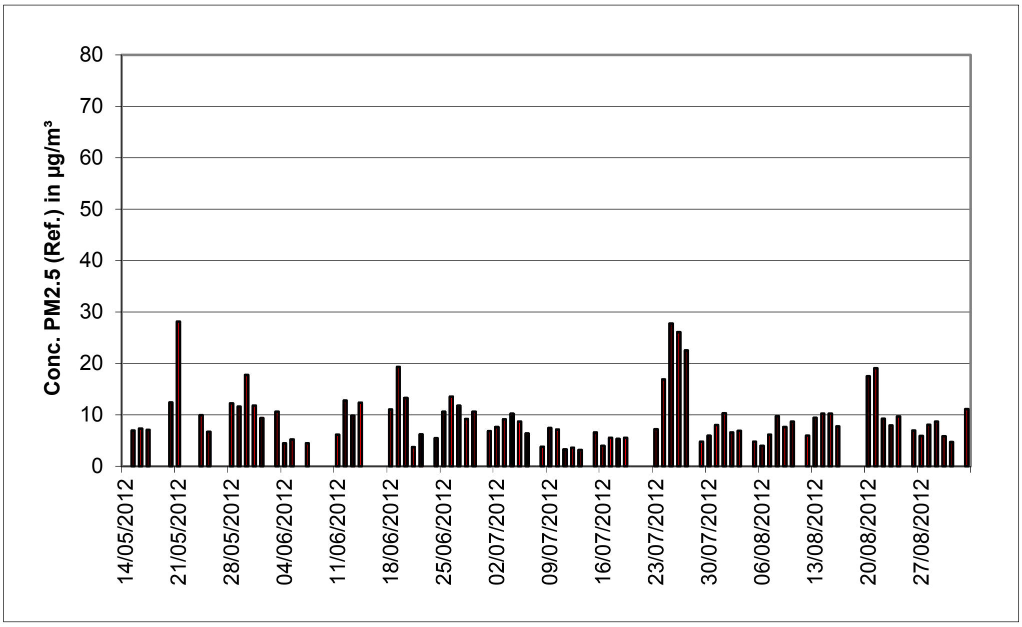



*Figure 20: Course of $PM_{2.5}$ concentrations (reference) at test site “Cologne, summer”*

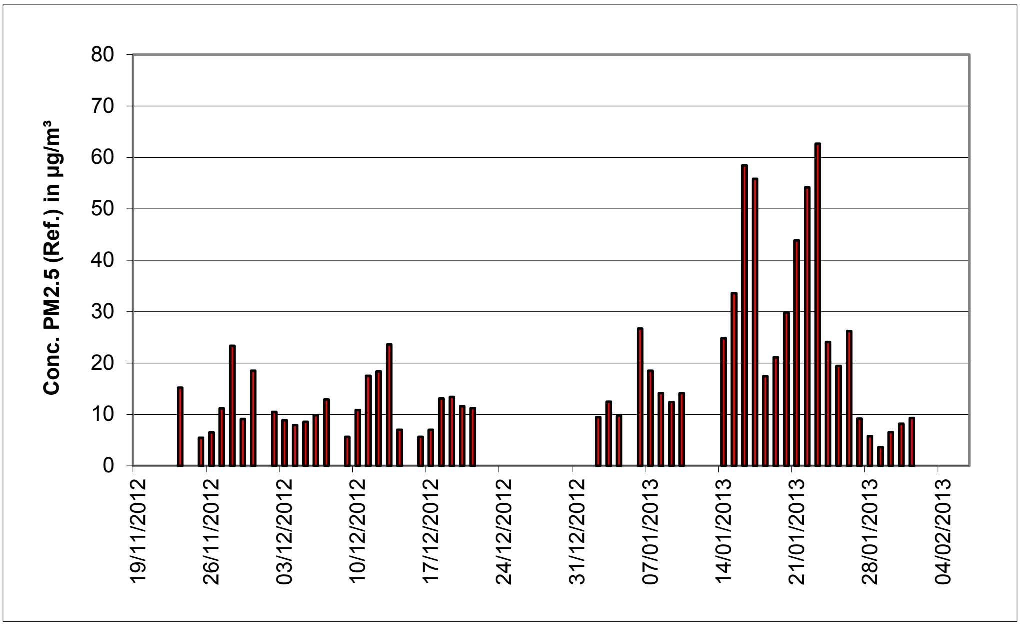



*Figure 21: Course of $PM_{2.5}$ concentrations (reference) at test site “Cologne, winter”*

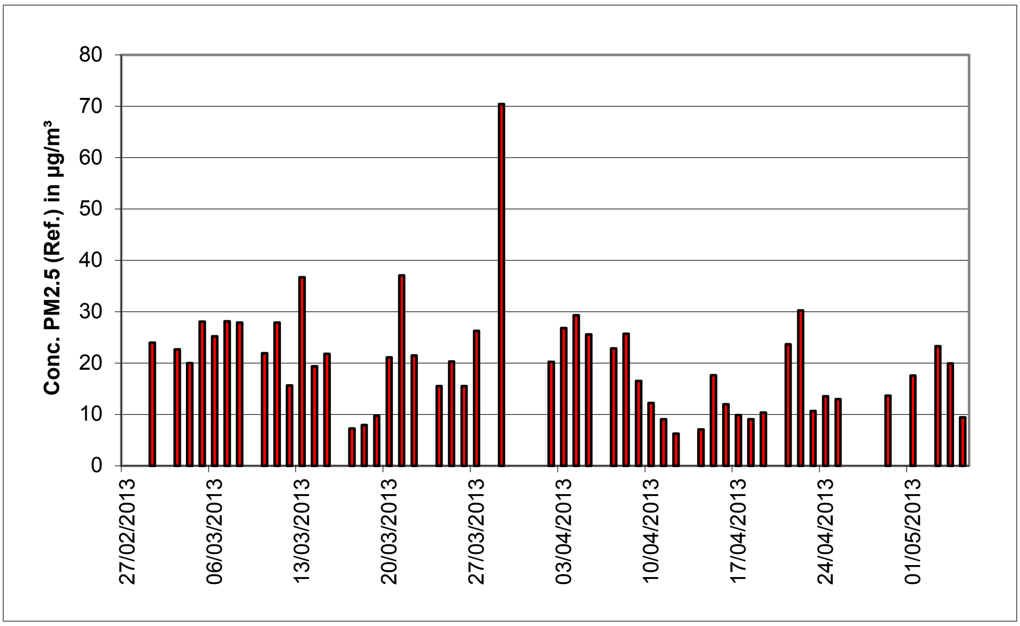



*Figure 22: Course of $PM_{2.5}$ concentrations (reference) at test site “Bonn, winter”*

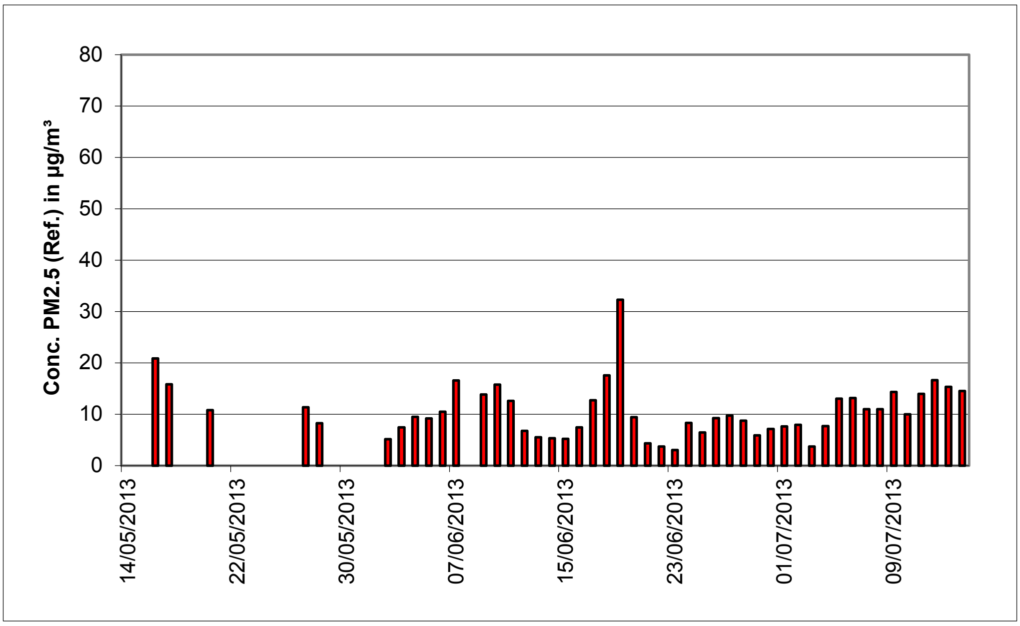



*Figure 23: Course of $PM_{2.5}$ concentrations (reference) at test site “Bornheim, summer”*

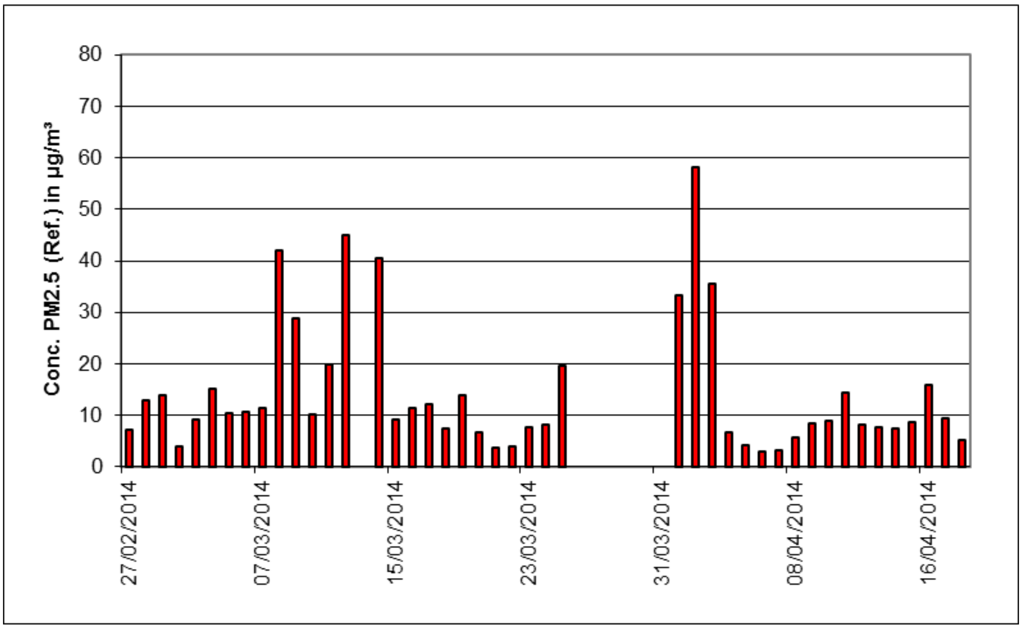



*Figure 24: Course of $PM_{2.5}$ concentrations (reference) at test site "Teddington, winter"*

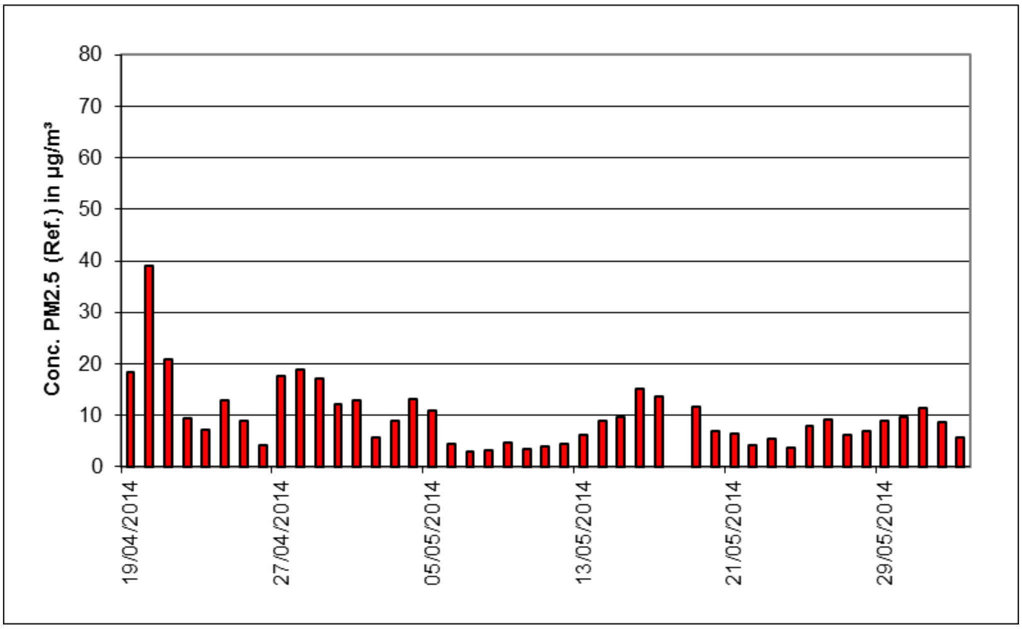



*Figure 25: Course of $PM_{2.5}$ concentrations (reference) at test site "Teddington, summer"*

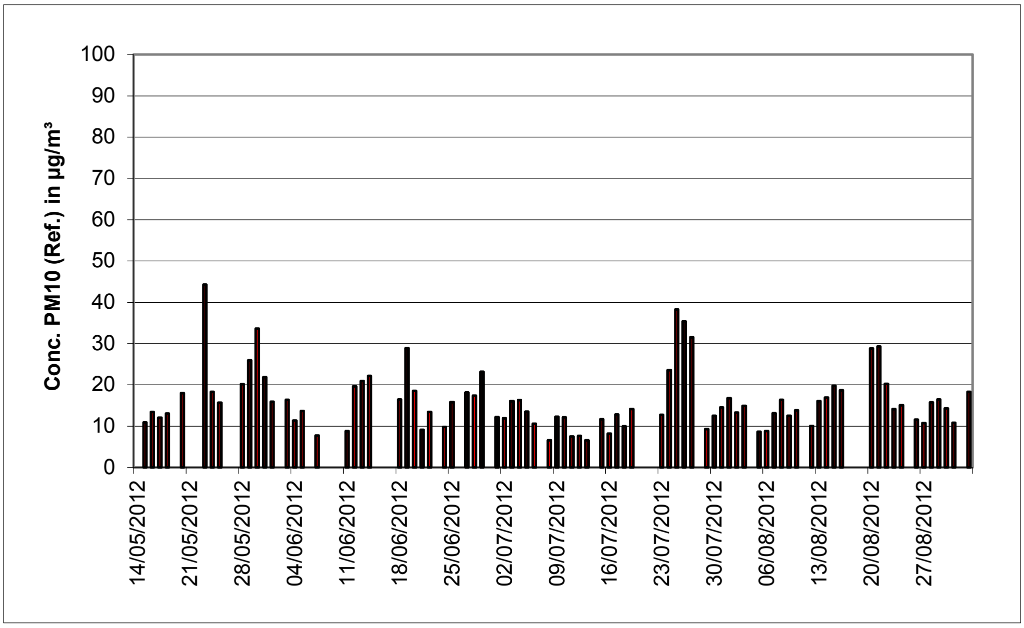



*Figure 26: Course of $PM_{10}$ concentrations (reference) at test site "Cologne, summer"*

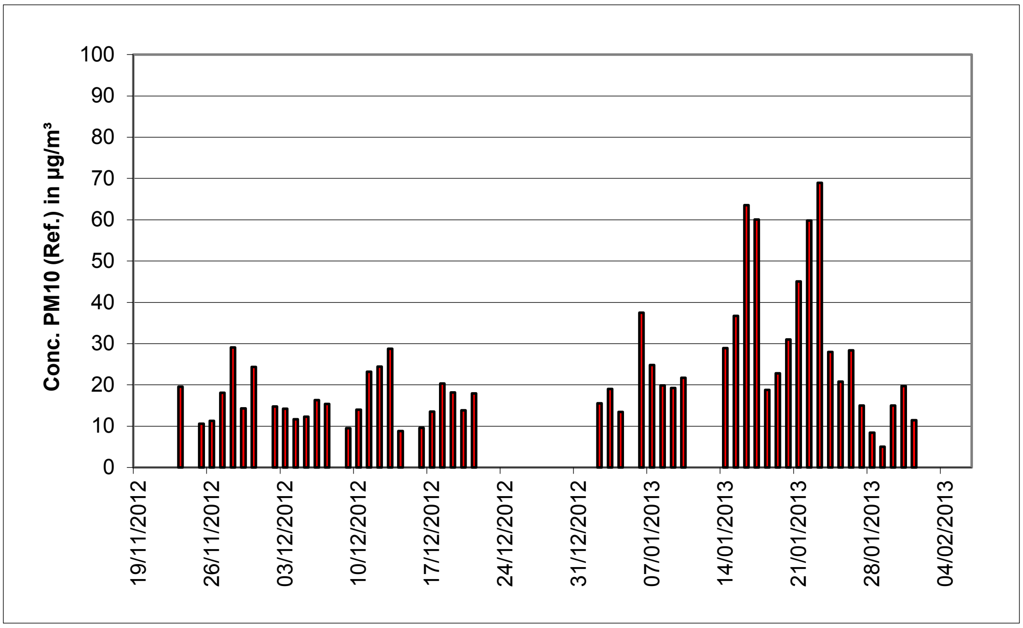



*Figure 27: Course of $PM_{10}$ concentrations (reference) at test site "Cologne, winter"*

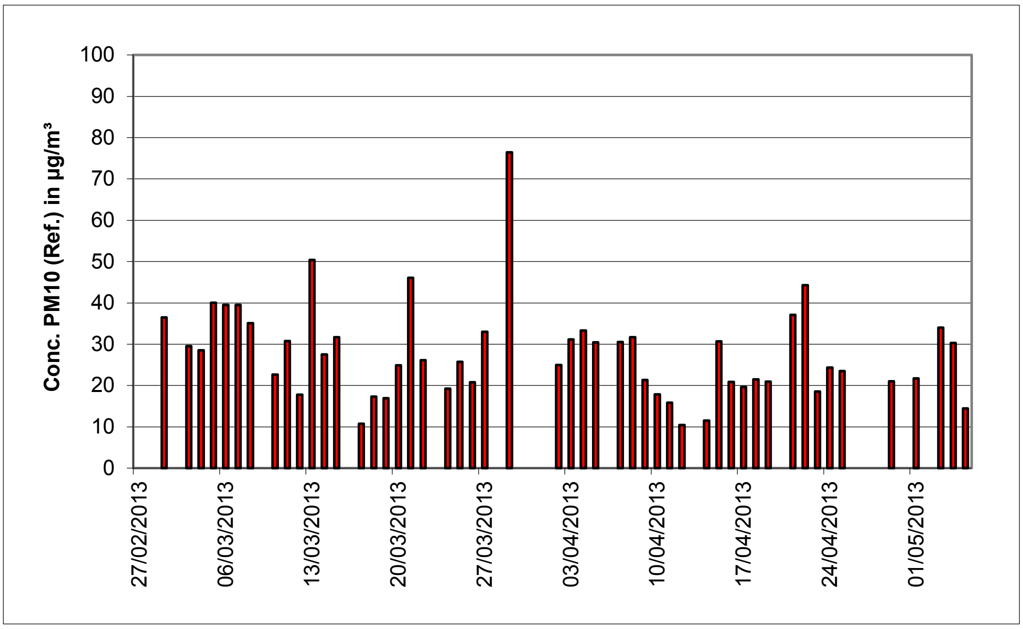



*Figure 28: Course of $PM_{10}$ concentrations (reference) at test site “Bonn, winter”*

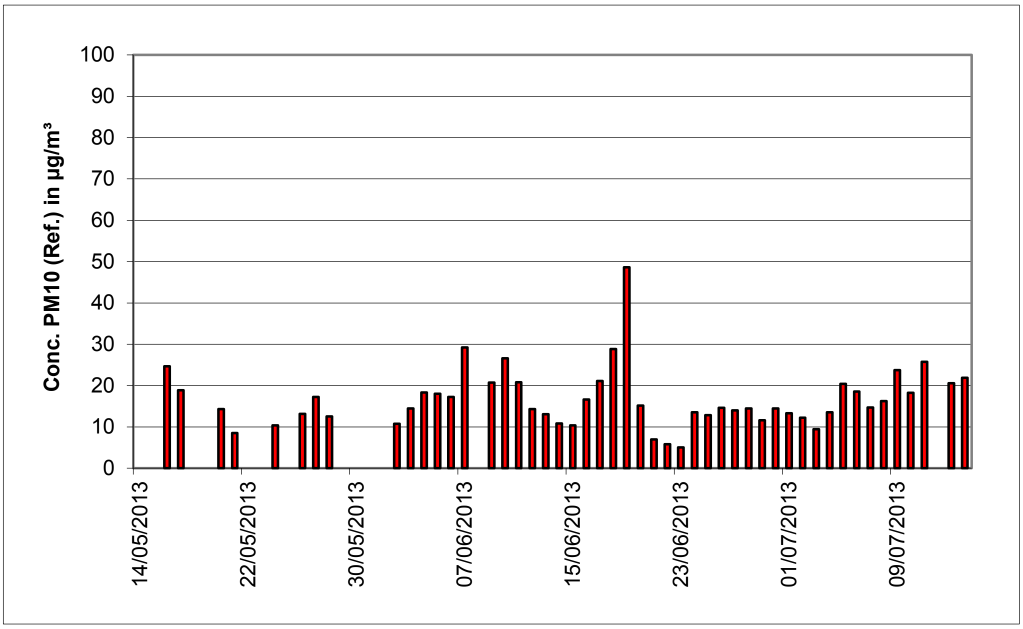



*Figure 29: Course of $PM_{10}$ concentrations (reference) at test site “Bornheim, summer”*

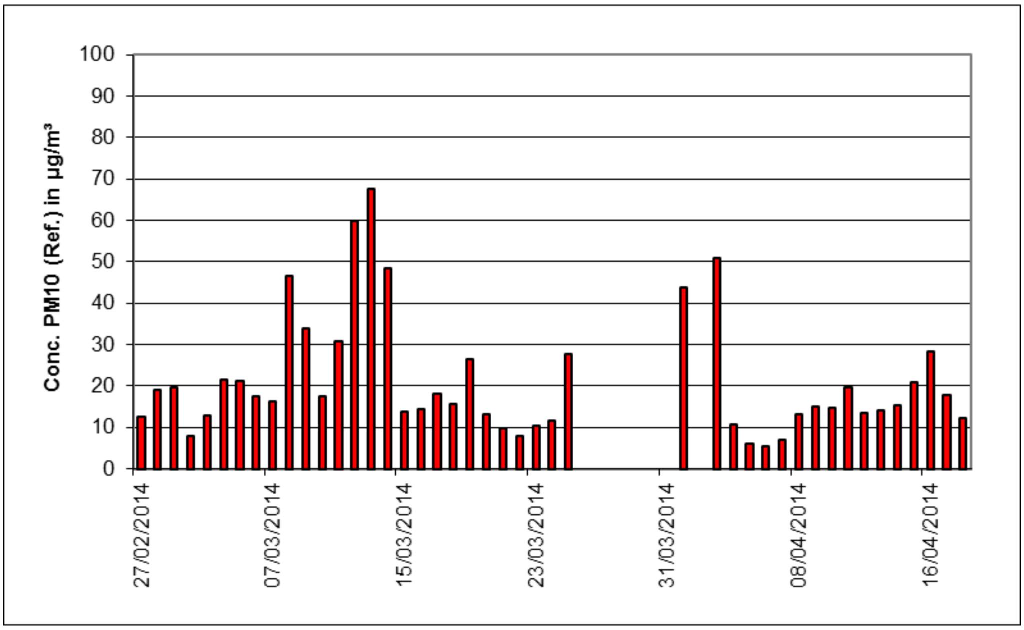



*Figure 30: Course of $PM_{10}$ concentrations (reference) at test site "Teddington, winter"*

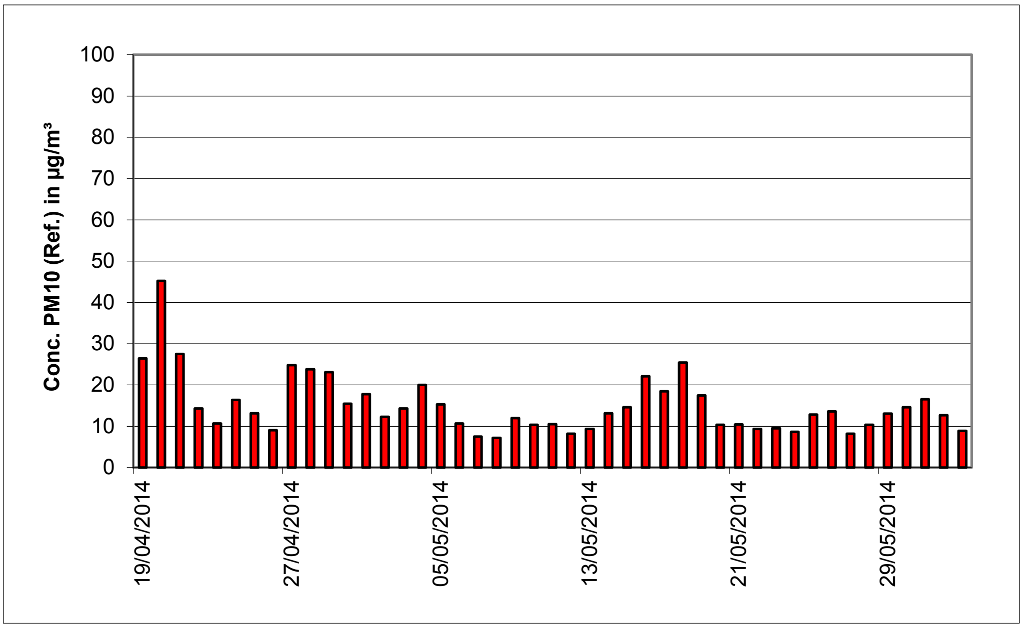



*Figure 31: Course of $PM_{10}$ concentrations (reference) at test site "Teddington, summer"*

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

*Figure 32: Field test site Cologne, summer & winter*

*Figure 33: Field test site Bonn, winter*

Figure 34: Field test site Bornheim, summer

Figure 35: Field test site Teddington, UK

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

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

Germany:

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

UK:

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

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

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

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

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

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

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

**Sampling duration**

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

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

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

**Data handling**

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

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

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

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

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

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

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

The following value pairs were discarded:

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

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

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

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

**Filter handling– mass determination**

The following filters were used in the type approval test:

*Table 14: Used filter materials*

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

The filters were handled in compliance with Standard EN 14907.

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

## 5. Reference measurement method

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

1. as reference device for $PM_{10}$: Small Filter Device Low Volume Sampler LVS3
   Manufacturer: Ingenieurbüro Sven Leckel,
   Leberstraße 63, Berlin, Germany
   Date of construction: 2007
   $PM_{10}$ sampling head
2. as reference device for $PM_{2.5}$: Small Filter Device Low Volume Sampler LVS3
   Manufacturer: Ingenieurbüro Sven Leckel,
   Leberstraße 63, Berlin, Deutschland
   Date of construction: 2007
   $PM_{2.5}$ sampling head

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

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

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

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

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

# 6. Test results of initial type approval

## 6.1 4.1.1 Measured value display

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

## 6.2 Equipment

Additional equipment is not required.

## 6.3 Method

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Figure 36 shows the user interface with the current concentrations.

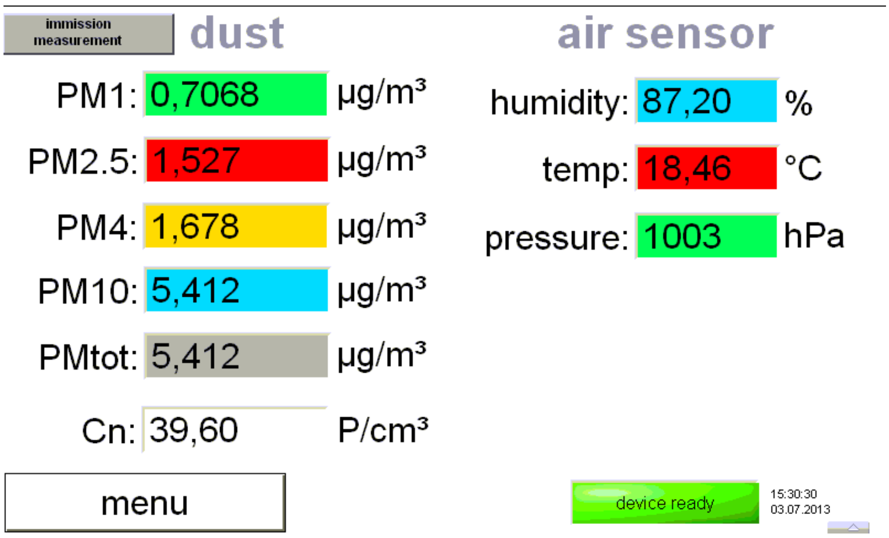



*Figure 36: Display of measured concentrations*

## 6.1 4.1.2 Easy maintenance

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

## 6.2 Equipment

Additional equipment is not required.

## 6.3 Method

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

## 6.4 Evaluation

The operator shall carry out the following maintenance work:

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

## 6.1 4.1.3 Functional check

*If the operation or the functional check of the measuring system requires particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.*
*Test gas units included in the measuring system shall indicate their operational readiness to the measuring system by a status signal and shall provide direct as well as remote control via the measuring system.*

## 6.2 Technical equipment

Operator's manual, zero filter, CalDust 1100.

## 6.3 Method

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

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

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

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

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

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

## 6.4 Evaluation

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

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

## 6.5 Assessment

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

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

See chapter 6.1 5.3.12 Long-term drift

## 6.1 4.1.4 Setup times and warm-up times

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

## 6.2 Equipment

A timer was provided additionally.

## 6.3 Method

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

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

## 6.4 Evaluation

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

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

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

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

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

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

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

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

## 6.5 Assessment

Setup and warm-up times were determined.

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 4.1.5 Instrument design

*The instruction manual shall include specifications of the manufacturer regarding the design of the measuring system. These elements are:*
*Instrument shape (e.g. bench mounting, rack mounting, free mounting)*
*mounting position (e.g. horizontal or vertical mounting)*
*safety requirements*
*dimensions*
*weight*
*power consumption.*

## 6.2 Equipment

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

## 6.3 Method

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

## 6.4 Evaluation

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

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 4.1.6 Unintended adjustment

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

## 6.2 Technical equipment

No additional tools are required here.

## 6.3 Method

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

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

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

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 4.1.7 Data output

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

## 6.2 Equipment

PC with "TeamViewer" software or USB flash drive

## 6.3 Method

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

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

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

The AMS does not provide analogue output signals.

## 6.4 Evaluation

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

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

## 6.5 Assessment

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

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

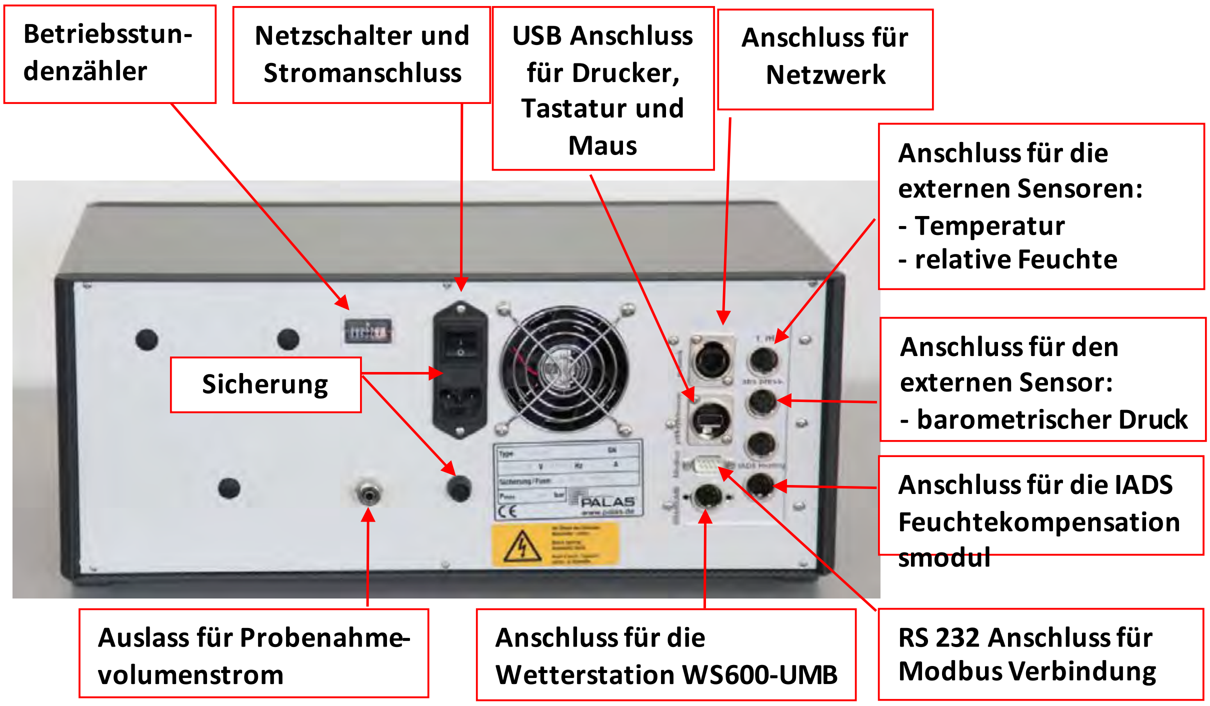



*Figure 37: Rear side of the Fidas® 200 S control unit*

**Key**

Betriebsstundenzähler: Operating hour meter

Netzschalter und Stromanschluss: Power switch and power connection

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

Anschluss für Netzwerk: Network connection

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

Anschluss für den externen Sensor: barometrischer Druck:

Connection for external sensor: barometric pressure

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

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

Anschluss für die Wetterstation WS600-UMB:

Connection fort he weather station WS600-UMB

Auslass für Probenahmevolumenstrom:

Exhaust for sample flow

## 6.1 5.1 General

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

## 6.2 Equipment

Not required here.

## 6.3 Method

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test result

For this module, refer to item 6.4.

## 6.1 5.2.1 Certification ranges

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

## 6.2 Equipment

No additional tools are required here.

## 6.3 Method

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

## 6.4 Evaluation

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

*Table 15: Certification ranges*

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

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

$PM_{10}$: 50 µg/m³

$PM_{2.5}$: 30 µg/m³

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

## 6.1 5.2.2 Measuring range

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

## 6.2 Equipment

No additional tools are required.

## 6.3 Method

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

## 6.4 Evaluation

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 5.2.3 Negative output signals

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

## 6.2 Equipment

No additional tools are required here.

## 6.3 Method

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 5.2.4 Failure in the mains voltage

*In case of malfunction of the measuring system or failure in the mains voltage for a period of up to 72 h, uncontrolled emission of operation and calibration gas shall be avoided. The instrument parameters shall be secured by buffering against loss caused by failure in the mains voltage. When mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement according to the operating instructions.*

## 6.2 Equipment

Not required here.

## 6.3 Method

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

## 6.4 Evaluation

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 5.2.5 Operating states

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

## 6.2 Equipment

PC for data acquisition.

## 6.3 Method

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

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

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 5.2.6 Switch-over

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

## 6.2 Equipment

Not required here.

## 6.3 Method

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

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 5.2.7 Maintenance interval

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

## 6.2 Equipment

Not required here.

## 6.3 Method

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

## 6.4 Evaluation

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

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of results

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

## 6.1 5.2.8 Availability

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

## 6.2 Equipment

Not required here.

## 6.3 Method

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

## 6.4 Evaluation

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

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

The following downtimes have been recorded:

SN 0111:

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

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

SN 0112:

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

Apart from that no further downtimes were recorded.

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

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

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

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

## 6.1 5.2.9 Instrument software

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

## 6.2 Equipment

Not required here.

## 6.3 Method

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

## 6.4 Evaluation

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

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

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

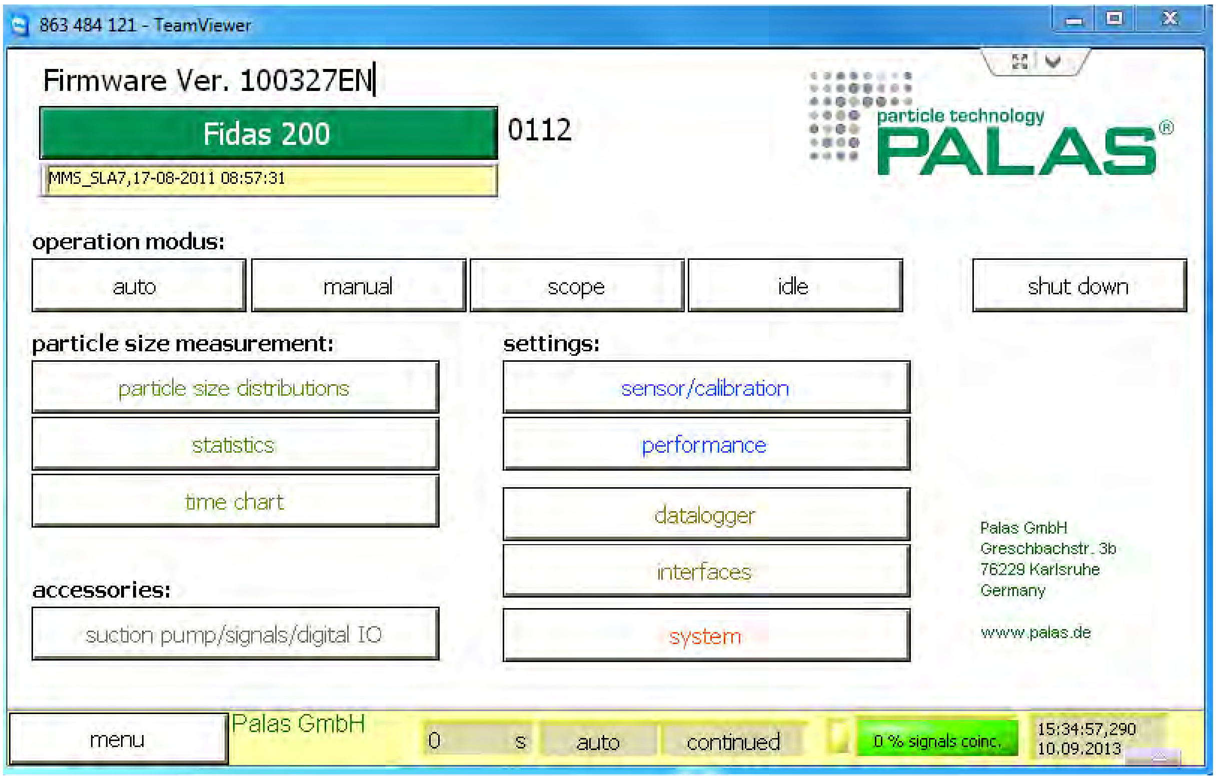



*Figure 38: Display of software version – here 100327EN – the label “EN” was only used by Palas in order to mark the firmware used in the type approval test and will not appear in the future*

## 6.1 5.3.1 General

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

## 6.2 Equipment

Not required here.

## 6.3 Method

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

## 6.4 Evaluation

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

6.1 5.3.2 Repeatability standard deviation at zero point

→ no performance criterion defined

6.1 5.3.3 Repeatability standard deviation at reference point

→ not applicable to particulate measuring devices

6.1 5.3.4 Linearity (lack of fit)

→ not applicable to particulate measuring devices

6.1 5.3.7 Sensitivity coefficient of surrounding temperature

→ no performance criterion defined

6.1 5.3.8 Sensitivity coefficient of supply voltage

→ no performance criterion defined

6.1 5.3.11 Standard deviation from paired measurements

→ no performance criterion defined

6.1 5.3.12 Long-term drift

→ no performance criterion defined

6.1 5.3.13 Short-term drift

→ not applicable to particulate measuring devices

6.1 5.3.18 Overall uncertainty

→ not applicable to particulate measuring devices

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

The following procedure was suggested:

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

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 5.3.2 Repeatability standard deviation at zero point

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

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

Note:

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

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

## 6.2 Equipment

Zero filter for testing the zero point.

## 6.3 Method

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

## 6.4 Evaluation

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

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

*Table 18: Detection limit $PM_{10}$*

| | | Device SN 0111 | Device SN 0112 |
|---|---|---|---|
| Number of values n | | 15 | 15 |
| Average of the zero values $\overline{x_0}$ | µg/m³ | 0,0001924 | 0,0000002 |
| Standard deviation of the values $s_{\overline{x0}}$ | µg/m³ | 0,0004064 | 0,0000003 |
| Student-Factor $t_{n-1;0,95}$ | | 2,14 | 2,14 |
| Detection limit x | µg/m³ | **8,7E-04** | **6,6E-07** |

*Table 19: Detection limit $PM_{2.5}$*

| | | Device SN 0111 | Device SN 0112 |
|---|---|---|---|
| Number of values n | | 15 | 15 |
| Average of the zero values $\overline{x_0}$ | µg/m³ | 0,0001638 | 0,0000002 |
| Standard deviation of the values $s_{\overline{x0}}$ | µg/m³ | 0,0004036 | 0,0000003 |
| Student-Factor $t_{n-1;0,95}$ | | 2,14 | 2,14 |
| Detection limit x | µg/m³ | **8,7E-04** | **6,6E-07** |

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

## 6.1 5.3.3 Repeatability standard deviation at reference point

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

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

Note:

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

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.4 Linearity (lack of fit)

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

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

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

Note:

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

## 6.2 Equipment

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

## 6.3 Method

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

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

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

Performance criterion met? -

## 6.6 Detailed presentation of test results

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

## 6.1 5.3.5 Sensitivity coefficient of sample gas pressure

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

Note:

This test item is irrelevant to particulate measuring systems.

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.6 Sensitivity coefficient of sample gas temperature

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

Note:

This test item is irrelevant to particulate measuring systems.

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.7 Sensitivity coefficient of surrounding temperature

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

Note:

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

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

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

## 6.2 Equipment

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

## 6.3 Method

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

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

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

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

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

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

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

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

## 6.4 Evaluation

Zero point:

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

Reference value: $B_0$ = 2 µg/m³

Reference point:

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

## 6.5 Assessment

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

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

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

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

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

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

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

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

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

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

## 6.1 5.3.8 Sensitivity coefficient of supply voltage

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

Note:

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

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

## 6.2 Equipment

Isolation transformer, CalDust 1100 for testing the reference point.

## 6.3 Method

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

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

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

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

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

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

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

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

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

## 6.1 5.3.9 Cross-sensitivity

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

Note:

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

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.10 Averaging effect

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

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

Note:

This test item is irrelevant to particulate measuring systems.

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.11 Standard deviation from paired measurements

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

Note:

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

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

## 6.2 Equipment

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

## 6.3 Method

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

## 6.4 Evaluation

The reproducibility is calculated as follows:

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

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

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

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

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

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

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

For individual values refer to annex 5 of the appendix.

## 6.1 5.3.12 Long-term drift

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

Note:

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

*The temporal change in the measured value at zero concentration shall not exceed the reference value $B_0$ in 24 h and in the maintenance interval.*
*The temporal change in the measured value in the range of the reference value $B_1$ shall not be greater than ± 5 % of $B_1$ in 24 h and in the maintenance interval.*

## 6.2 Equipment

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

## 6.3 Method

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

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

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

## 6.4 Evaluation

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

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

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

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

## 6.5 Assessment

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

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

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

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

Performance criterion met? no

## 6.6 Detailed presentation of test results

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

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

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

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

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

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

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

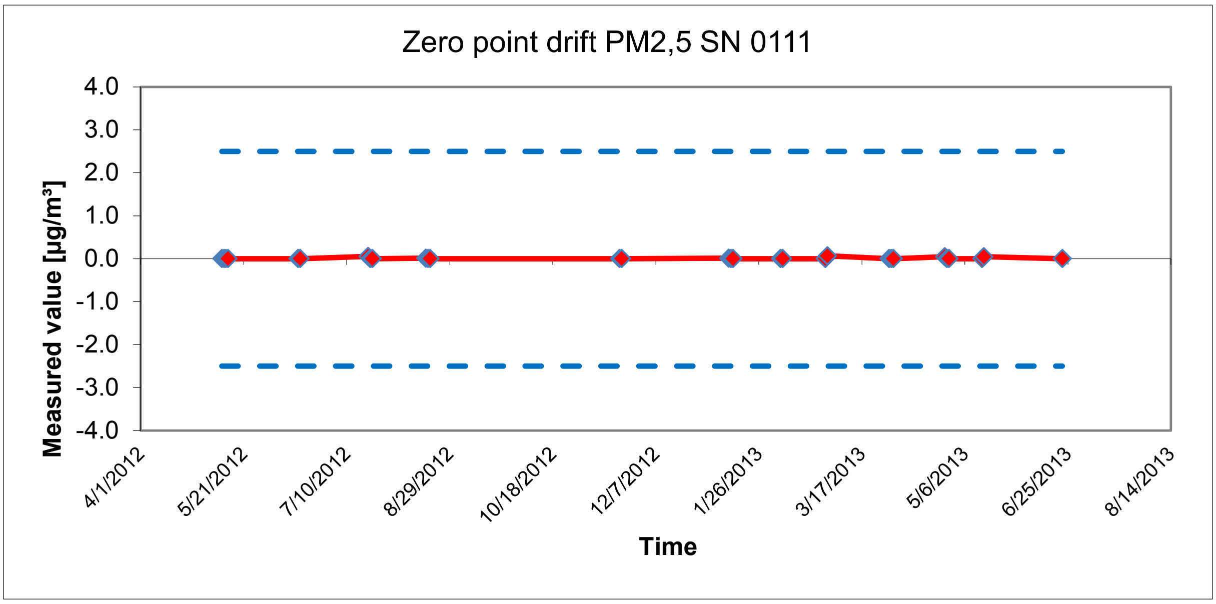



*Figure 39: Zero point drift SN 0111, measured component $PM_{2.5}$*

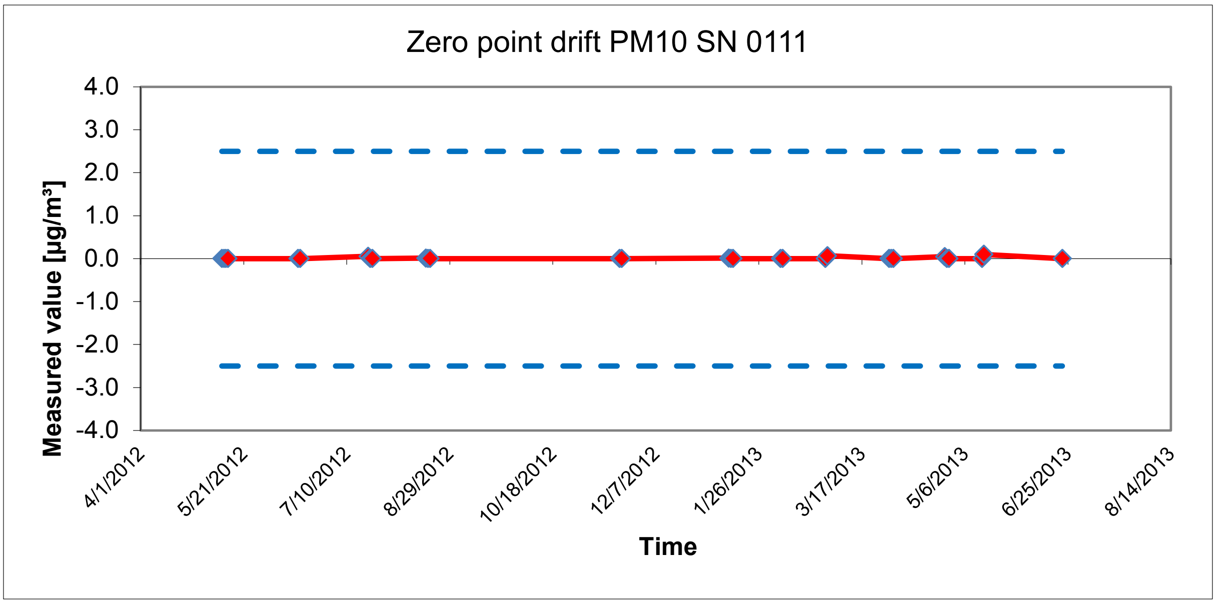



*Figure 40: Zero point drift SN 0111, measured component $PM_{10}$*

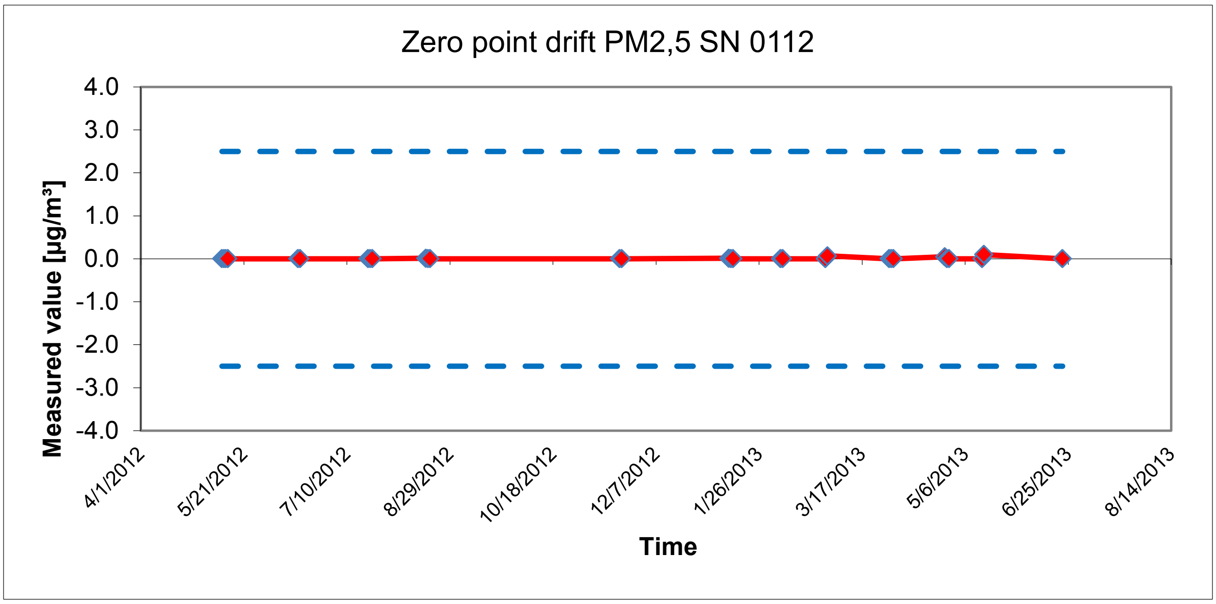



*Figure 41: Zero point drift SN 0112, measured component $PM_{2.5}$*

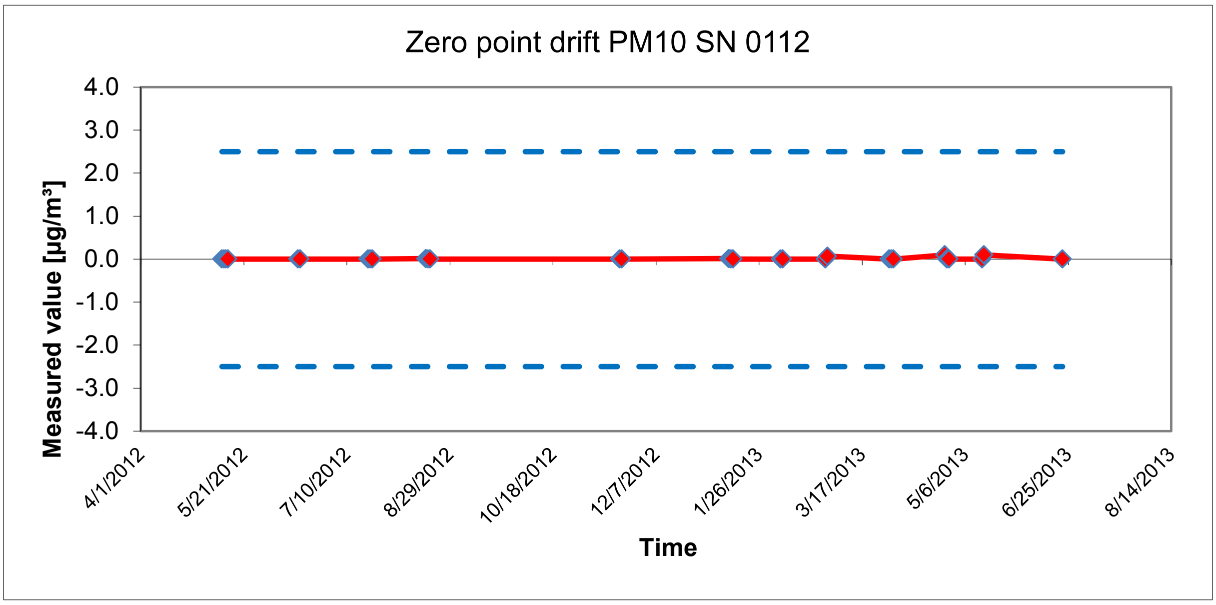



*Figure 42: Zero point drift SN 0112, measured component $PM_{10}$*

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

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

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

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

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

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

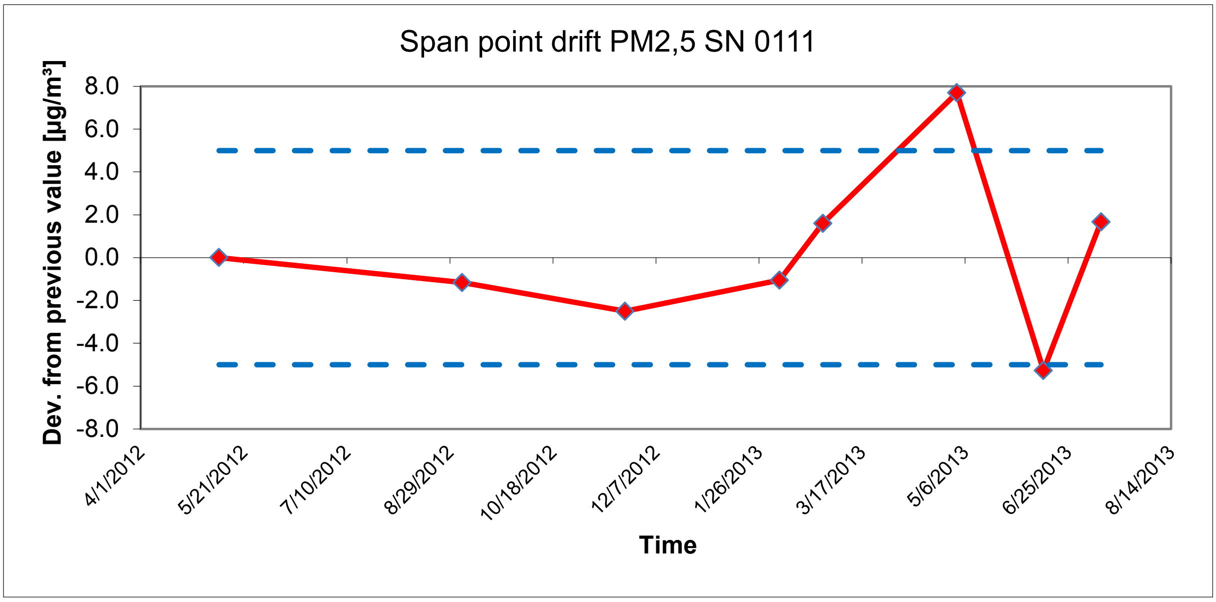



*Figure 43: Drift of the measured value SN 0111, measured component $PM_{2.5}$*

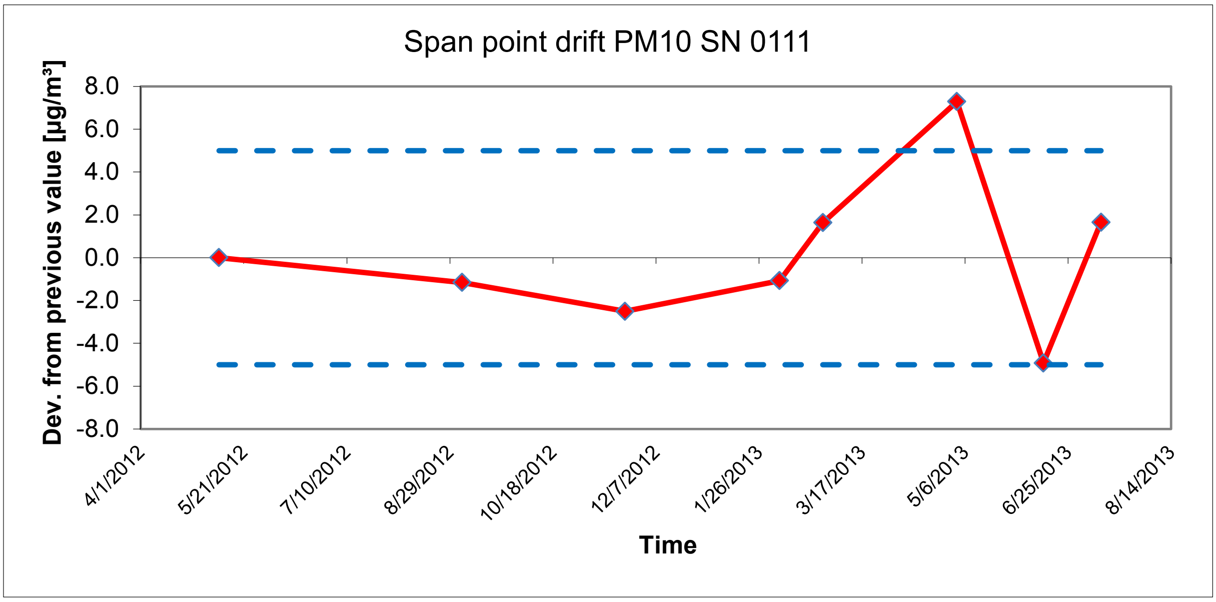



*Figure 44: Drift of the measured value SN 0111, measured component $PM_{10}$*

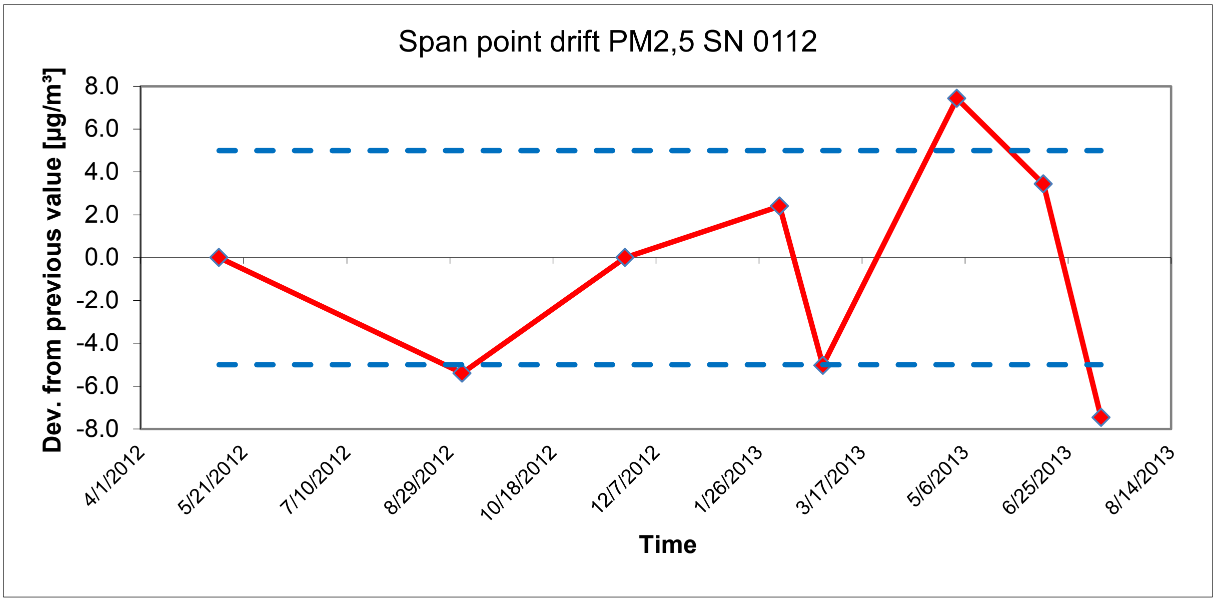



*Figure 45: Drift of the measured value SN 0112, measured component $PM_{2.5}$*

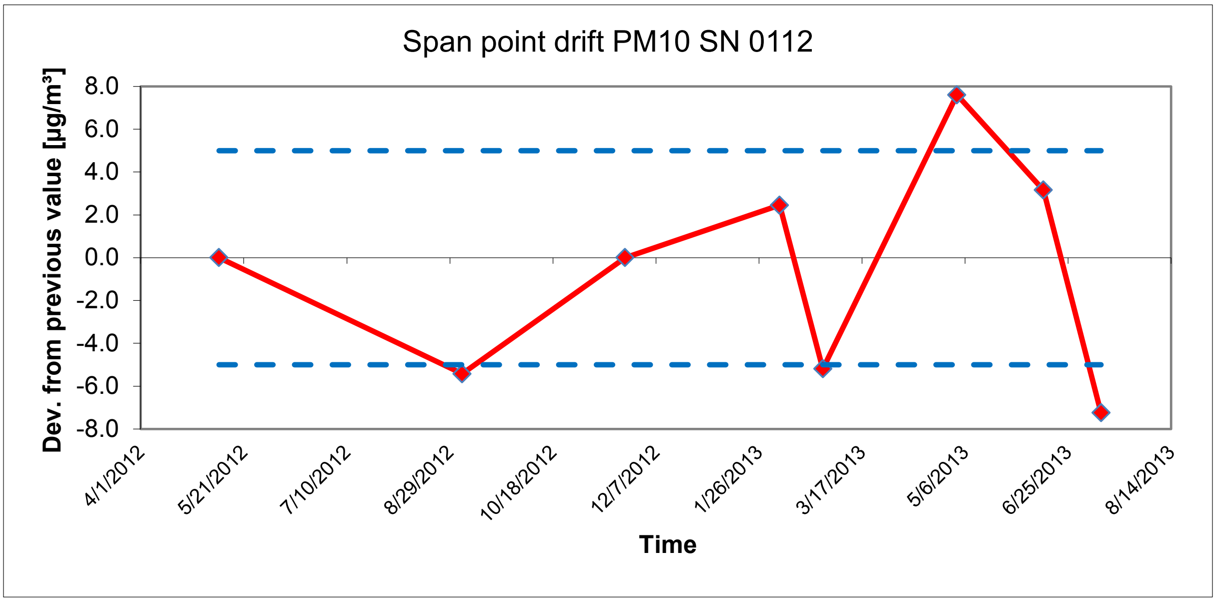



*Figure 46: Drift of the measured value SN 0112, measured component $PM_{10}$*

## 6.1 5.3.13 Short-term drift

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

Note:

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

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.14 Response time

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

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

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

Note:

This test item is irrelevant to particulate measuring systems.

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.15 Difference between sample and calibration port

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

Note:

This test item is irrelevant to particulate measuring systems.

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.16 Converter efficiency

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

Note:

This test item is irrelevant to particulate measuring systems.

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

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

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

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

Note:

This test item is irrelevant to particulate measuring systems.

## 6.2 Equipment

Not applicable.

## 6.3 Method

Not applicable.

## 6.4 Evaluation

Not applicable.

## 6.5 Assessment

Not applicable.

Performance criterion met? -

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 5.3.18 Overall uncertainty

*The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the applicable EU Directives on air quality listed in Annex A, Table A 1 of VDI Standard 4202, Sheet 1 (September 2010).*

Note:

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

## 6.2 Equipment

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

## 6.3 Method

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? -

## 6.6 Detailed presentation of test results

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

## 6.1 5.4.1 General

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

## 6.2 Equipment

No equipment is necessary to test this performance criterion.

## 6.3 Method

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

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

## 6.4 Evaluation

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

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

## 6.5 Assessment

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

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

No equipment is necessary to test this performance criterion.

## 6.1 5.4.2 Equivalency of the sampling system

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

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

## 6.2 Equipment

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

## 6.3 Method

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

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

## 6.4 Evaluation

Requirement according to Standard EN 12341:

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

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

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

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

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

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

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

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

## 6.5 Assessment

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

Performance criterion met? no

## 6.6 Detailed presentation of test results

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

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

| **SN 0111** | **Number of paired values N** | **Slope m** | **Intercept b** | **$R^2$** |
|---|---|---|---|---|
| Cologne, summer | 81 | 1.016 | -1.226 | 0.95 |
| Cologne, winter | 51 | 1.056 | -1.071 | 0.99 |
| Bonn, winter | 50 | 1.024 | 0.455 | 0.97 |
| Bornheim, summer | 45 | 1.094 | -1.481 | 0.95 |
| | | | | |
| **SN 0112** | **Number of paired values N** | **Slope m** | **Intercept b** | **$R^2$** |
| 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** | **$R^2$** |
|---|---|---|---|---|
| SN 0111 | 227 | 1.061 | -1.295 | 0.97 |
| SN 0112 | 227 | 1.025 | -1.195 | 0.97 |

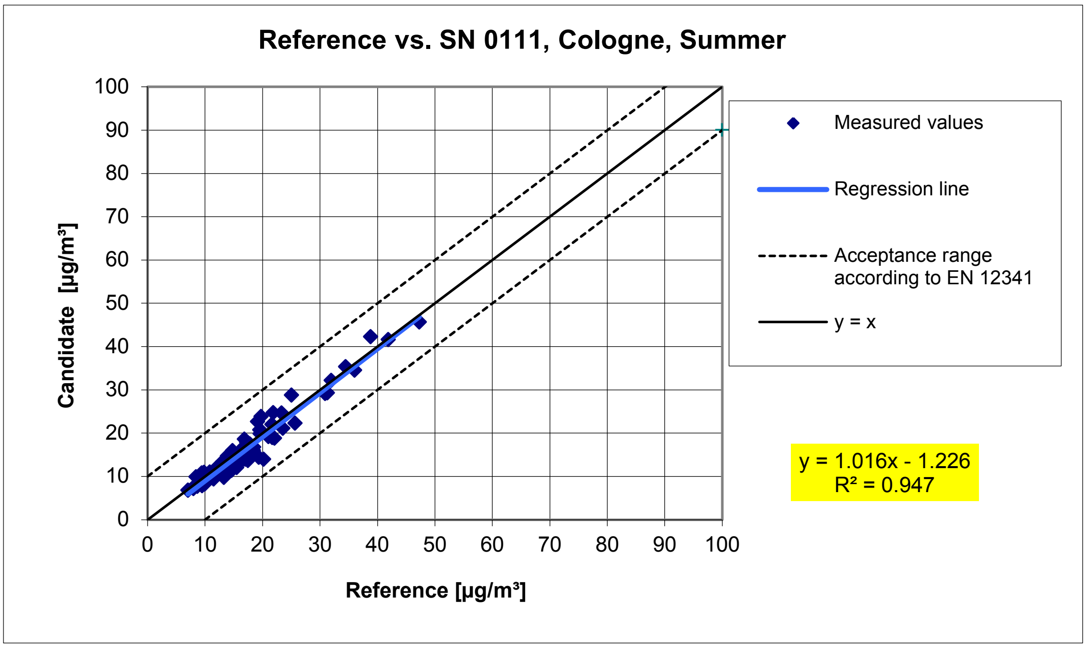



*Figure 47: Reference equivalence function SN 0111, test site Cologne, summer*

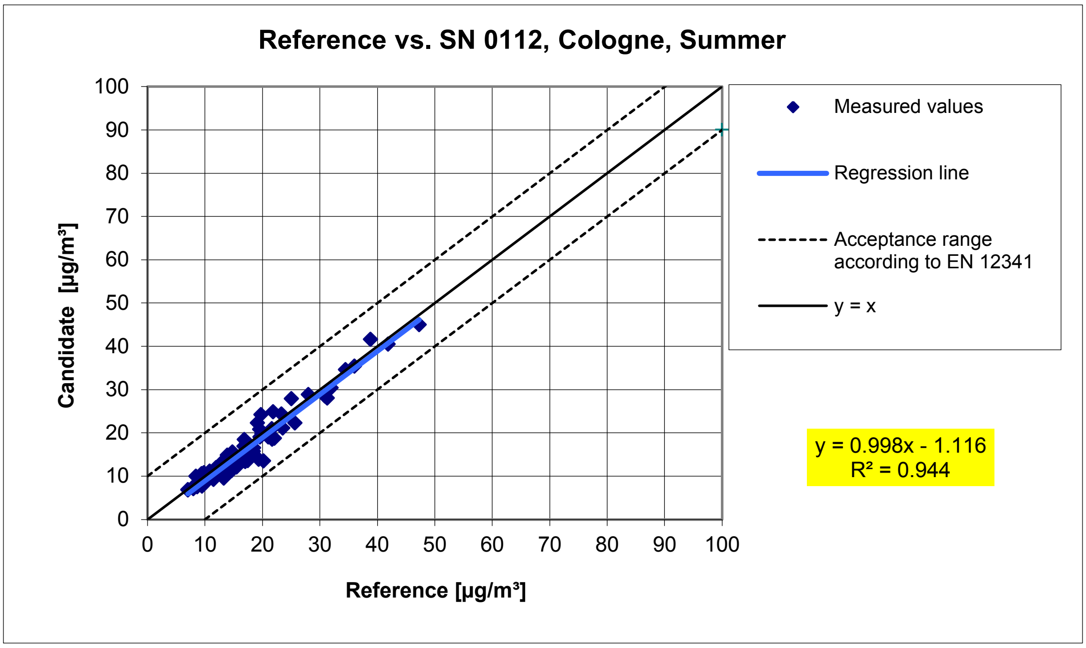



*Figure 48: Reference equivalence function SN 0112, test site Cologne, summer*

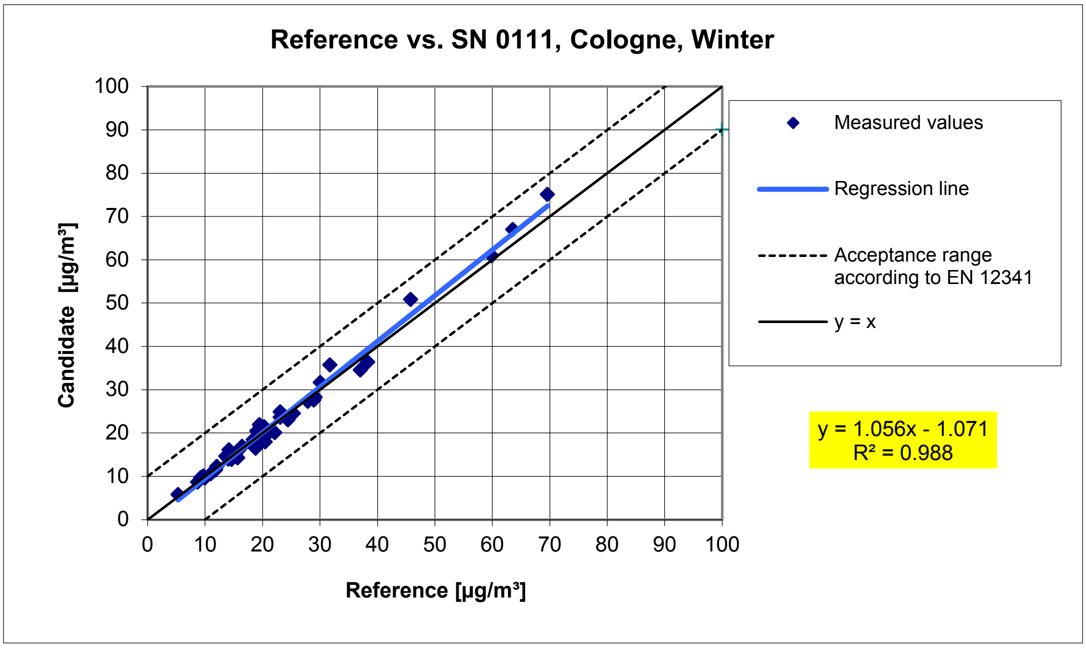



*Figure 49: Reference equivalence function SN 0111, test site Cologne, winter*

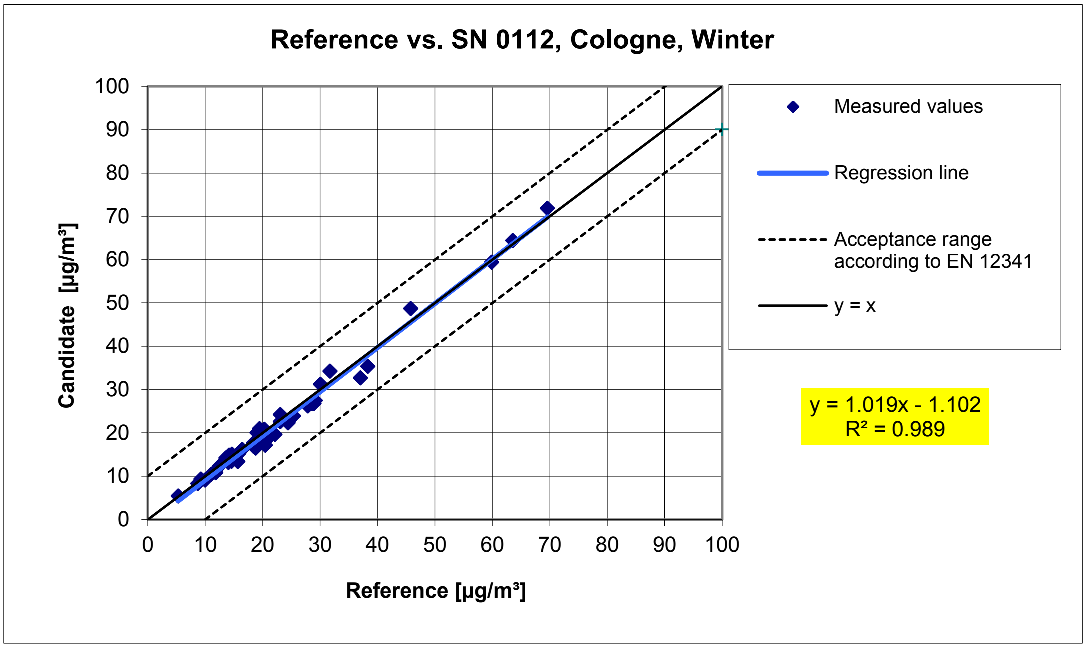



*Figure 50: Reference equivalence function SN 0112, test site Cologne, winter*

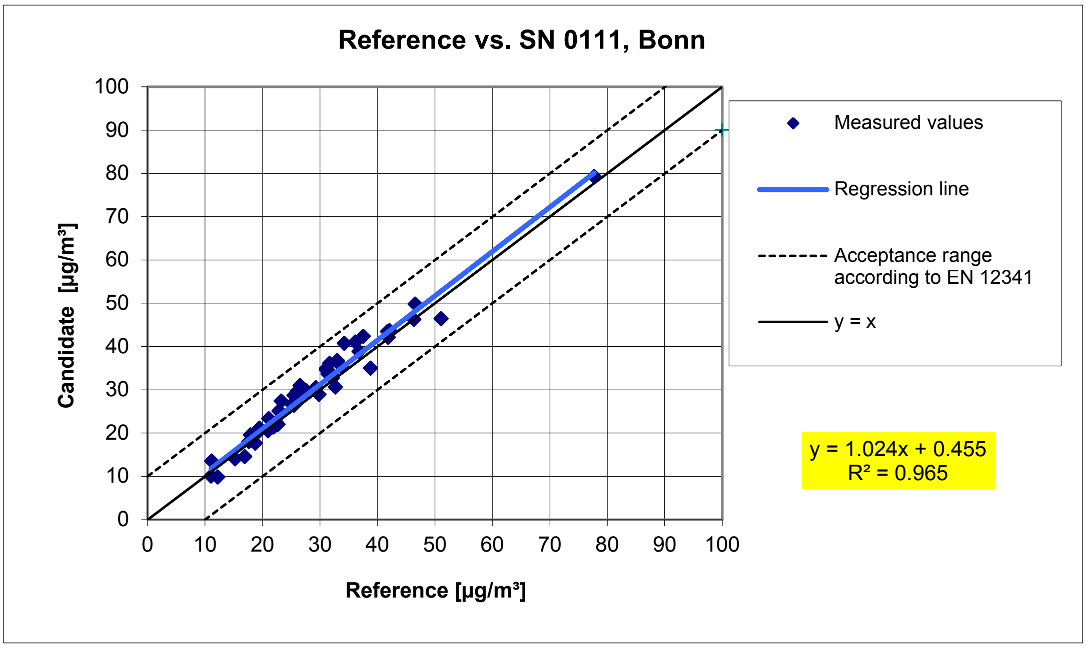



*Figure 51: Reference equivalence function SN 0111, test site Bonn, winter*

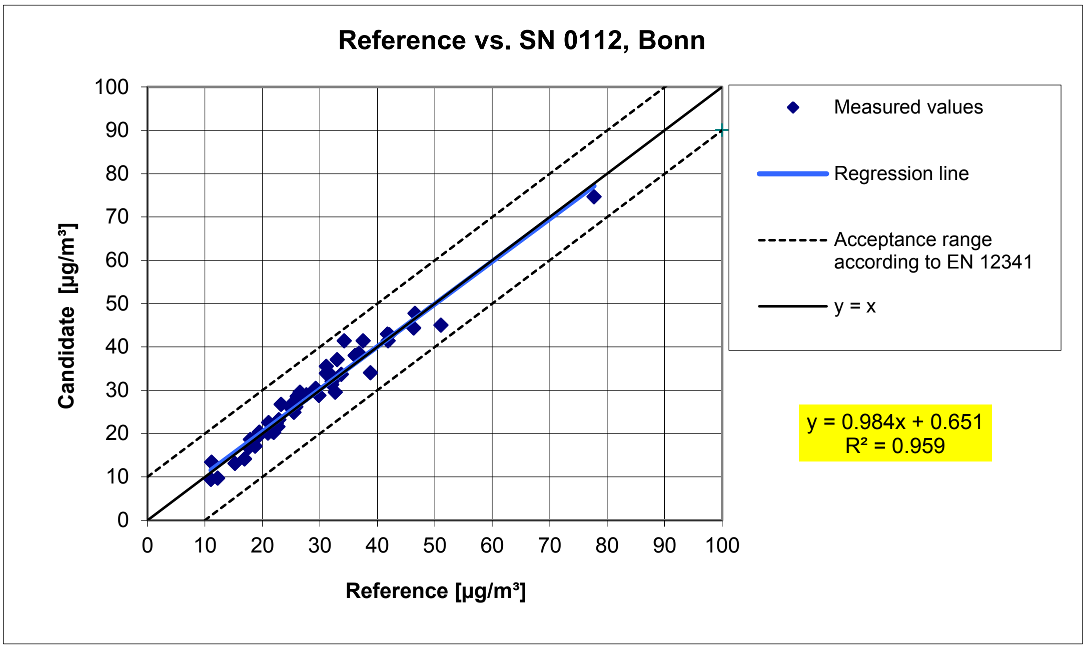



*Figure 52: Reference equivalence function SN 0112, test site Bonn, winter*

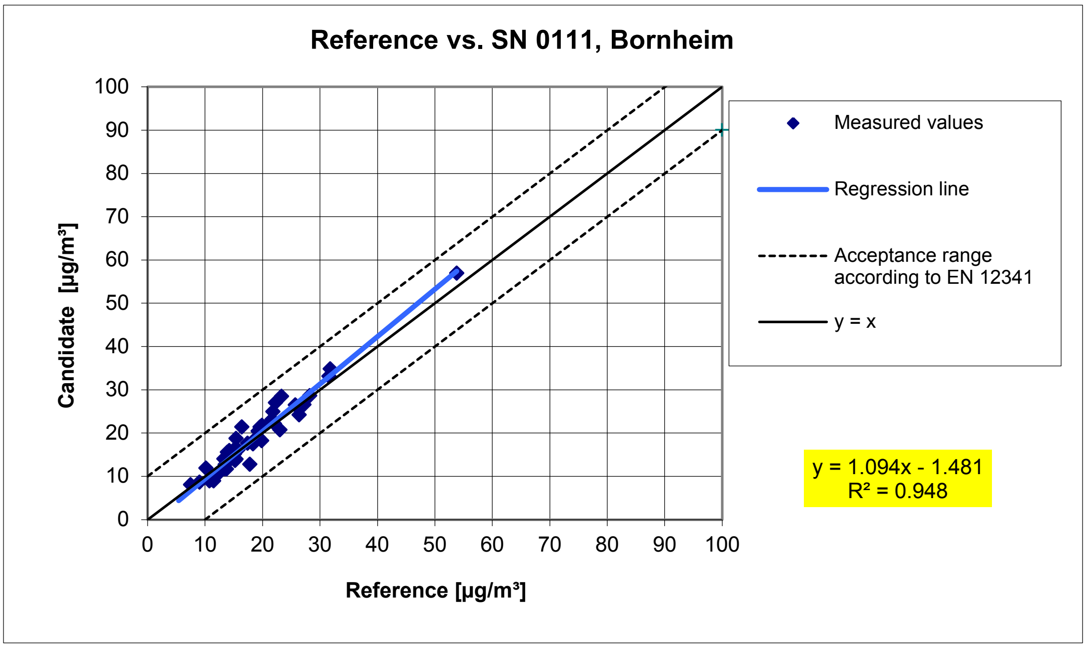



*Figure 53: Reference equivalence function SN 0111, test site Bornheim, summer*

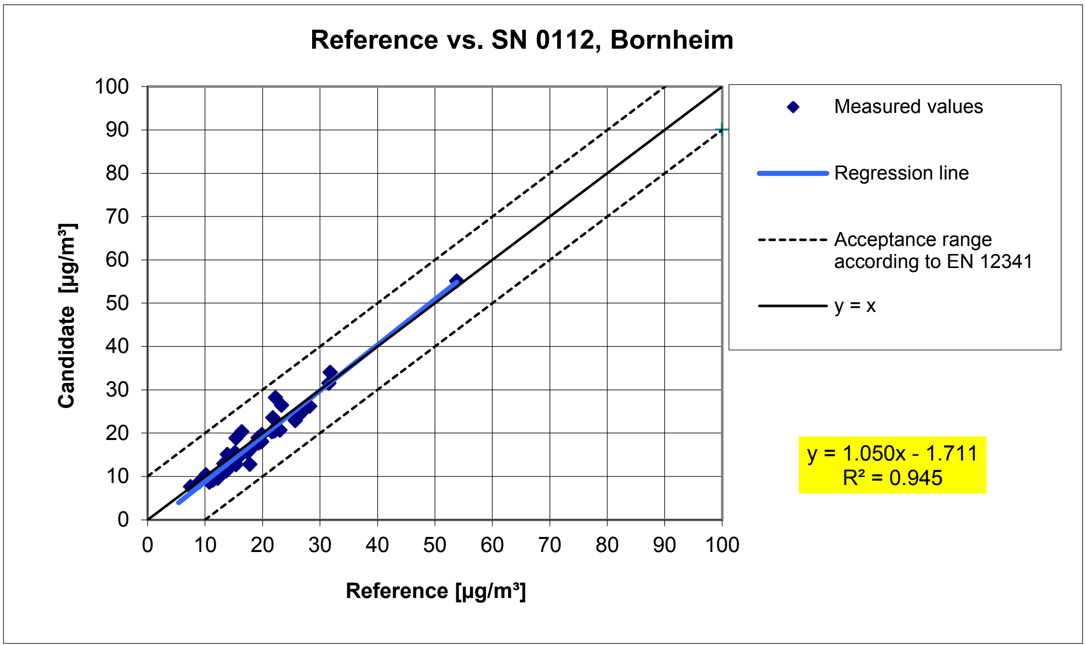



*Figure 54: Reference equivalence function SN 0112, test site Bornheim, summer*

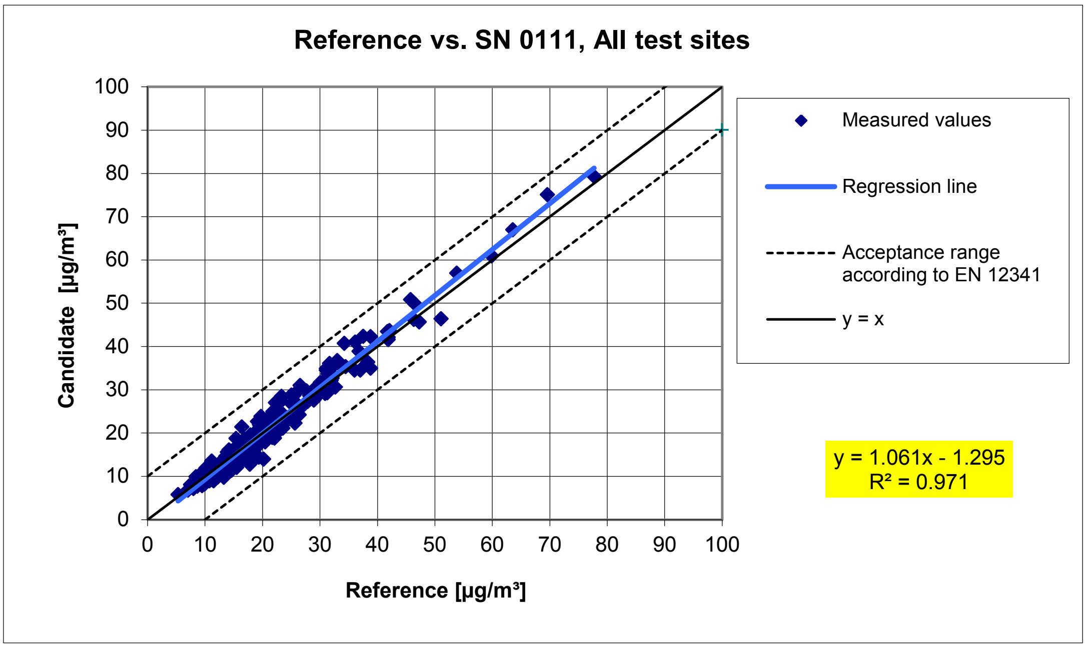



*Figure 55: Reference equivalence function SN 0111, all sites*

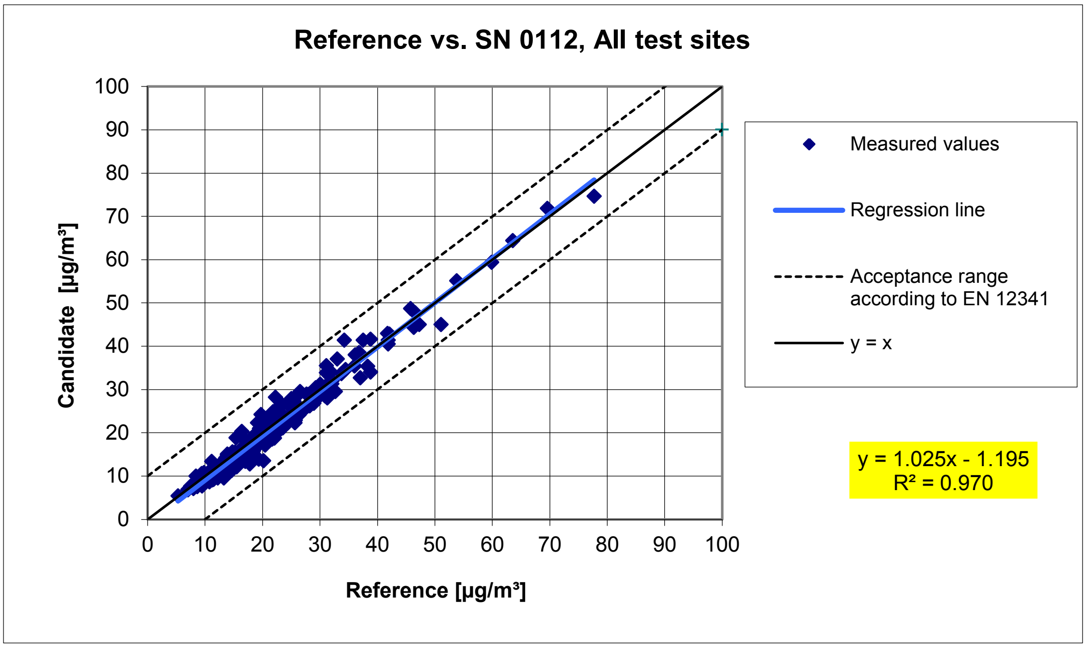



*Figure 56: Reference equivalence function SN 0112, all sites*

## 6.1 5.4.3 Reproducibility of the sampling systems

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

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

## 6.2 Equipment

No equipment is necessary to test this performance criterion.

## 6.3 Method

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

At least 15 valid data pairs were obtained per site.

## 6.4 Evaluation

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

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

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

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

With respect to a):

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

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

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 ≤ 100 µg/m³ is calculated as follows:

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

With respect to b):

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

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

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

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

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

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

## 6.5 Assessment

The following is applicable to all field test sites:

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

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

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

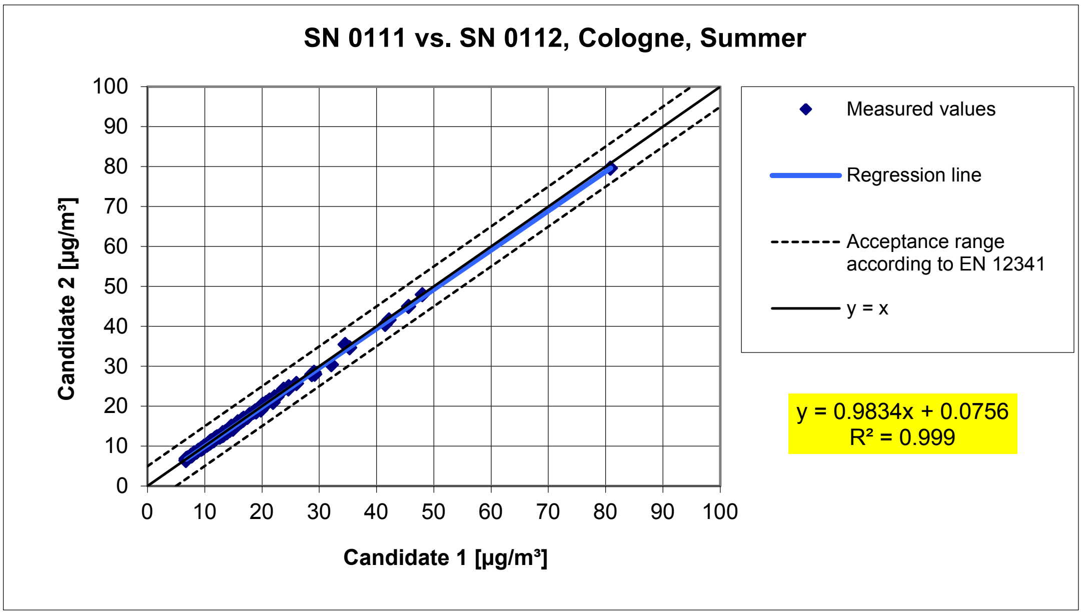



*Figure 57: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Cologne, summer*

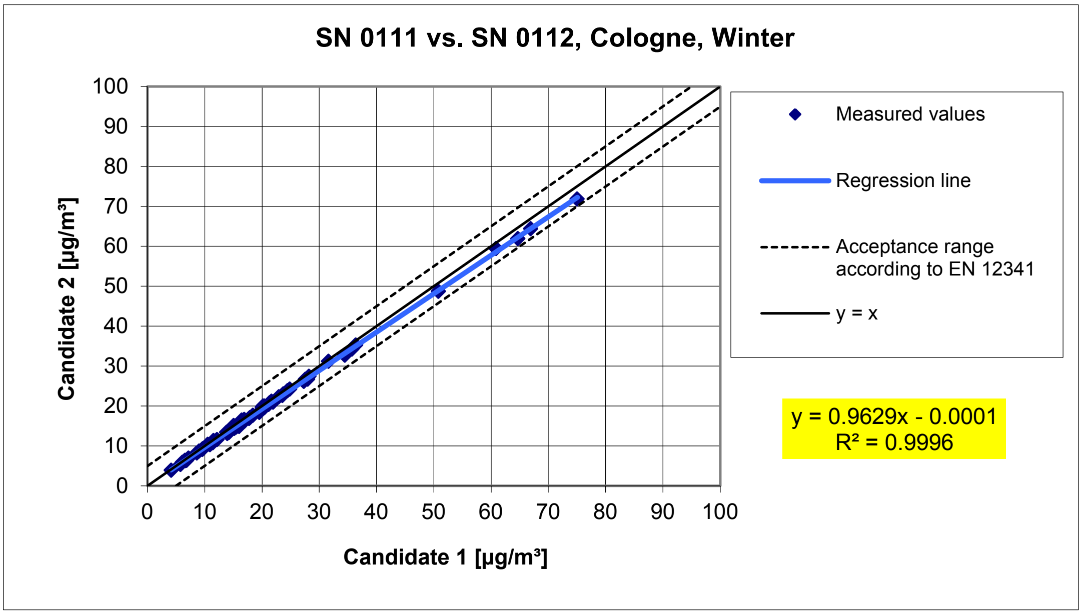



*Figure 58: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Cologne, winter*

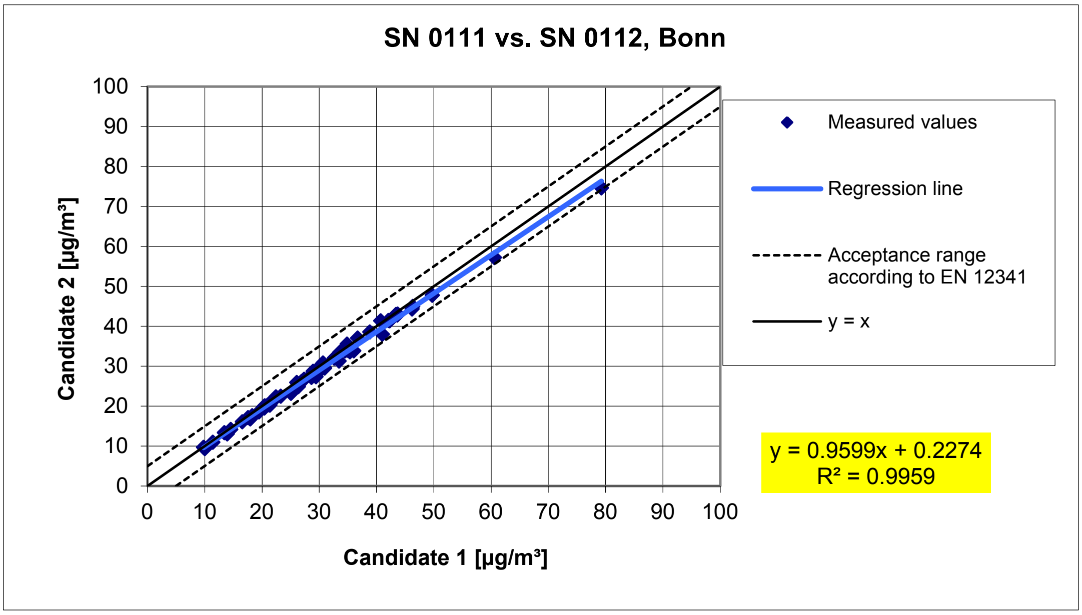



*Figure 59: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Bonn, winter*

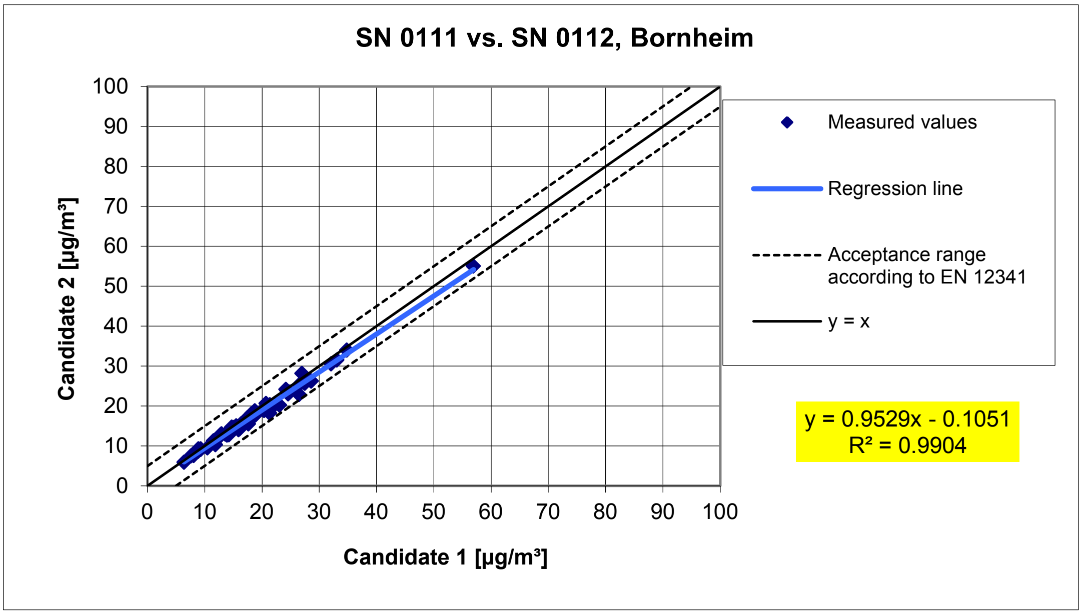



*Figure 60: Results of parallel measurements with the tested devices SN 0111 / SN 0112, test site Bornheim, summer*

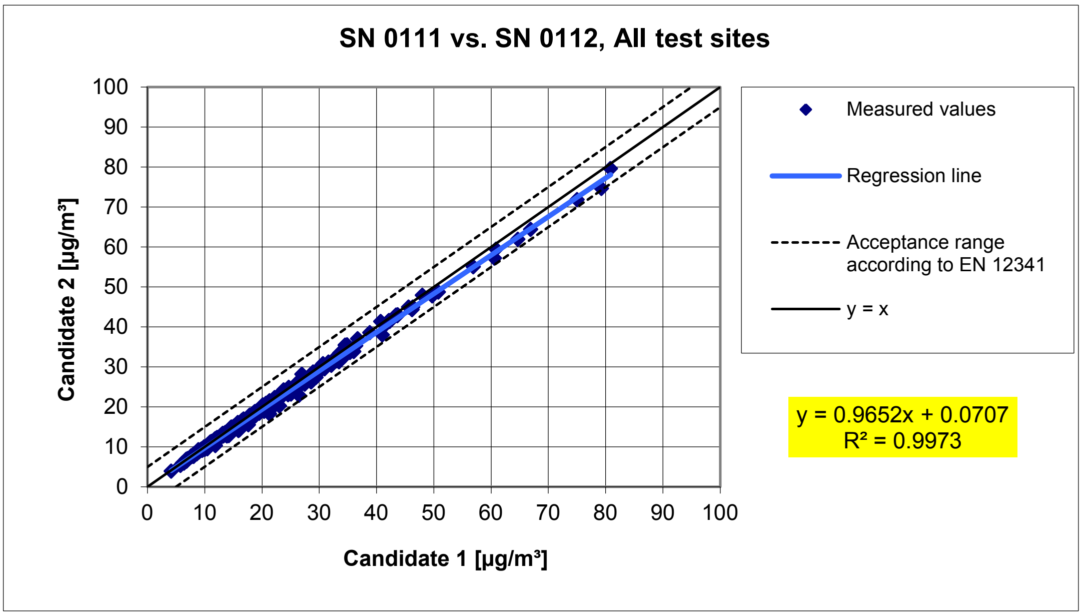



*Figure 61: Results of parallel measurements with the tested devices SN 0111 / SN 0112, all test sites*

## 6.1 5.4.4 Calibration

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

## 6.2 Equipment

Refer to module 5.4.2. or module 5.4.10

## 6.3 Method

For $PM_{10}$:

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

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

The quantities of the calibration function

$$y = m * x + b$$

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

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

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

The resulting quantities are given in Table 35.

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

| Device no. | Calibration function | | Analytical function | |
|---|---|---|---|---|
| | Y = m * x + b | | x = 1/m * y - b/m | |
| | m | b | 1/m | b/m |
| | µg/m³ / µg/m³ | µg/m³ | µg/m³ / µg/m³ | µg/m³ |
| System 1 (SN 0111) | 1.061 | -1.295 | 0.943 | -1.221 |
| System 2 (SN 0112) | 1.025 | -1.195 | 0.976 | -1.166 |

For $PM_{2.5}$:

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

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

The quantities of the calibration function

$$y = m * x + b$$

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

$$x = 1/m * y – b/m$$

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

The resulting quantities are given in Table 36.

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

| Device no. | Calibration function | | Analytical function | |
|---|---|---|---|---|
| | Y = m * x + b | | x = 1/m * y - b/m | |
| | m | b | 1/m | b/m |
| | µg/m³ / µg/m³ | µg/m³ | µg/m³ / µg/m³ | µg/m³ |
| System 1 (SN 0111) | 1.096 | -0.408 | 0.912 | -0.372 |
| System 2 (SN 0112) | 1.056 | -0.234 | 0.947 | -0.222 |

## 6.4 Evaluation

Refer to 6.3.

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Refer to modules 5.4.2. and 5.4.10.

## 6.1 5.4.5 Cross sensitivity

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

## 6.2 Equipment

Not required here.

## 6.3 Method

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

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

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

## 6.4 Evaluation

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

| | |
|---|---|
| Annual limit value $PM_{2.5}$ = 25 µg/m³ | 10 % of the annual limit value = 2.5 µg/m³ |
| Annual limit value $PM_{10}$ = 40 µg/m³ | 10 % of the annual limit value = 4 µg/m |

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Table 37 and Table 38 provide summaries of the results.

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

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

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

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

Single values are provided in annexes 5 and 6.

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

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

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

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

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

## 6.1 5.4.6 Averaging effect

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

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

## 6.2 Equipment

Additionally a timer was used.

## 6.3 Method

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

## 6.4 Evaluation

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

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

## 6.5 Assessment

The measuring system allows the formation of daily mean values.

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Not required here.

## 6.1 5.4.7 Constancy of sample volumetric flow

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

## 6.2 Equipment

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

## 6.3 Method

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

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

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

*Table 41: Results of flow rate checks*

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

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

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

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

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

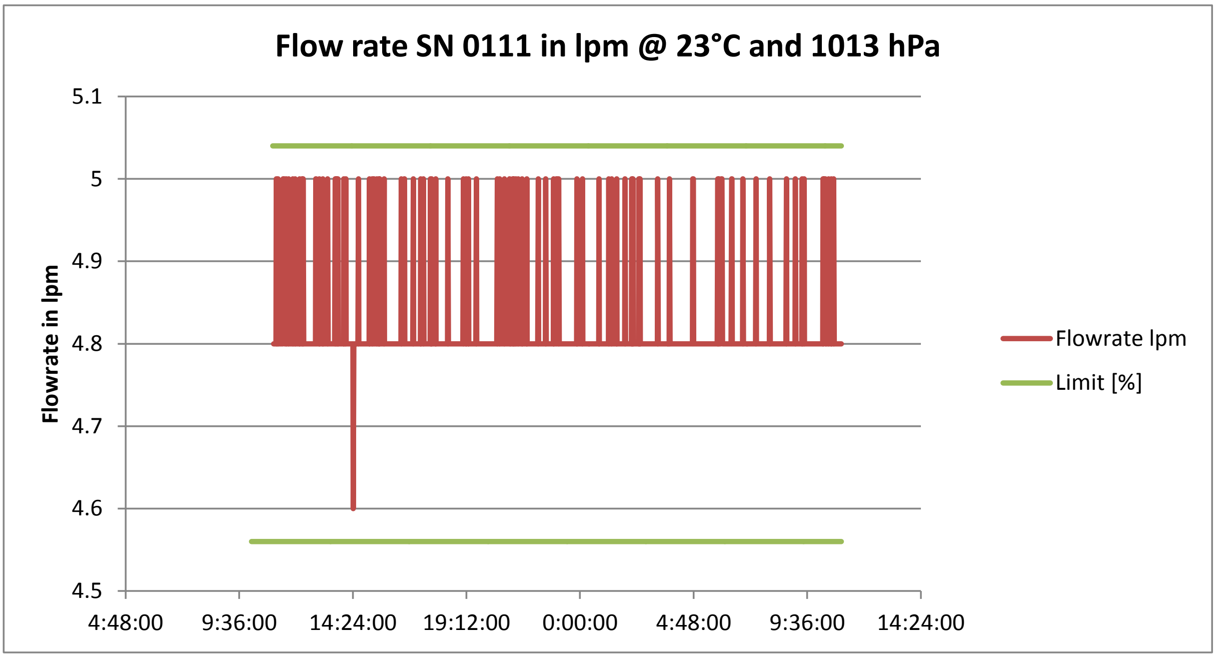



*Figure 62: Flow rate of device SN 0111*

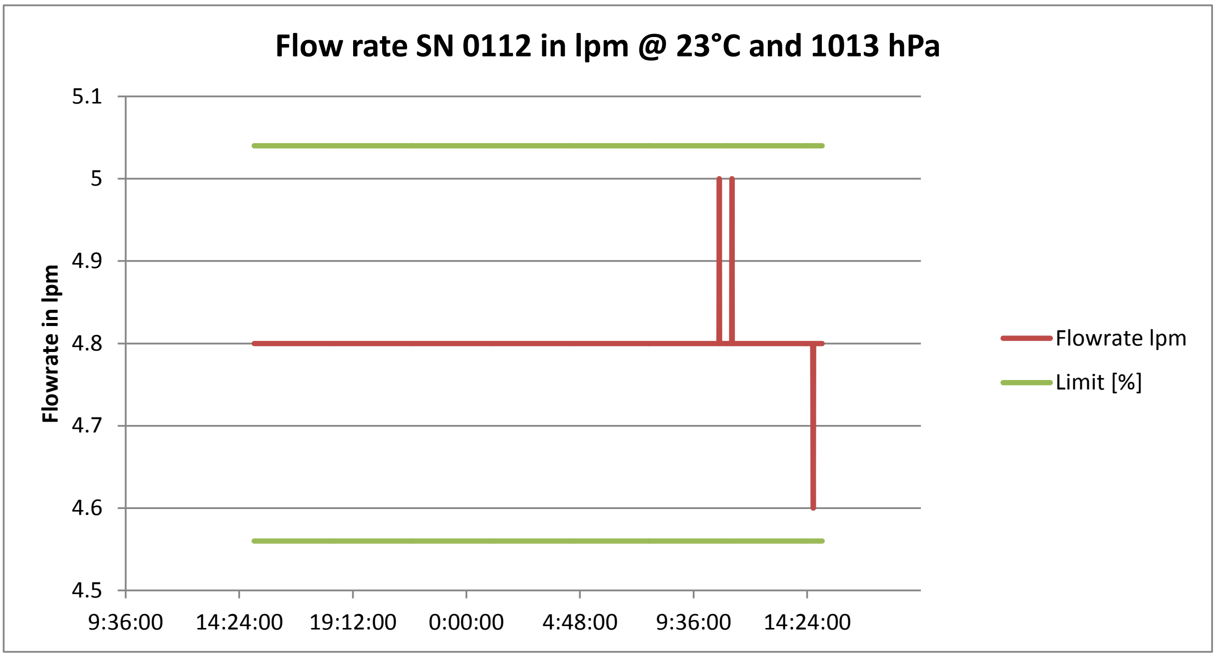



*Figure 63: Flow rate of device SN 0112*

## 6.1 5.4.8 Tightness of the measuring system

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

## 6.2 Equipment

Not required here.

## 6.3 Method

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

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

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

## 6.4 Evaluation

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

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

Table 43 lists the values obtained in leakage testing.

*Table 43: Results from leakage testing during the field tests*

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

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

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

1. At least 20 % of the concentration values from the complete dataset (determined by means of reference method) shall exceed the upper assessment threshold for annual limit values determined in 2008/50/EC [8], i.e. 28 µg/m³ for $PM_{10}$ and 17 µg/m³ for $PM_{2.5}$. If this requirement cannot be met due to overall low concentration levels,a minimum number of 32 data pairs is considered a sufficient (WG15 January 2015).
2. The uncertainty between the candidates must be less than 2.5 µg/m³ for all data and for two sub datasets corresponding to all the data split greater than or equal to and lower than 30 µg/m³ or 18 µg/m³ for $PM_{10}$ and $PM_{2.5}$ respectively.
3. The uncertainty between the reference devices must be less than 2.0 µg/m³.
4. The expanded uncertainty ($W_{CM}$) is calculated at 50 µg/m³ for $PM_{10}$ and 30 µg/m³ for $PM_{2.5}$ for each candidate against the mean value of the reference method. In each of the following cases, the expanded uncertainty shall not exceed 25 %:
   - Complete dataset;
   - Dataset with PM concentrations greater/equal 30 µg/m³ for $PM_{10}$ or greater/equal 18 µg/m³ for $PM_{2.5}$, provided that the dataset contains 40 or more valid data pairs;
   - Datasets for each field test site.
5. For the complete dataset to be accepted it is required that the slope b differs insignificantly from 1: $|b-1| \leq 2 \cdot u(b)$ and that the intercept a differs insignificantly from 0: $|a| \leq 2 \cdot u(a)$. Should these requirements not be met, the candidates may be calibrated using the values for slope and/or intercept from the complete dataset.

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

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

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

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

## 6.1 5.4.9 Determination of uncertainty between candidates $u_{bs}$

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

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

## 6.2 Equipment

No equipment is necessary to test this performance criterion.

## 6.3 Method

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

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

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

## 6.4 Evaluation

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

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

Uncertainty is determined for:

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

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

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

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

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

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

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

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

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

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

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

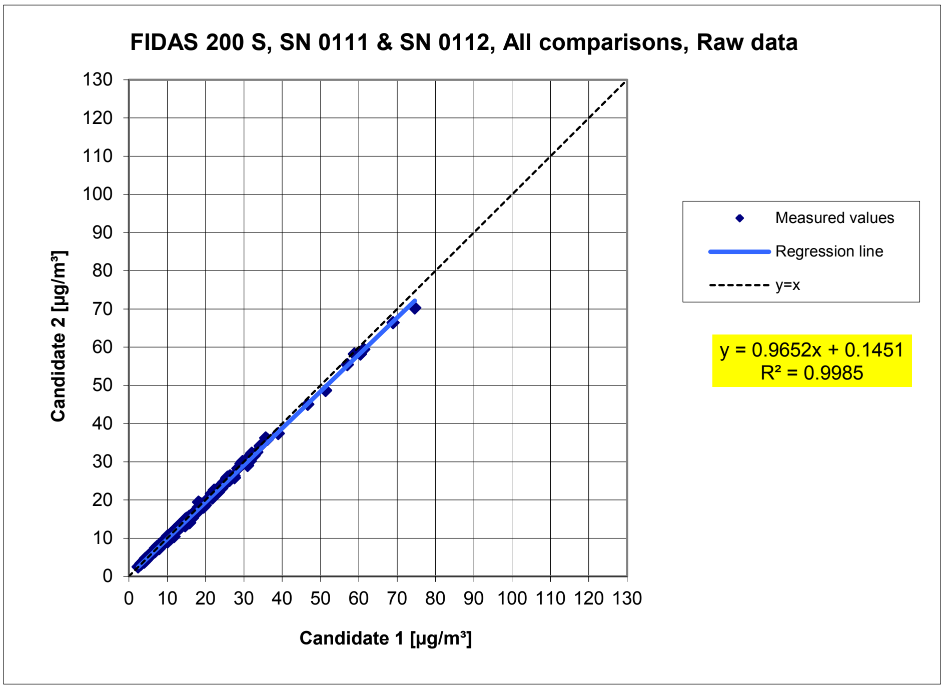



*Figure 64:* *Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites*

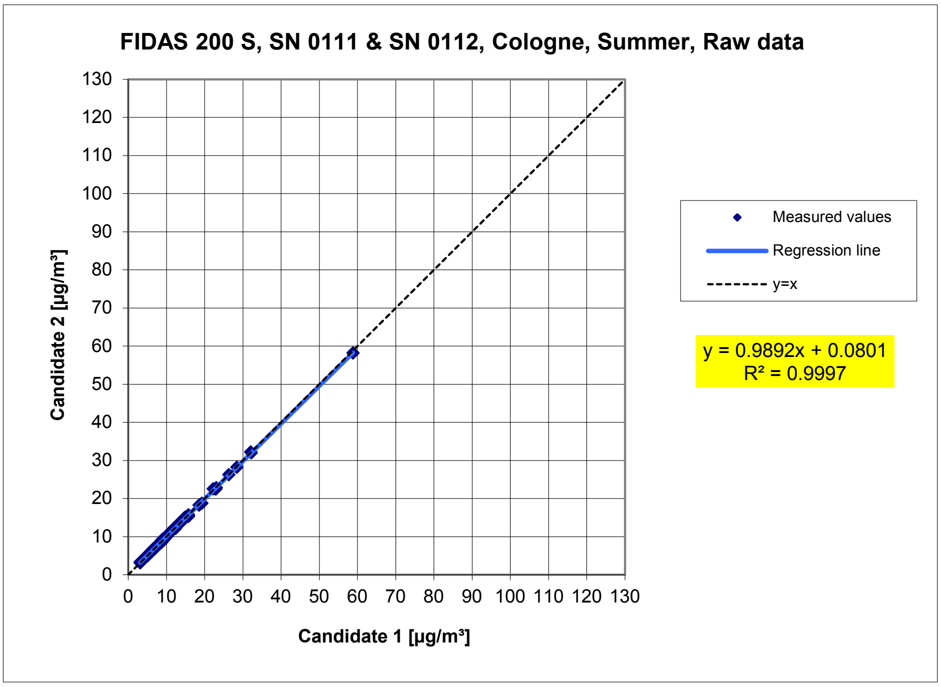



*Figure 65:* *Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Cologne, summer*

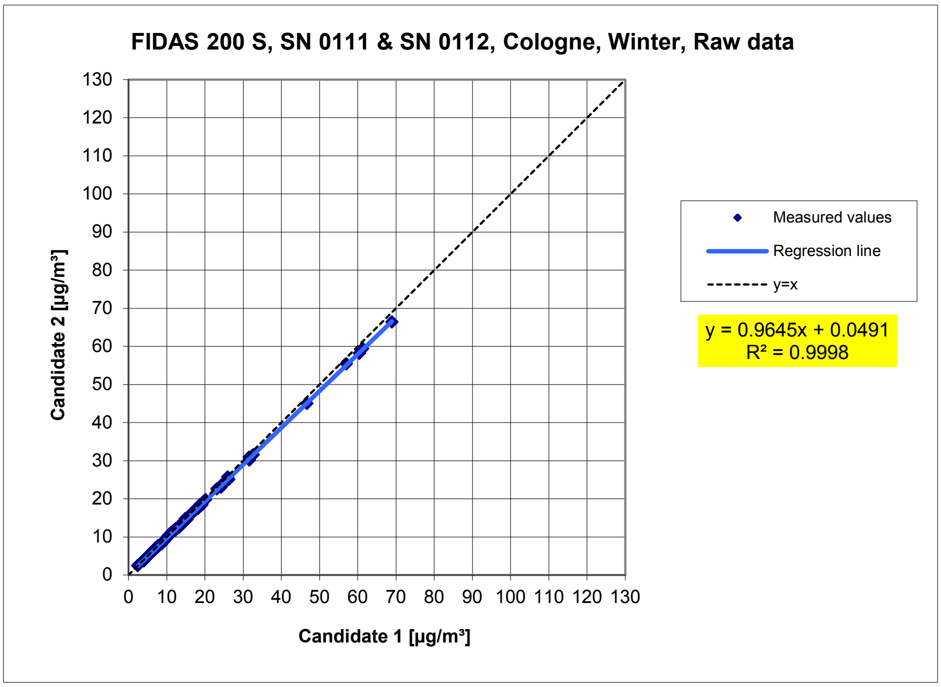



*Figure 66: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Cologne, winter*

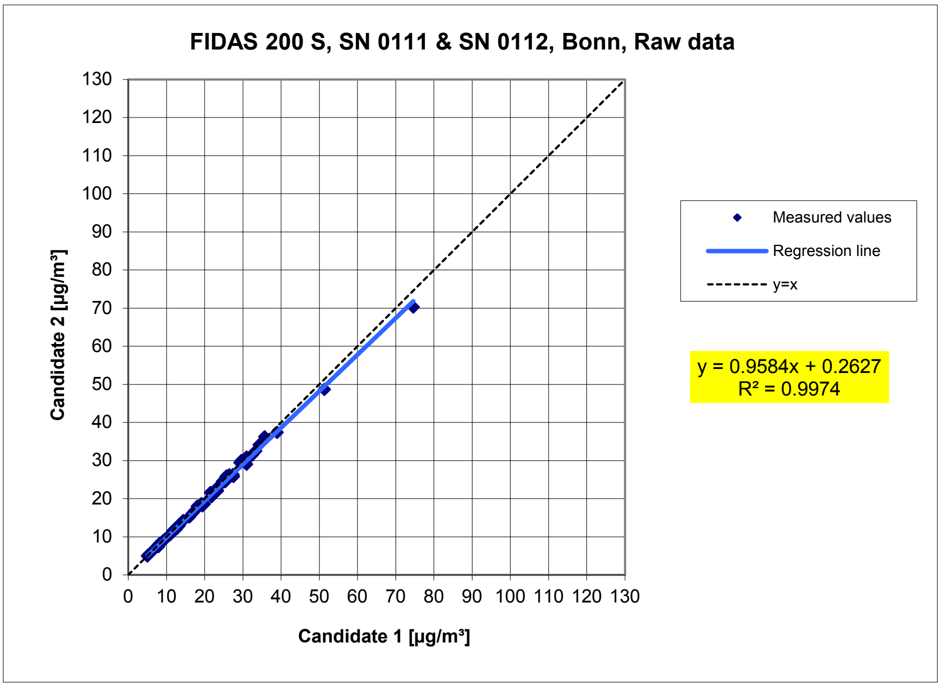



*Figure 67: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Bonn, winter*

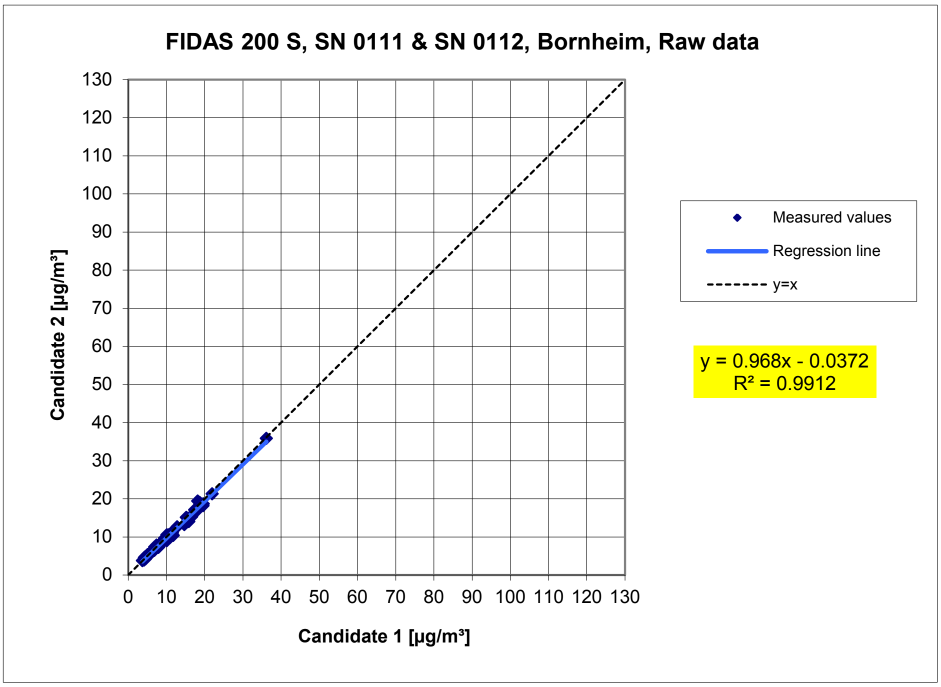



*Figure 68: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Bornheim, summer*

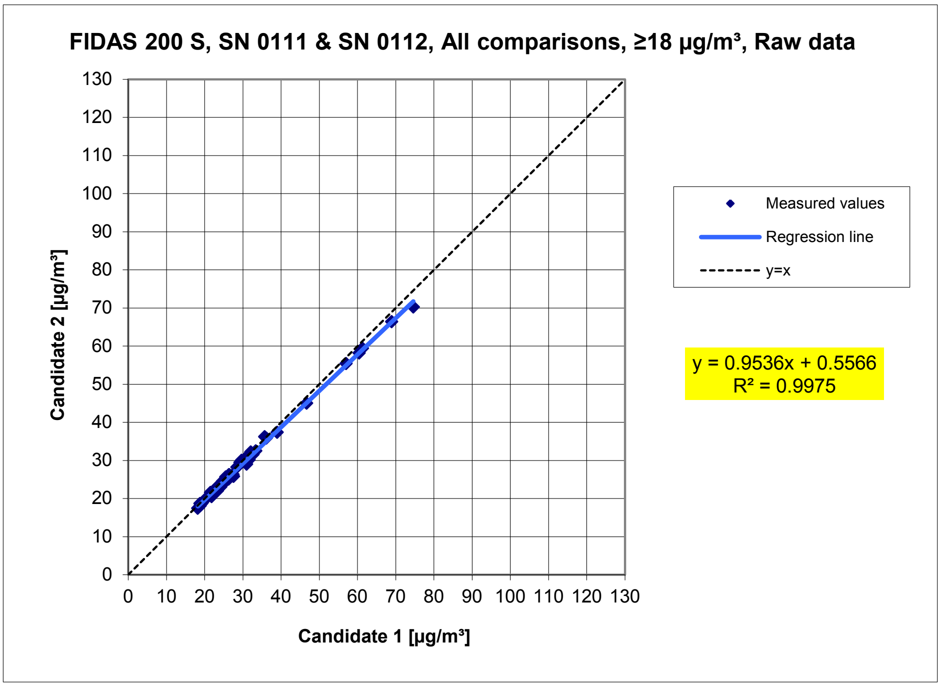



*Figure 69: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites, values ≥ 18 µg/m³*

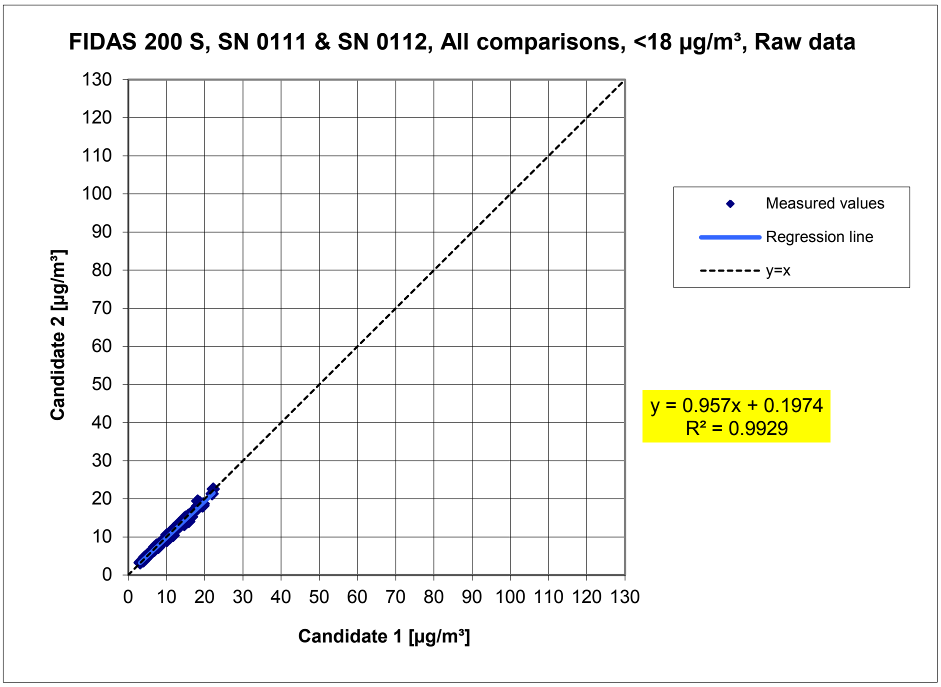



*Figure 70: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites, values < 18 µg/m³*

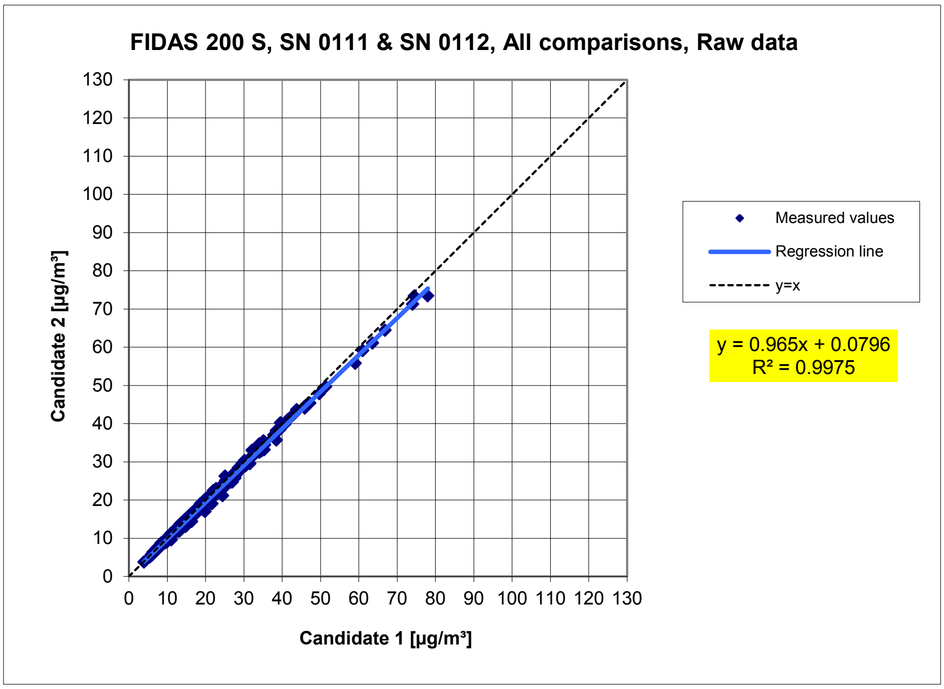



*Figure 71: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, all test sites*

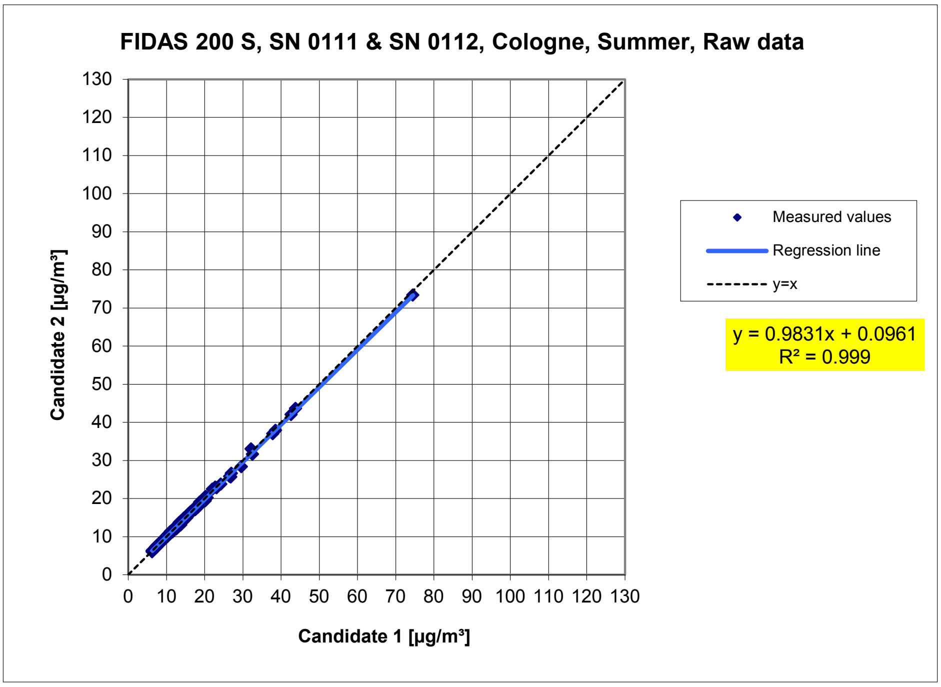



*Figure 72: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, test site Cologne, summer*

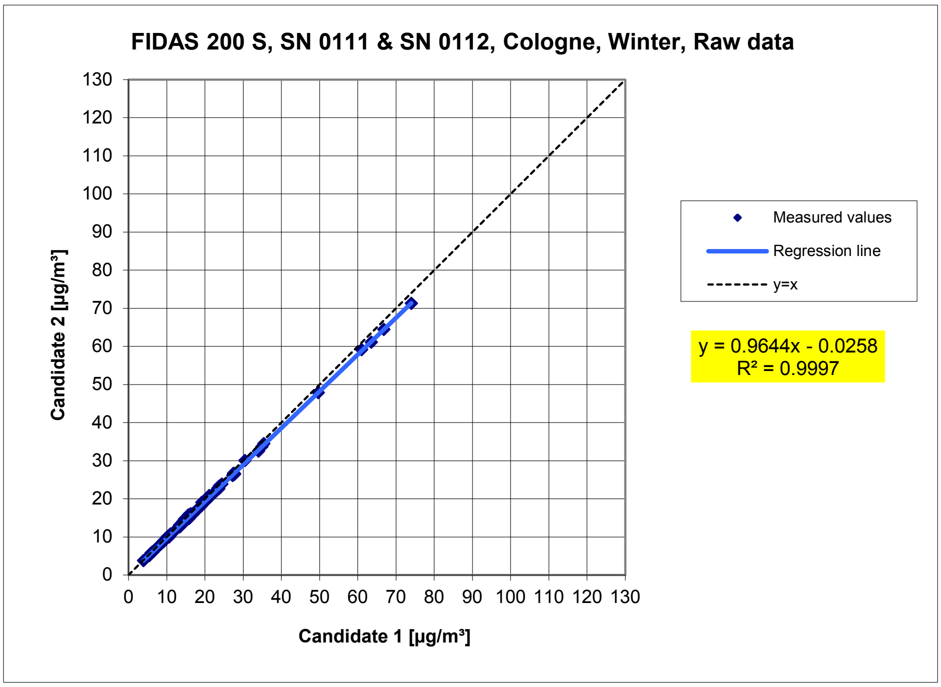



*Figure 73: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, test site Cologne, winter*

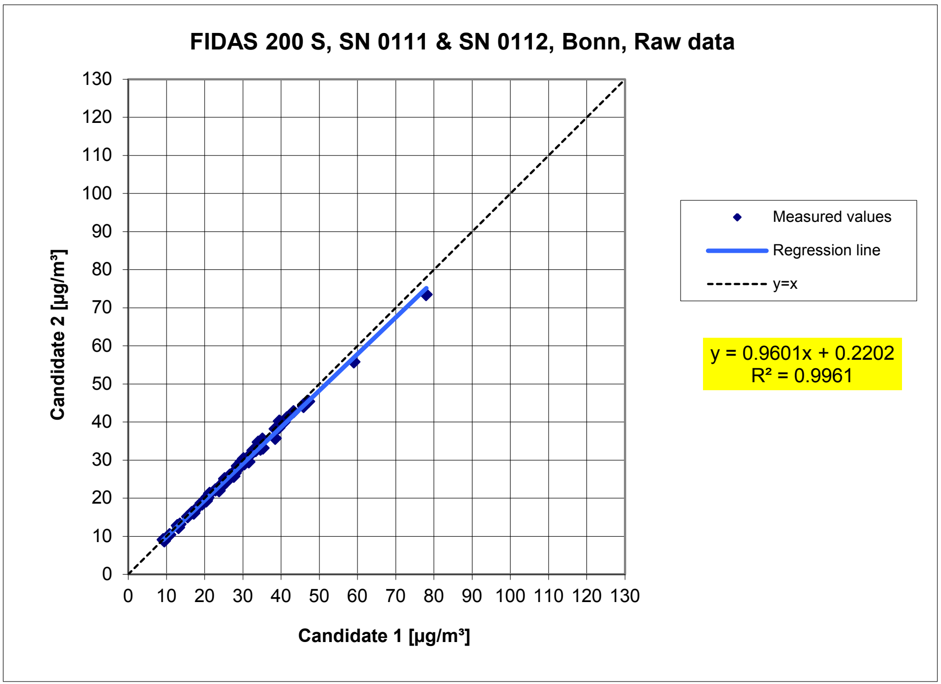



*Figure 74: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, test site Bonn, winter*

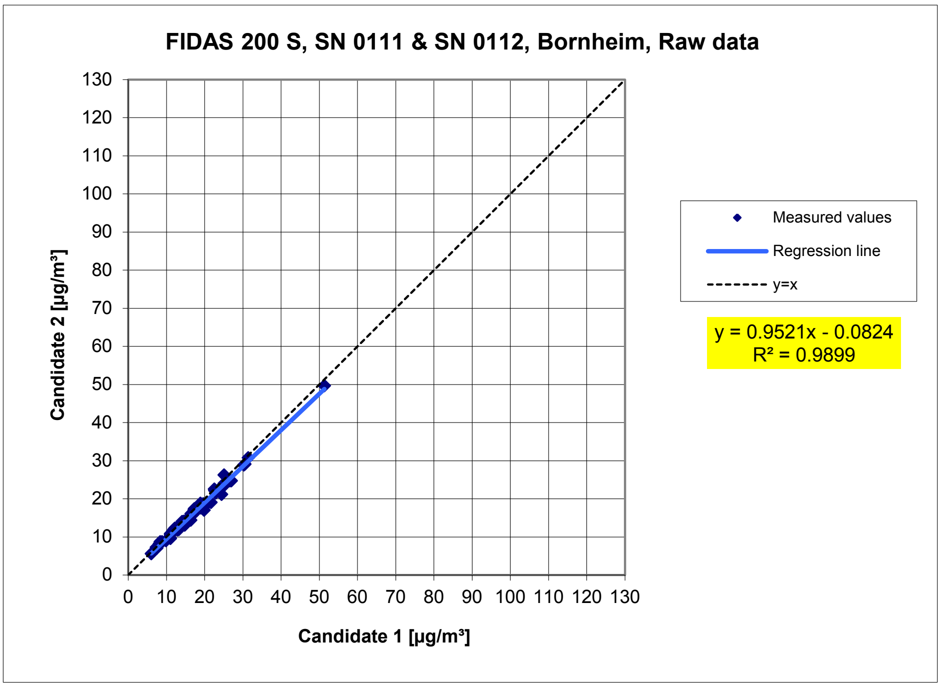



*Figure 75: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, test site Bornheim, summer*

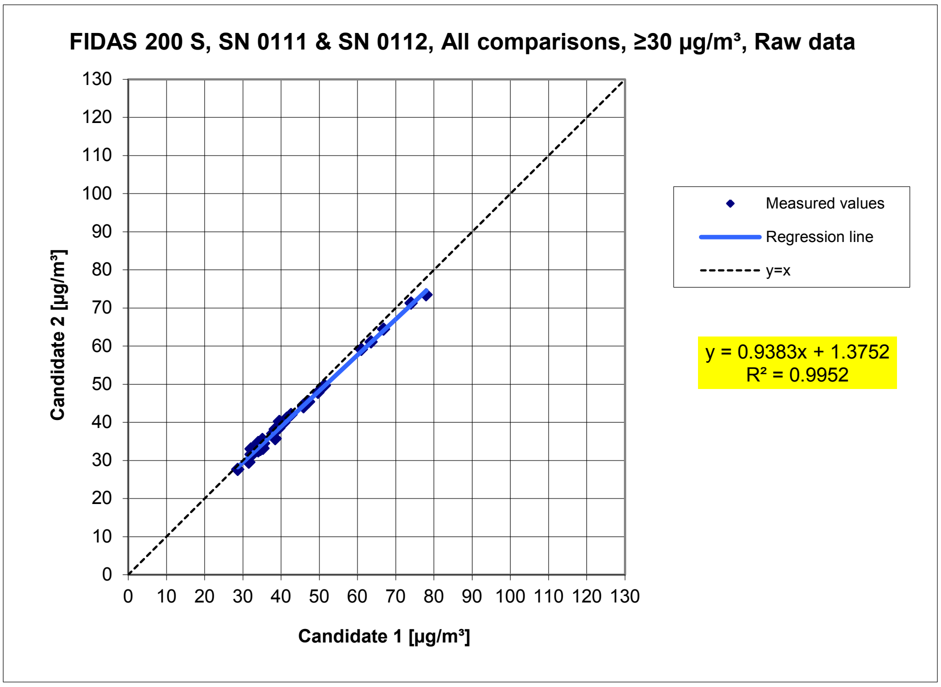



*Figure 76: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, all test sites, values ≥ 30 µg/m³*

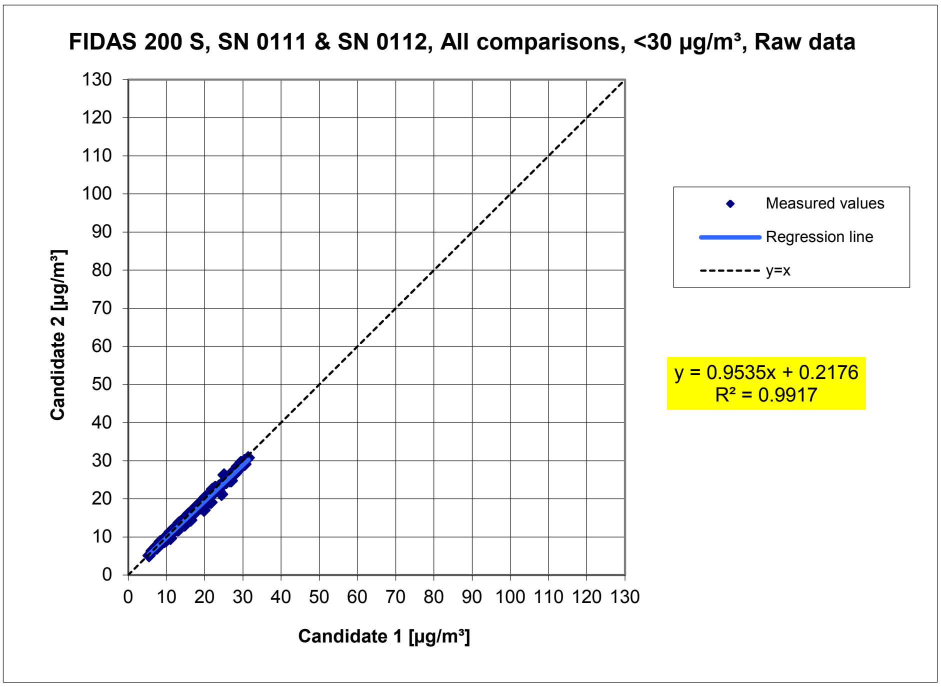



*Figure 77: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, all test sites, values < 30 µg/m³*

## 6.1 5.4.10 Calculation of expanded uncertainty between candidates

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

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

## 6.2 Equipment

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

## 6.3 Method

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

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

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

## 6.4 Evaluation

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

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

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

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

Regression is calculated for:

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

For further evaluation, the results of the uncertainty $u_{c\_s}$ of the candidates compared with the reference method is described in the following equation, which describes $u_{CR}$ as a function of the OM concentration $x_i$.

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

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

$u(x_i)$ = random uncertainty of the reference procedure, if the value $u_{bs}$, which is calculated for using the candidates, can be used in this test (refer to item 6.1 5.4.9 Determination of uncertainty between candidates ubs)

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

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

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

Uncertainty $u_{CR}$ is calculated for:

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

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

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

and that

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

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

[Item 9.5.4] The combined uncertainty of the candidates $w_{c,CM}$ is calculated for each dataset by combining the contributions from 9.5.3.1 and 9.5.3.2 according to the following equation:

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

For each dataset, the uncertainty $w_{c,CM}$ is calculated at the level of $y_i$ = 30 µg/m³ for $PM_{2.5}$ and at the level of $y_i$ = 50 µg/m³ for $PM_{10}$.

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

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

In practice k=2 for large n

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

1. $W_{CM} \leq W_{dqo} \rightarrow$ Candidate method is considered equivalent to the reference method

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

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

## 6.5 Assessment

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

Performance criterion met? no

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

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

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

| Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 30 | µg/m³ |
| Status of measured values | Raw data | | Allowed uncertainty | 25 | % |
| | | | | | |
| **Cologne, Summer** | | | | | |
| Uncertainty between Reference | **0.66** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.12** | **µg/m³** | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | **81** | | | **82** | |
| Slope b | **1.119** | | | **1.116** | |
| Uncertainty of b | **0.034** | | | **0.035** | |
| Ordinate intercept a | **-0.925** | | | **-0.885** | |
| Uncertainty of a | **0.363** | | | **0.378** | |
| Expanded meas. uncertainty $W_{CM}$ | **20.11** | **%** | | **20.13** | **%** |
| **Cologne, Winter** | | | | | |
| Uncertainty between Reference | **0.54** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.55** | **µg/m³** | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | **51** | | | **50** | |
| Slope b | **1.051** | | | **1.014** | |
| Uncertainty of b | **0.014** | | | **0.014** | |
| Ordinate intercept a | **0.691** | | | **0.679** | |
| Uncertainty of a | **0.313** | | | **0.326** | |
| Expanded meas. uncertainty $W_{CM}$ | **17.05** | **%** | | **11.42** | **%** |
| **Bonn** | | | | | |
| Uncertainty between Reference | **0.62** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.70** | **µg/m³** | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | **50** | | | **50** | |
| Slope b | **1.114** | | | **1.070** | |
| Uncertainty of b | **0.025** | | | **0.027** | |
| Ordinate intercept a | **-0.783** | | | **-0.519** | |
| Uncertainty of a | **0.571** | | | **0.619** | |
| Expanded meas. uncertainty $W_{CM}$ | **21.21** | **%** | | **16.63** | **%** |
| **Bornheim** | | | | | |
| Uncertainty between Reference | **0.42** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.50** | **µg/m³** | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | **45** | | | **45** | |
| Slope b | **1.214** | | | **1.186** | |
| Uncertainty of b | **0.054** | | | **0.054** | |
| Ordinate intercept a | **-1.487** | | | **-1.606** | |
| Uncertainty of a | **0.644** | | | **0.643** | |
| Expanded meas. uncertainty $W_{CM}$ | **35.02** | **%** | | **29.11** | **%** |
| **All comparisons, ≥18 µg/m³** | | | | | |
| Uncertainty between Reference | **0.63** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.84** | **µg/m³** | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | **54** | | | **54** | |
| Slope b | **1.071** | | | **1.022** | |
| Uncertainty of b | **0.025** | | | **0.026** | |
| Ordinate intercept a | **0.185** | | | **0.713** | |
| Uncertainty of a | **0.754** | | | **0.80** | |
| Expanded meas. uncertainty $W_{CM}$ | **20.38** | **%** | | **16.90** | **%** |
| **All comparisons, <18 µg/m³** | | | | | |
| Uncertainty between Reference | **0.57** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.33** | **µg/m³** | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | **173** | | | **173** | |
| Slope b | **1.222** | | | **1.180** | |
| Uncertainty of b | **0.032** | | | **0.032** | |
| Ordinate intercept a | **-1.573** | | | **-1.399** | |
| Uncertainty of a | **0.328** | | | **0.331** | |
| Expanded meas. uncertainty $W_{CM}$ | **35.28** | **%** | | **28.40** | **%** |
| **All comparisons** | | | | | |
| Uncertainty between Reference | **0.58** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.48** | **µg/m³** | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | **227** | | | **227** | |
| Slope b | **1.096** | **significant** | | **1.056** | **significant** |
| Uncertainty of b | **0.011** | | | **0.011** | |
| Ordinate intercept a | **-0.408** | **significant** | | **-0.234** | **not significant** |
| Uncertainty of a | **0.190** | | | **0.196** | |
| Expanded meas. uncertainty $W_{CM}$ | **19.55** | **%** | | **14.68** | **%** |

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

For $PM_{2.5}$:

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

For $PM_{10}$:

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

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

## 6.6 Detailed presentation of test results

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

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

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

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

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

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

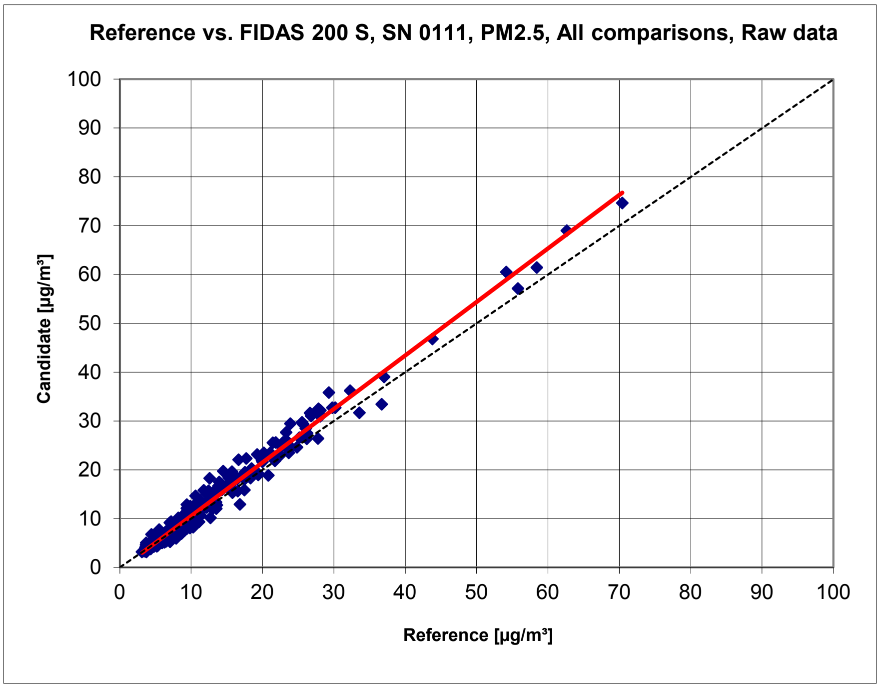



*Figure 78: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, all test sites*

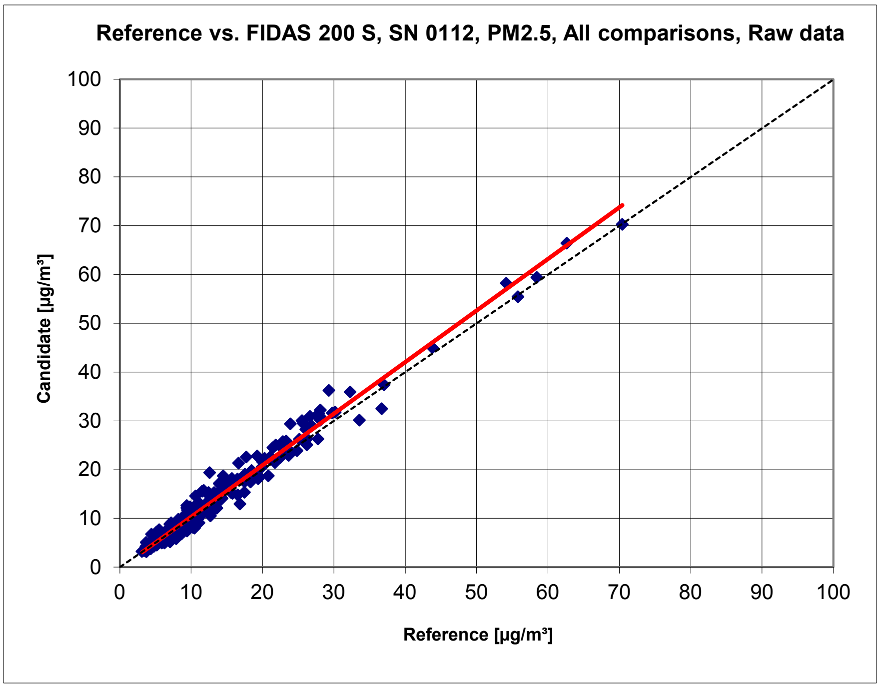



*Figure 79: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, all test sites*

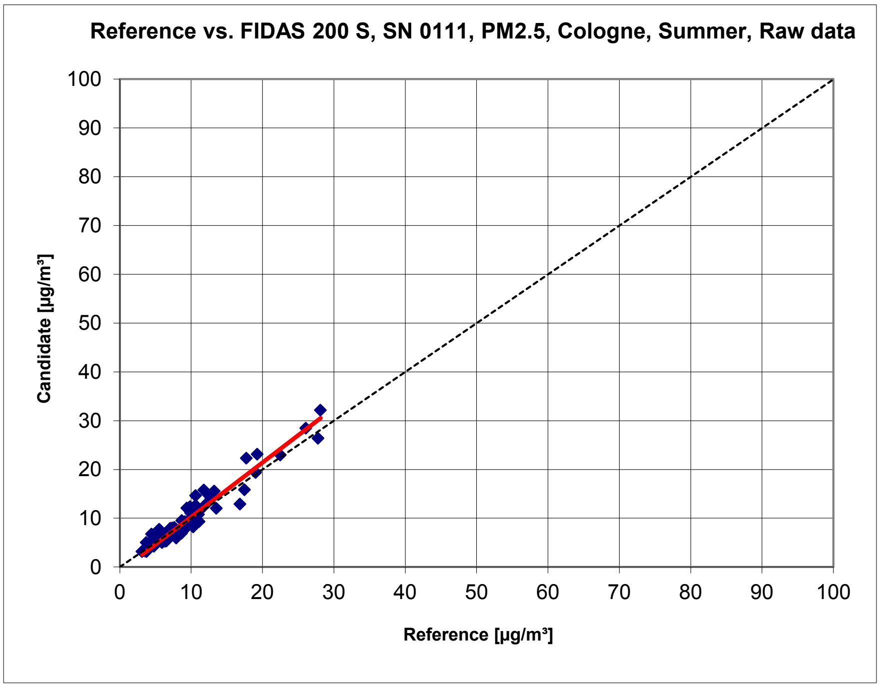



*Figure 80: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Cologne, summer*

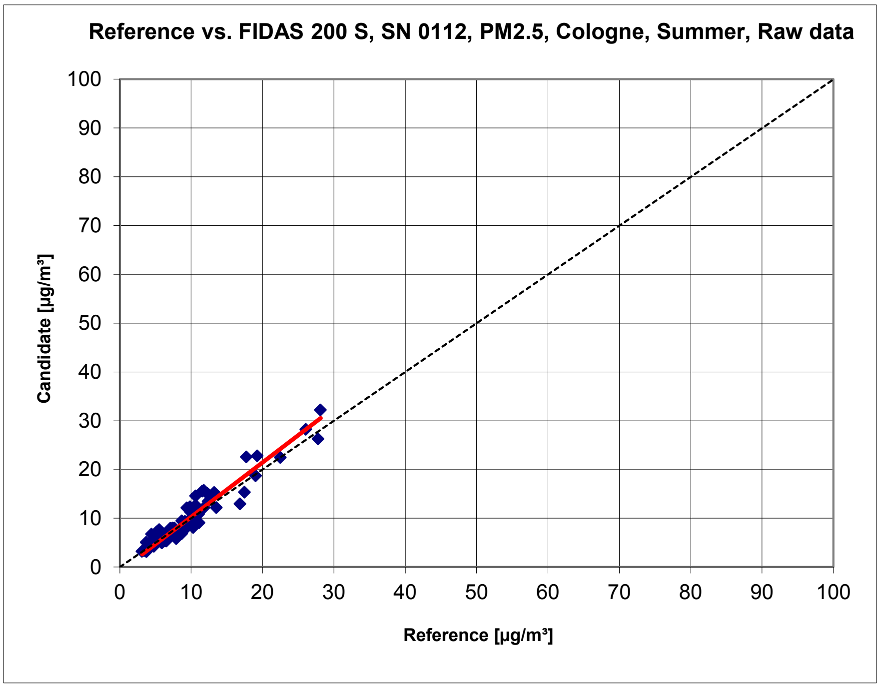



*Figure 81: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Cologne, summer*

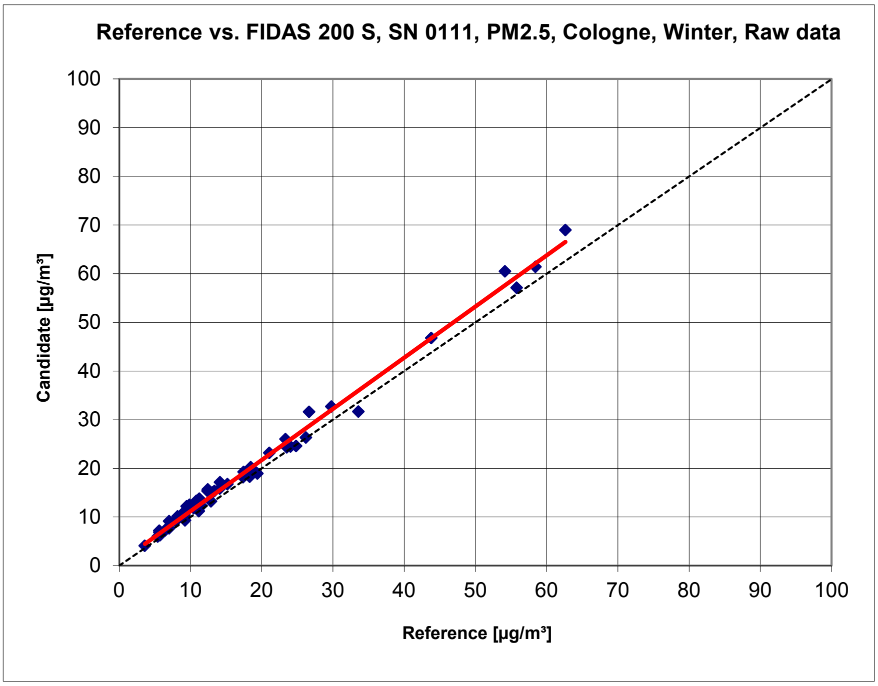



*Figure 82: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Cologne, winter*

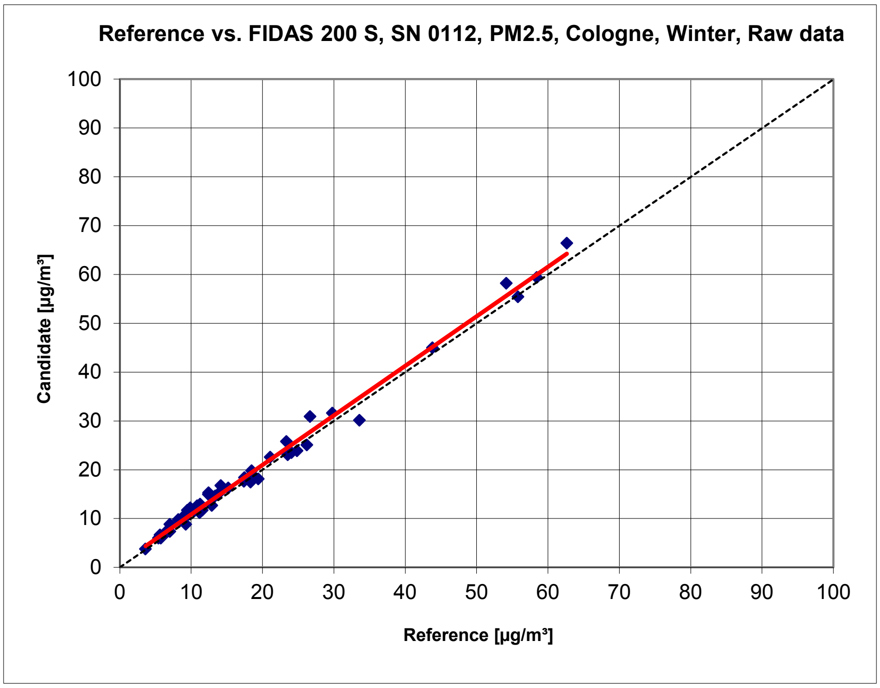



*Figure 83: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Cologne, winter*

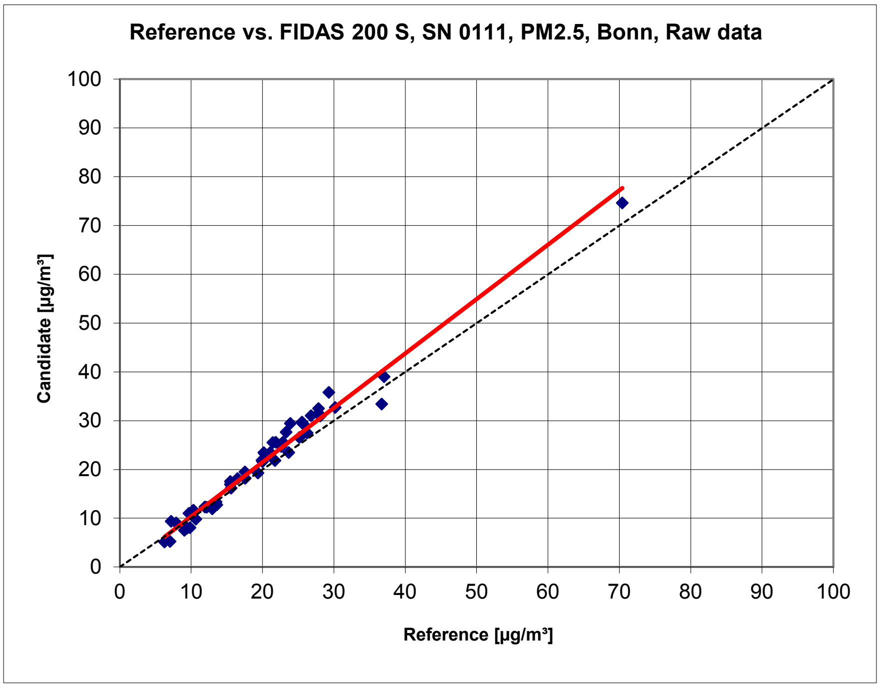



*Figure 84: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Bonn, winter*

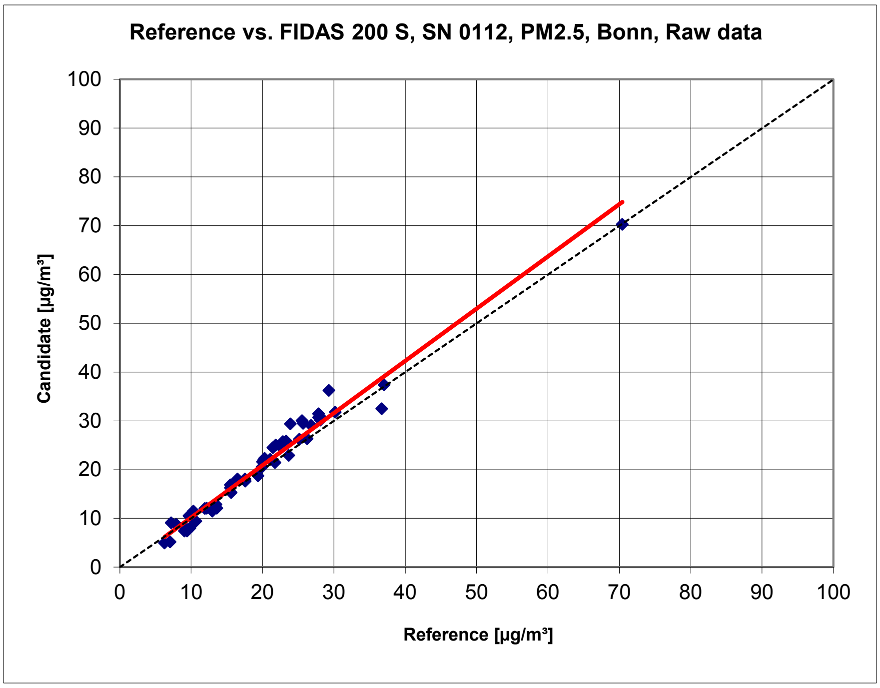



*Figure 85: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Bonn, winter*

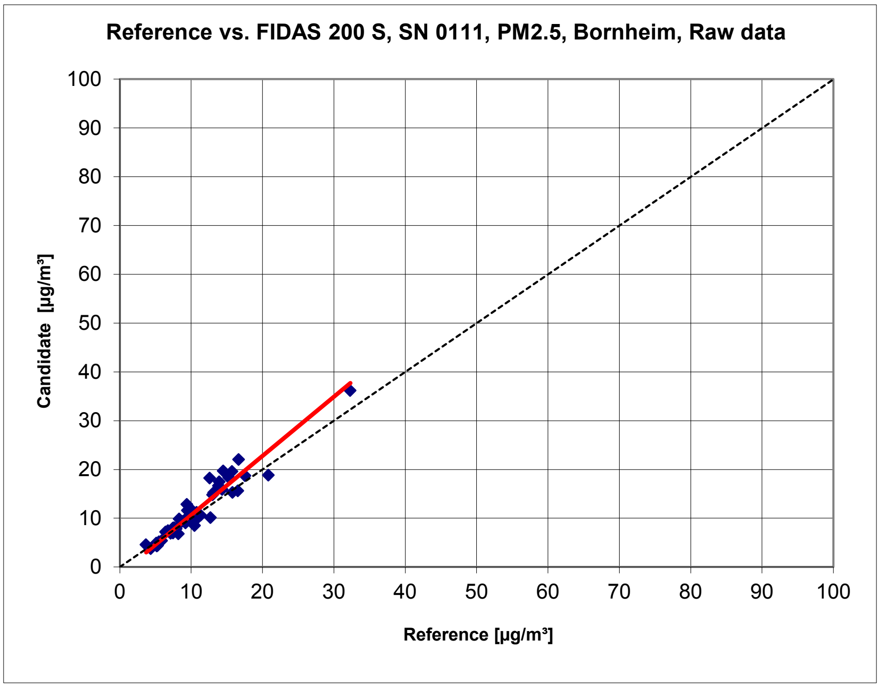



*Figure 86: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Bornheim, summer*

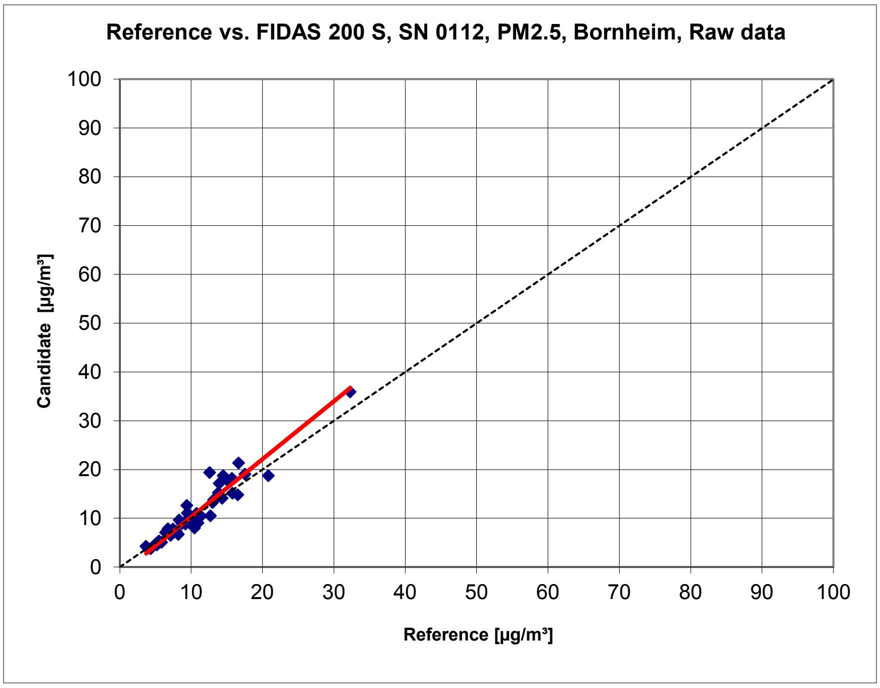



*Figure 87: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Bornheim, summer*

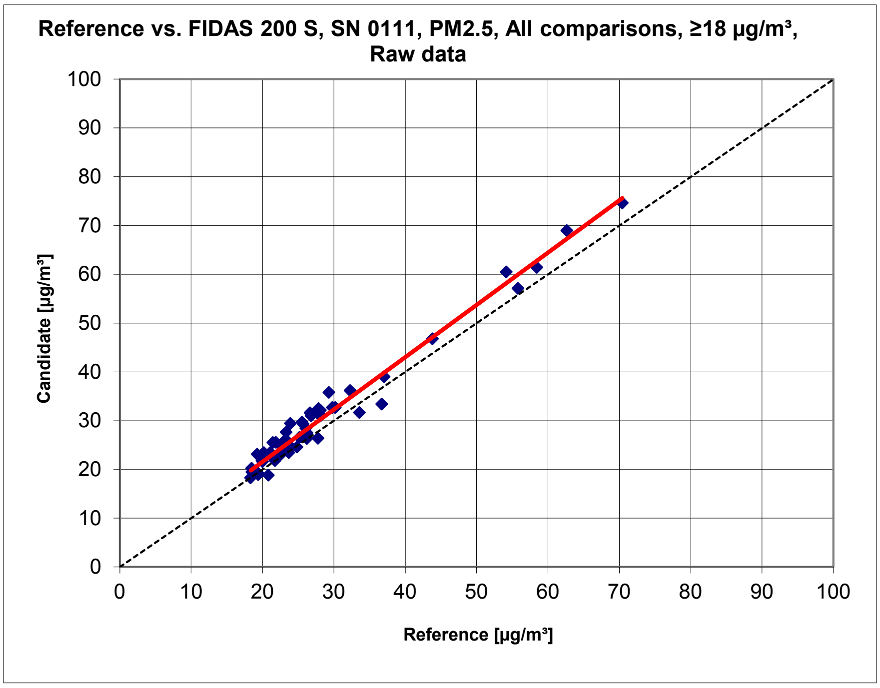



*Figure 88: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, values ≥ 18 µg/m³*

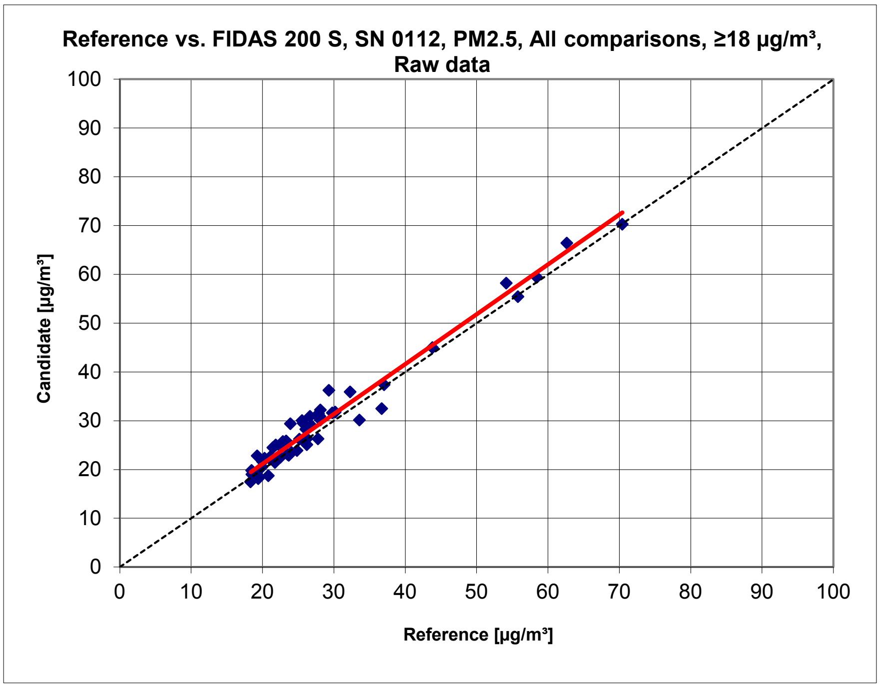



*Figure 89: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, values ≥ 18 µg/m³*

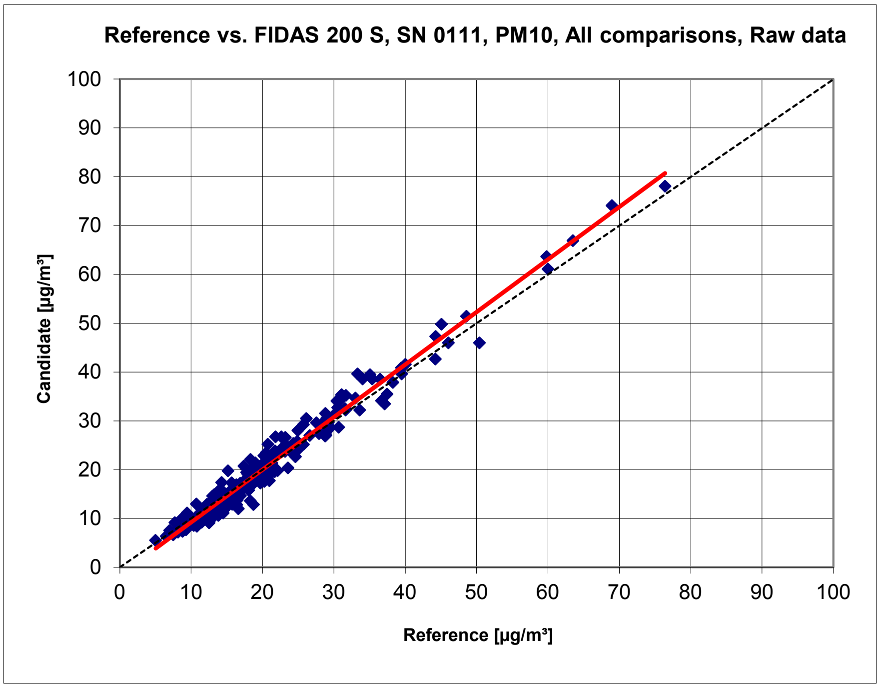



*Figure 90: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, all test sites*

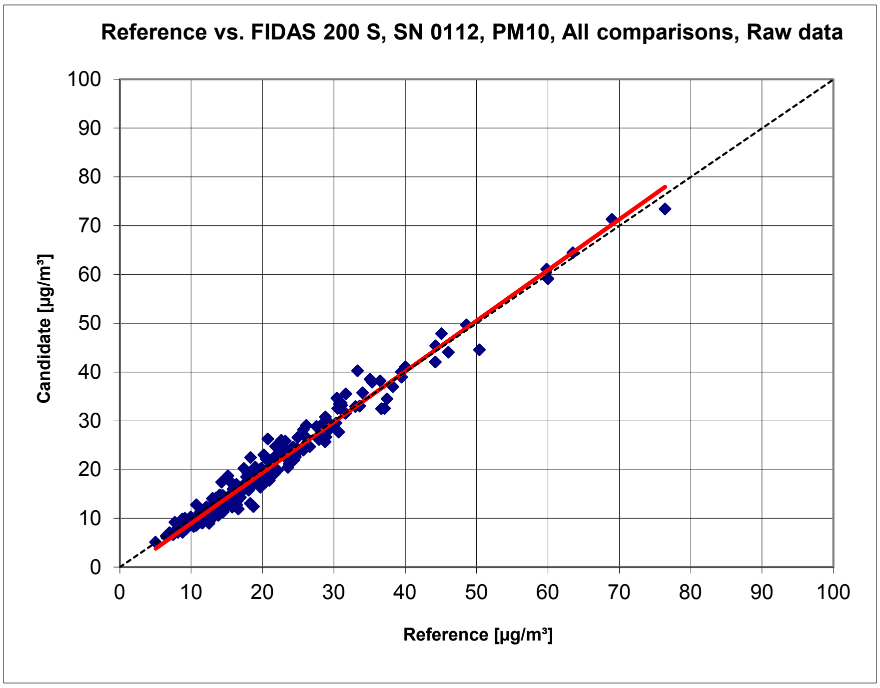



*Figure 91: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, all test sites*

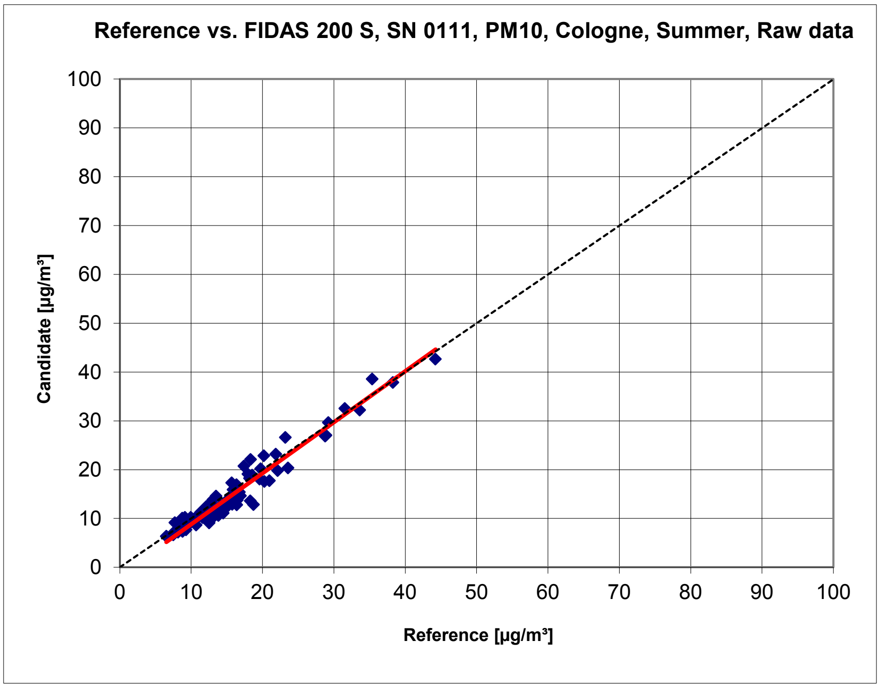



*Figure 92: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, Cologne, summer*

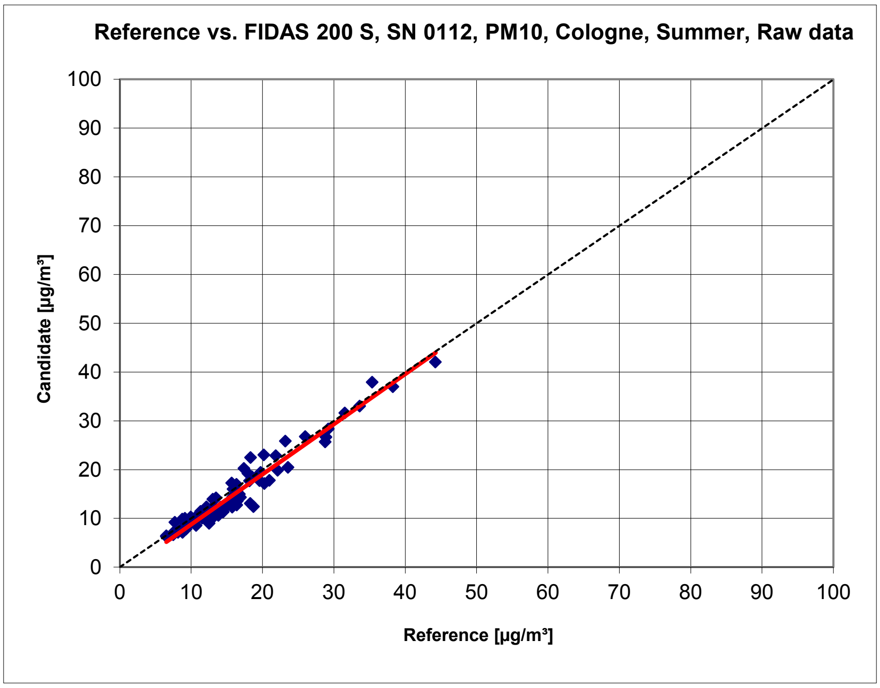



*Figure 93: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, Cologne, summer*

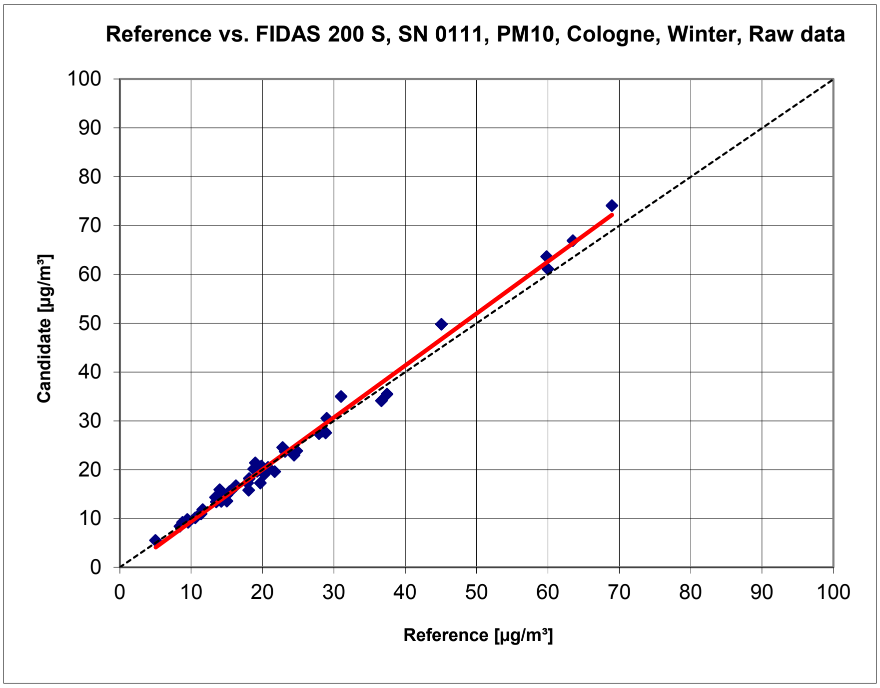



*Figure 94: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, Cologne, winter*

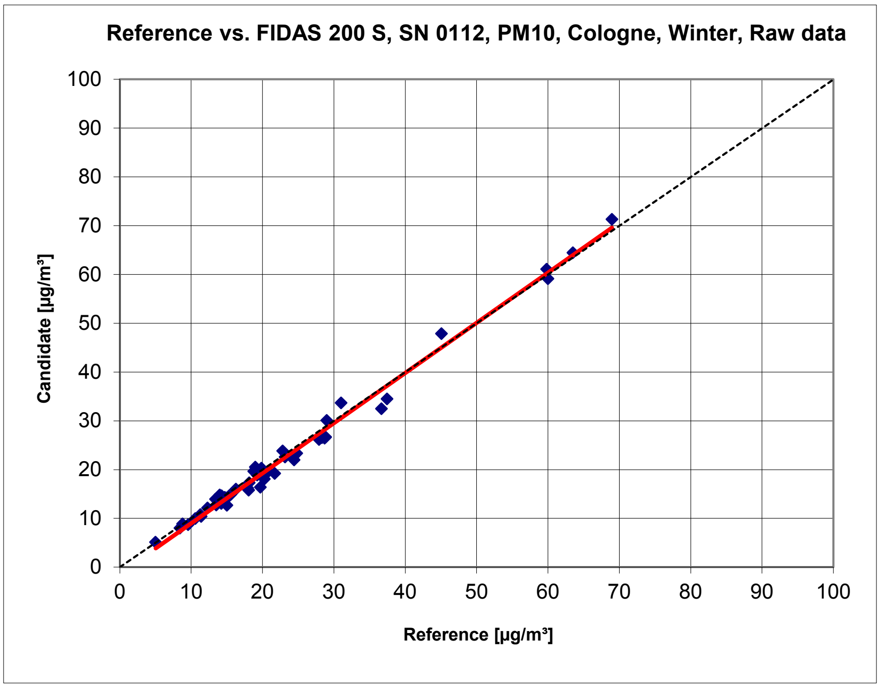



*Figure 95: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, Cologne, winter*

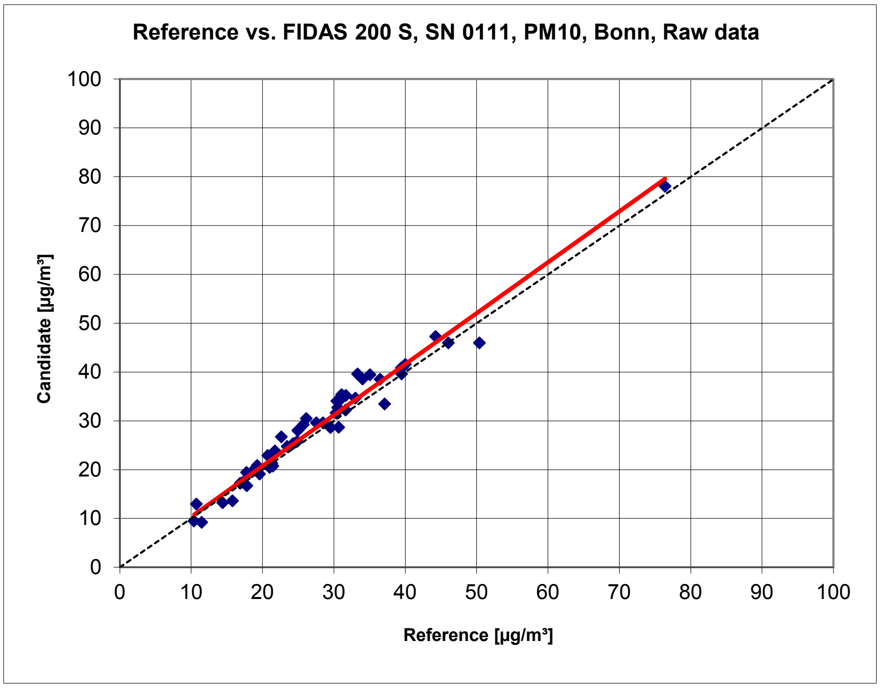



*Figure 96: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, Bonn, winter*

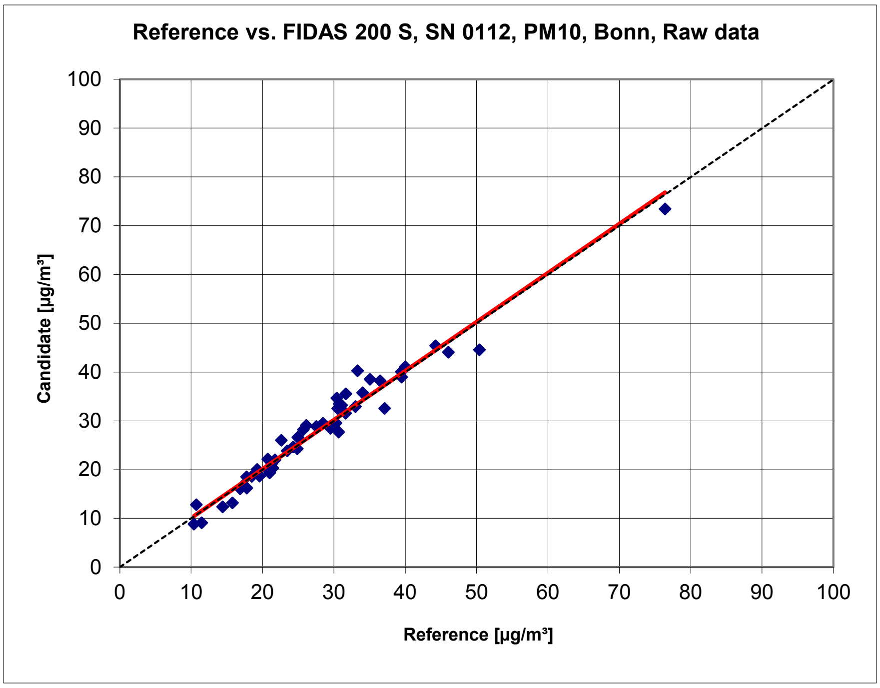



*Figure 97: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, Bonn, winter*

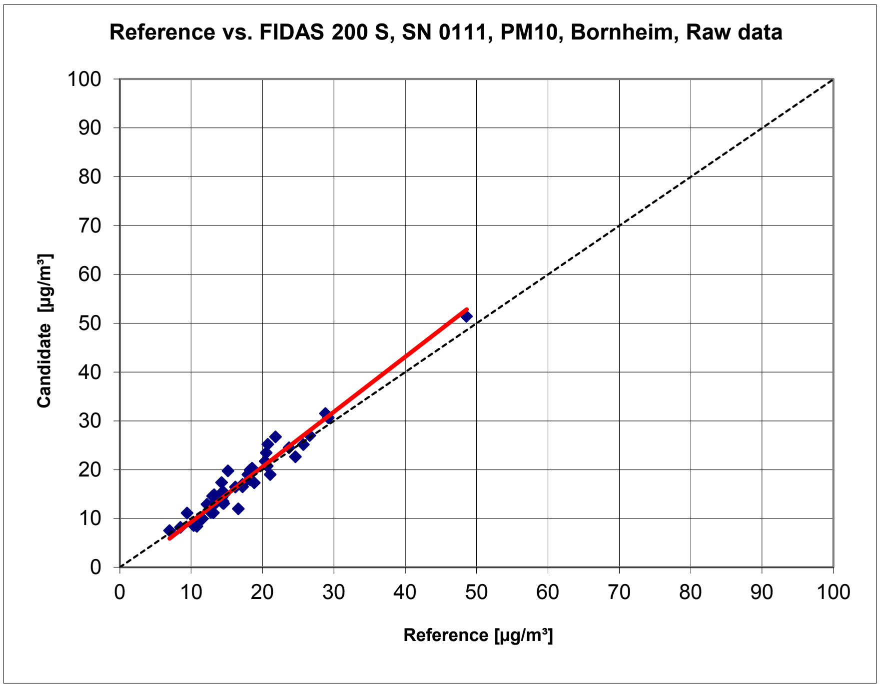



*Figure 98: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, Bornheim, summer*

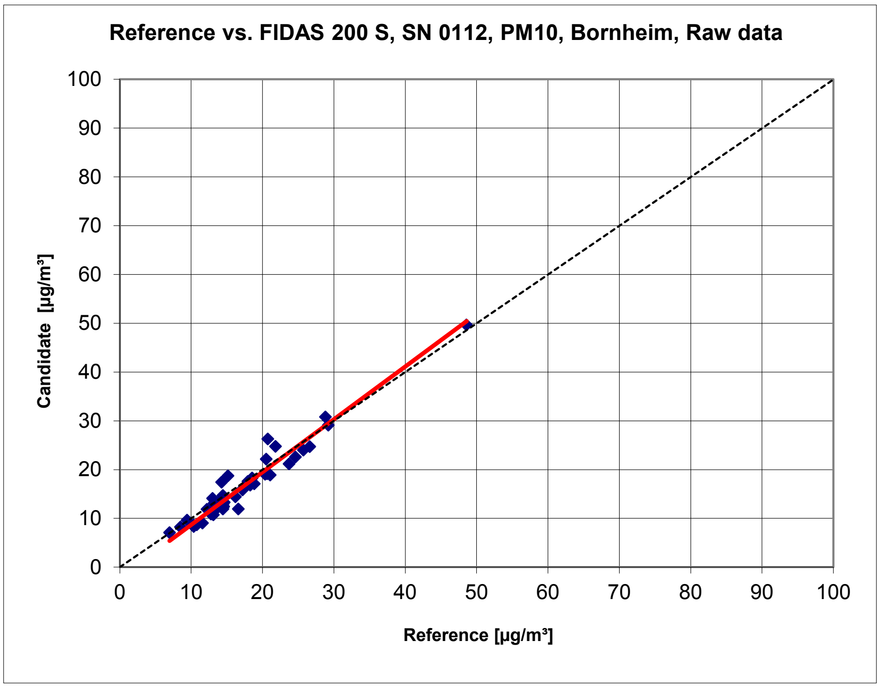



*Figure 99: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, Bornheim, summer*

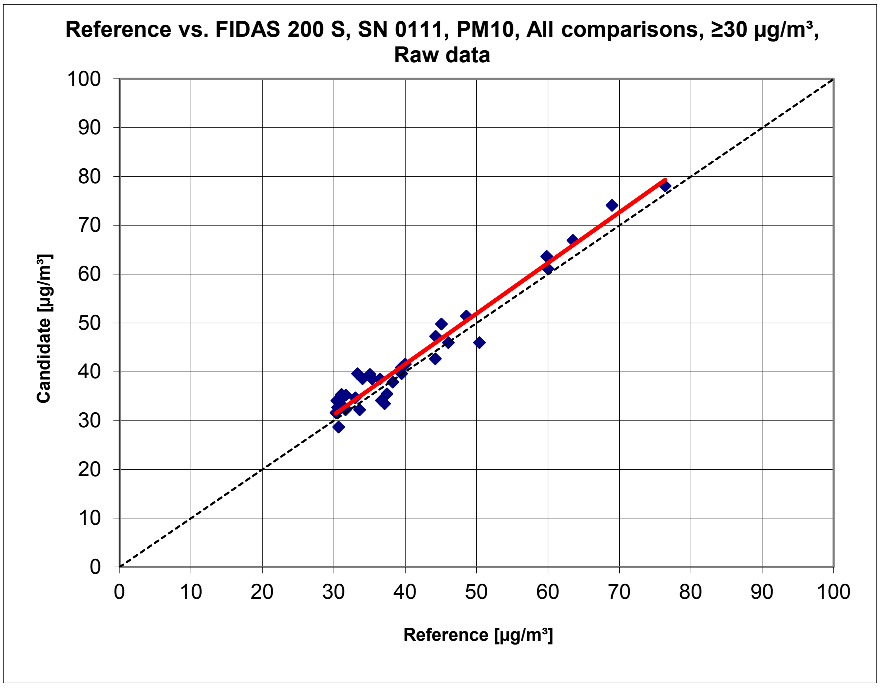



*Figure 100: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, values ≥ 30 µg/m³*

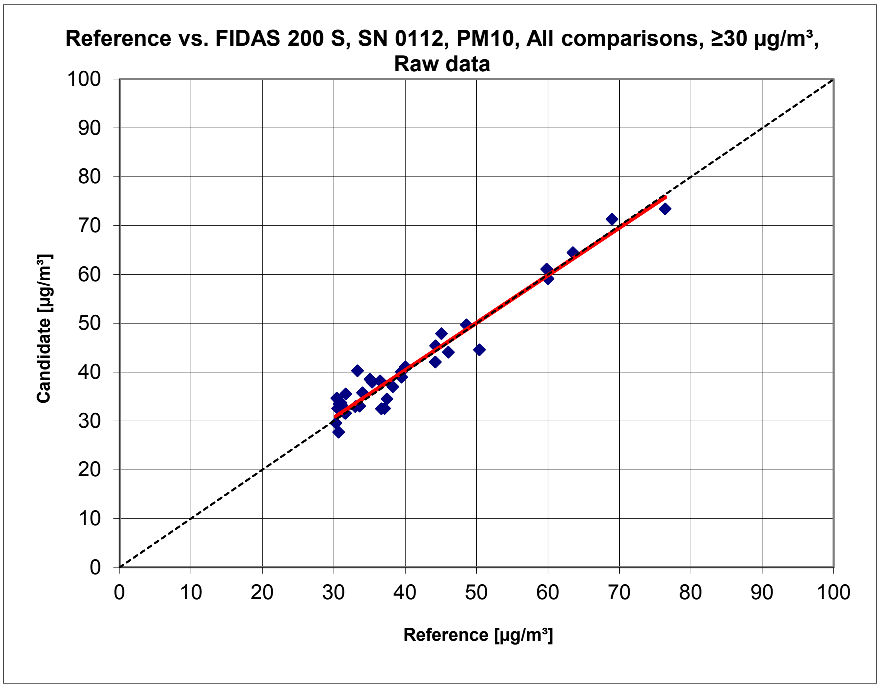



*Figure 101: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, values ≥ 30 µg/m³*

## 6.1 5.4.11 Application of correction factors and terms

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

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

## 6.2 Equipment

No equipment is necessary to test this performance criterion.

## 6.3 Method

Refer to module 5.4.10.

## 6.4 Evaluation

If evaluation of the raw data according to module 5.4.10 leads to a case where $W_{CM} > W_{dqo}$, which means that the candidate systems is not regarded equivalent to the reference method, it is permitted to apply a correction factor or term resulting from the regression equation obtained from the complete dataset. The corrected values shall satisfy the requirements for all datasets or subsets (refer to module 5.4.10). Moreover, a correction factor may be applied even for $W_{CM} \leq W_{dqo}$ in order to improve the accuracy of the candidate systems.

Three different cases may occur:

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

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

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

With respect to a)

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

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

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

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

and

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

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

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in annex B of [4]. RSS is determined analogue to the calculation in module 5.4.10.

With respect to b)

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

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

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

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

and

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

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

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in annex B of [4]. RSS is determined analogue to the calculation in module 5.4.10.

With respect to c)

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

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

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

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

and

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

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 $PM_{10}$. For $PM_{10}$, the requirements are met even without application of correction factors. The corrections of slope and intercept nevertheless lead to an improvement of the expanded measurement uncertainties of the full data comparison.

Performance criterion met? yes

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

For $PM_{2.5}$:

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

For $PM_{10}$:

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

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

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

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

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

## 6.6 Detailed presentation of test results

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

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

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

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

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

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

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

## 6.1 5.5 Requirements on multiple-component measuring systems

*Multiple-component measuring systems shall comply with the requirements set for each component, also in the case of simultaneous operation of all measuring channels.*

## 6.2 Equipment

Not applicable.

## 6.3 Method

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

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

## 6.4 Evaluation

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

## 6.5 Assessment

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

Performance criterion met? yes

## 6.6 Detailed presentation of test results

No equipment is necessary to test this performance criterion.

# 7. Extension of the equivalence test by English comparison campaigns

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

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

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

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

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

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

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

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

## 7.2 Equipment

No equipment is necessary to test this performance criterion.

## 7.3 Method

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

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

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

## 7.4 Evaluation

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

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

Uncertainty is determined for:

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

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

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

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

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

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

$n$ = number of 24 h values

### 7.5 Assessment

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

Performance criterion met? yes

## 7.6 Detailed presentation of test results

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

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

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

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

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

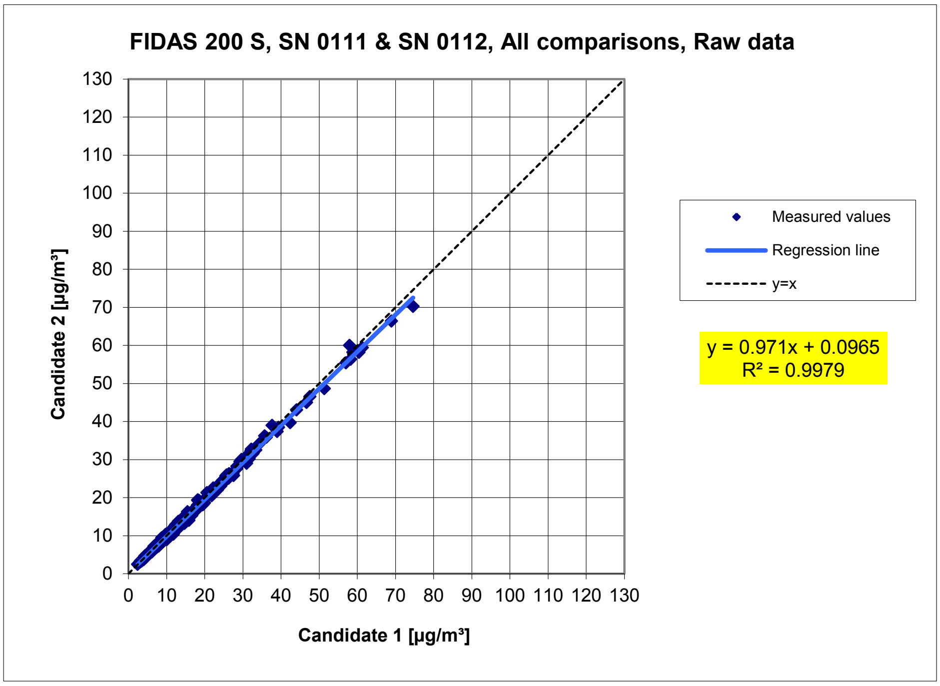



*Figure 102: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites (GER+UK), PM_ENVIRO_0011*

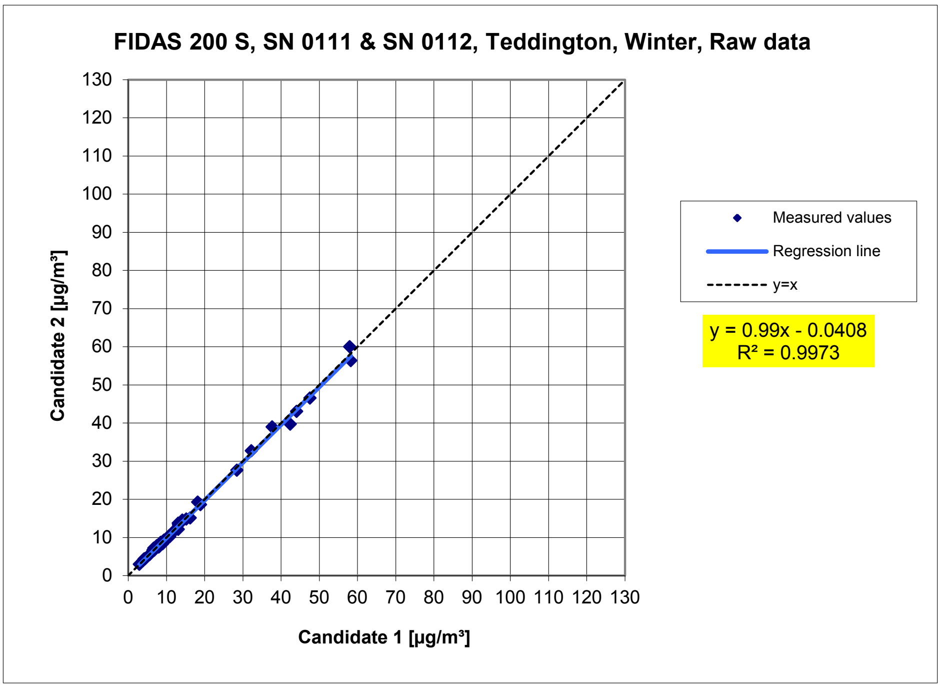



*Figure 103: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Teddington, winter, PM_ENVIRO_0011*

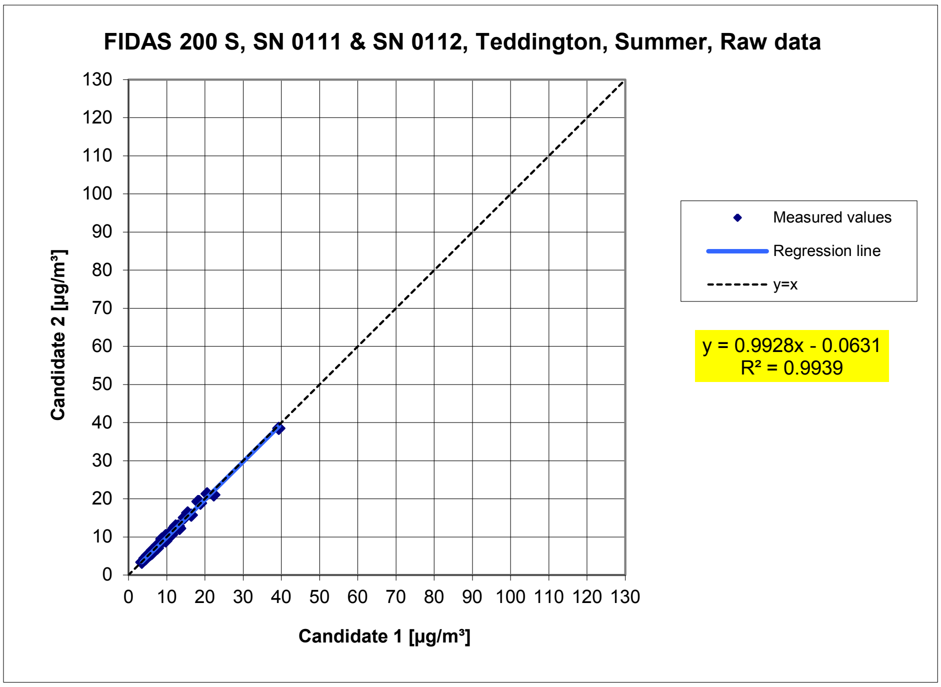



*Figure 104: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, test site Teddington, summer, PM_ENVIRO_0011*

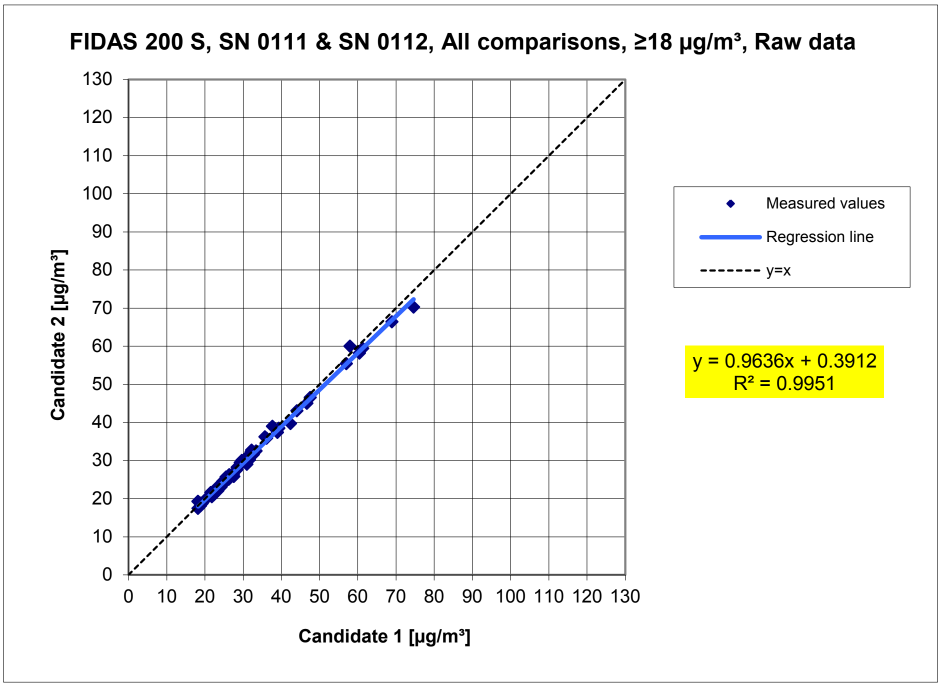



*Figure 105: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites (GER+UK), values ≥ 18 µg/m³, PM_ENVIRO_0011*

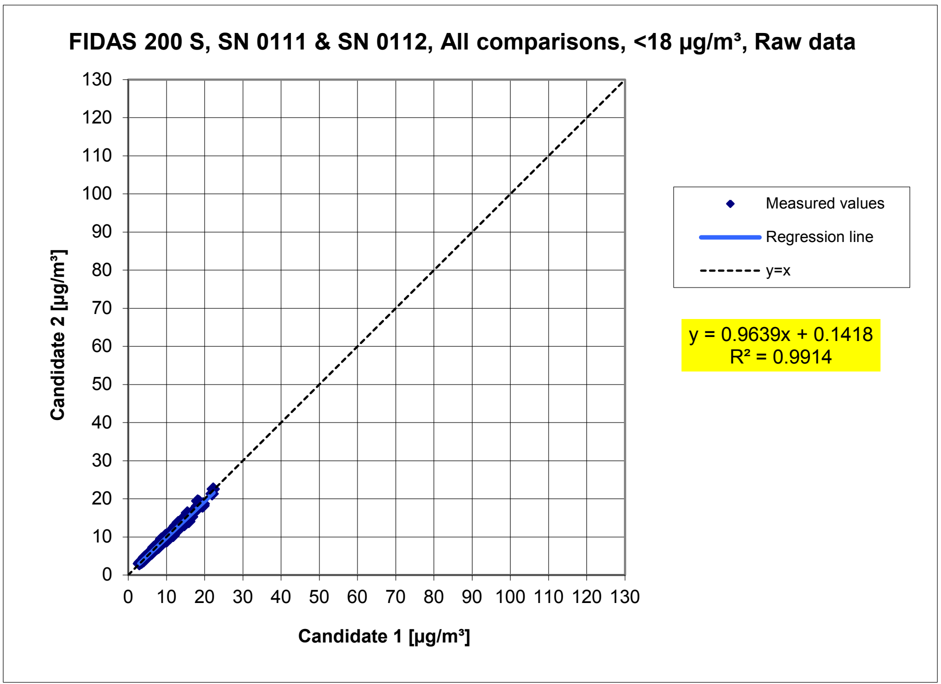



*Figure 106: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{2.5}$, all test sites (GER+UK), values < 18 µg/m³, PM_ENVIRO_0011*

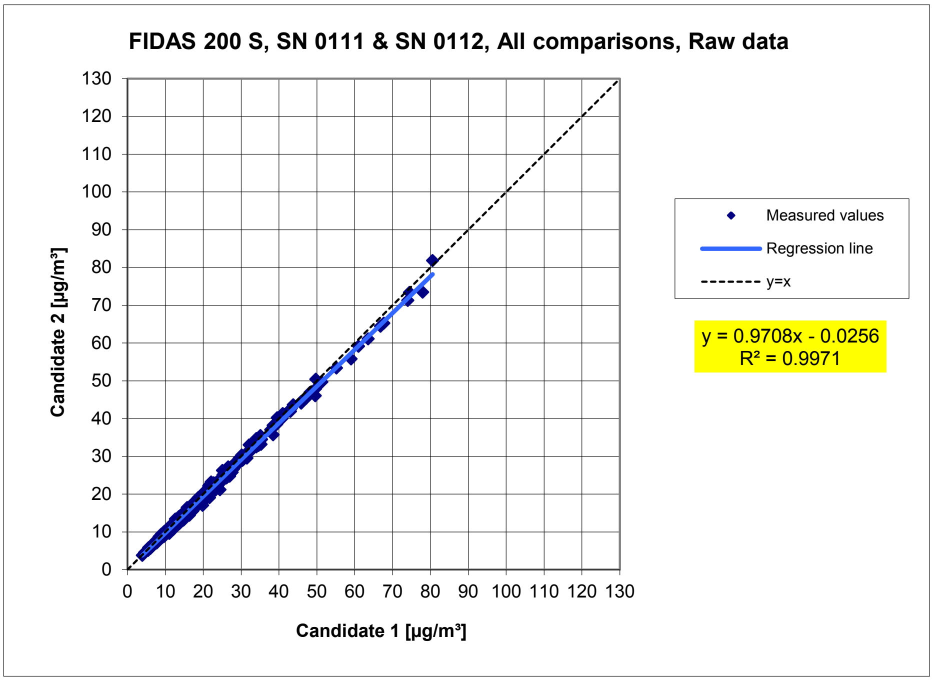



*Figure 107: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, all test sites (GER+UK), PM_ENVIRO_0011*

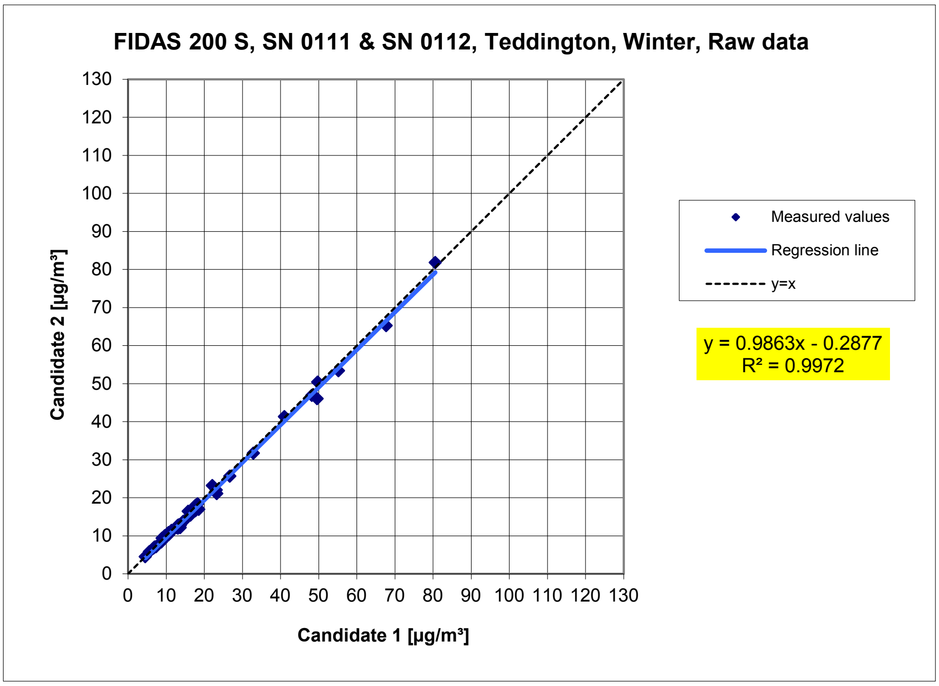



*Figure 108: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, test site Teddington, winter, PM_ENVIRO_0011*

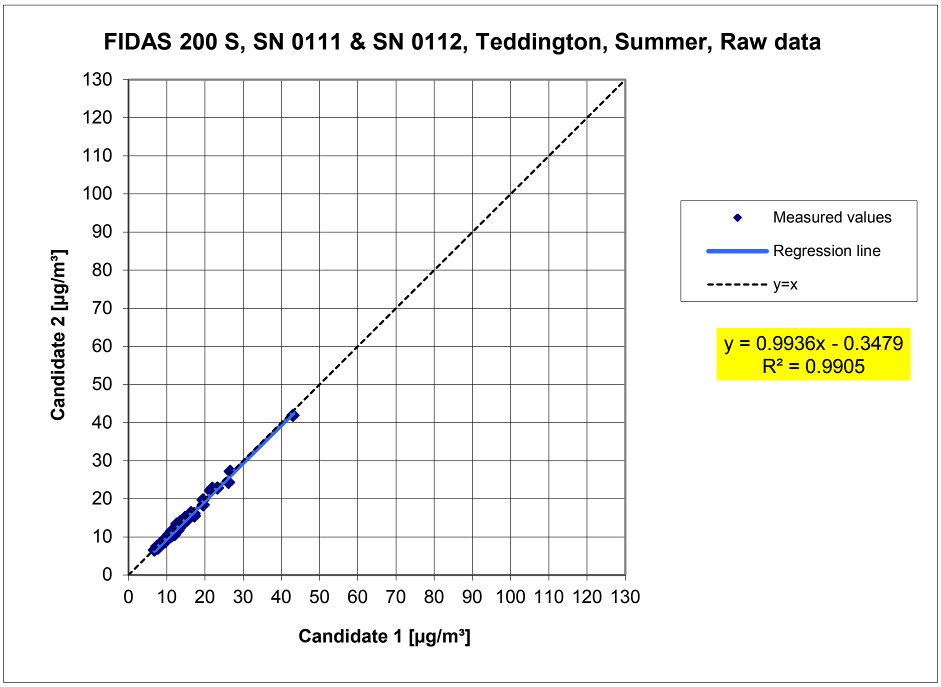



*Figure 109: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, test site Teddington, summer, PM_ENVIRO_0011*

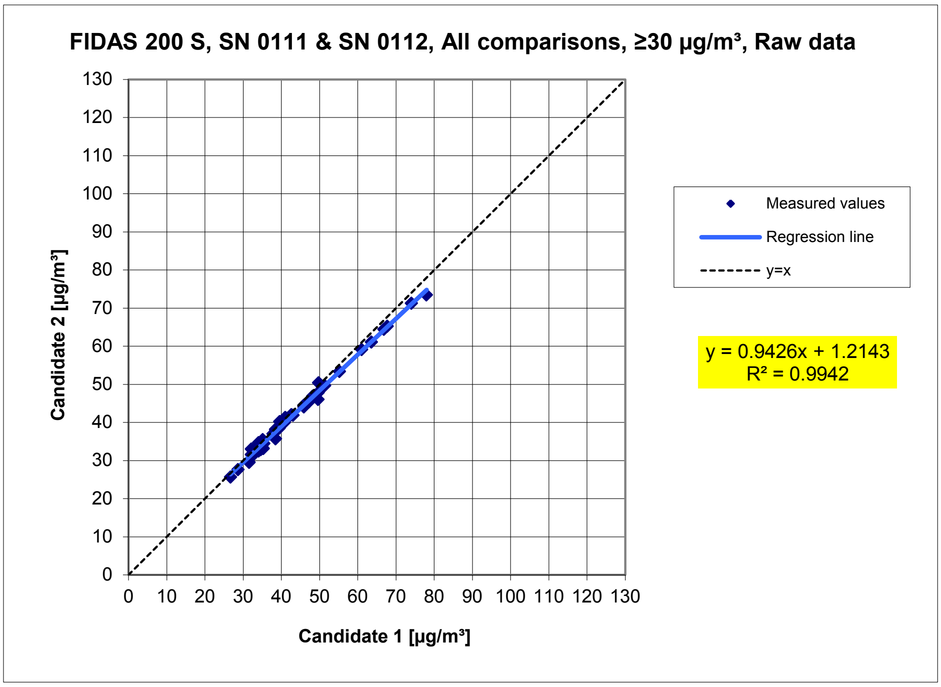



*Figure 110: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, all test sites (GER+UK), values ≥ 30 µg/m³, PM_ENVIRO_0011*

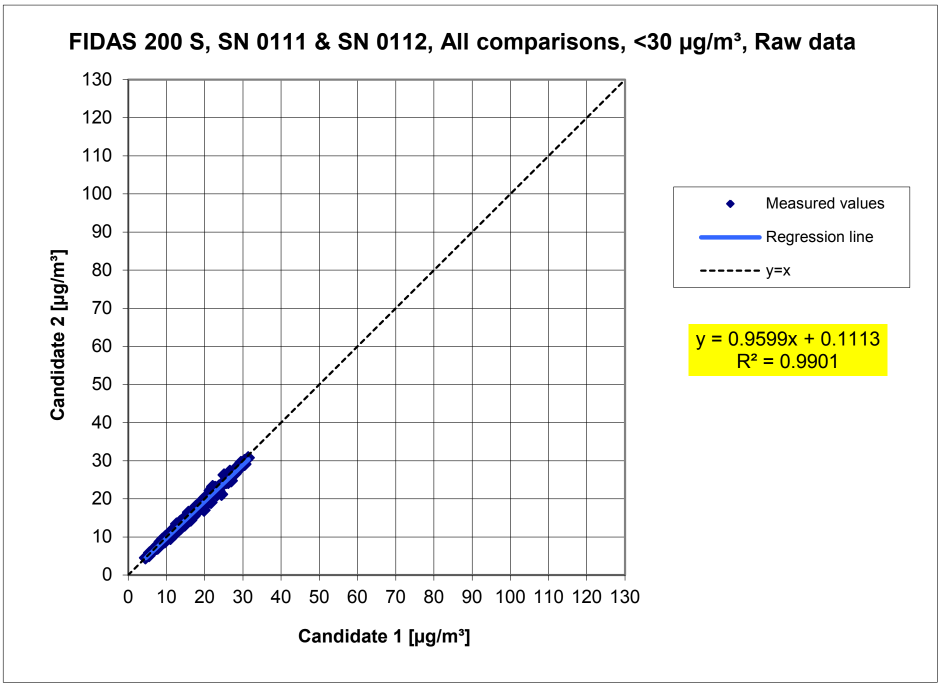



*Figure 111: Results of the parallel measurements with the devices SN 0111 / SN 0112, measured component $PM_{10}$, all test sites (GER+UK), values < 30 µg/m³, PM_ENVIRO_0011*

## 7.1 5.4.10 Calculation of expanded uncertainty between systems under test (PM_ENVIRO_0011, GER+UK)

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

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

## 7.2 Equipment

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

## 7.3 Method

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

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

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

## 7.4 Evaluation

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

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

The evaluated results are given in 8.6 of this test item.

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

Regression is calculated for:

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

For further evaluation, the results of the uncertainty $u_{c\_s}$ of the candidates compared with the reference method is described in the following equation, which describes $u_{CR}$ as a function of the OM concentration $x_i$.

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

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

$u(x_i)$ = random uncertainty of the reference procedure, if the value $u_{bs}$, which is calculated for using the candidates, can be used in this test (refer to item 6.1 5.4.9 Determination of uncertainty between candidates ubs)

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

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

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

Uncertainty $u_{CR}$ is calculated for:

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

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

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

and that

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

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

[Item 9.5.4] The combined uncertainty of the candidates $w_{c,CM}$ is calculated for each dataset by combining the contributions from 9.5.3.1 and 9.5.3.2 according to the following equation:

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

For each dataset, the uncertainty $w_{c,CM}$ is calculated at the level of $y_i$ = 30 µg/m³ for $PM_{2.5}$ and at the level of $y_i$ = 50 µg/m³ for $PM_{10}$.

[Item 9.5.5] The expanded relative uncertainty of the results of the candidates is calculated for each dataset by multiplying $w_{c,CM}$ with a coverage factor k according to the following equation:

$$W_{CM} = k \cdot w_{CM}$$

In practice k=2 for large n 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 $PM_{10}$ for all datasets under consideration are below the defined expanded relative uncertainty $W_{dqo}$ of 25 % for suspended particulate matter without the application of correction factors. The determined uncertainties $W_{CM}$ for $PM_{2.5}$ for all datasets under consideration with exception of Bornheim, summer are below the defined expanded relative uncertainty $W_{dqo}$ of 25 % for suspended particulate matter without the application of correction factors. Correction factors shall be applied according to chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK).

Performance criterion met? no

Because of the exceeded uncertainty $W_{CM}$ at the test site Bornheim, summer for $PM_{2.5}$, the significance of the slope for the complete dataset $PM_{2.5}$ and the significance of the slope and the intercept for $PM_{10}$, correction factors are applied according to chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK).

Table 54 and Table 55 provide an overview of all results from the equivalence test of the Fidas® 200 S for $PM_{2.5}$ and $PM_{10}$. In the event that a criterion has not been met, the respective cell is marked in red.

*Table 54: Overview of equivalence test of Fidas® 200 S for $PM_{2.5}$ (D+UK, PM_ENVIRO_0011)*

| Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 30 | µg/m³ |
| Status of measured values | Raw data | | Allowed uncertainty | 25 | % |
| **All comparisons** | | | | | |
| Uncertainty between Reference | **0.53** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.48** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **313** | | | | |
| Slope b | **1.060** | **significant** | | | |
| Uncertainty of b | **0.008** | | | | |
| Ordinate intercept a | **-0.210** | **not significant** | | | |
| Uncertainty of a | **0.144** | | | | |
| Expanded meas. uncertainty $W_{CM}$ | **14.43** | **%** | | | |
| **All comparisons, ≥18 µg/m³** | | | | | |
| Uncertainty between Reference | **0.60** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.85** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **67** | | | | |
| Slope b | **1.041** | | | | |
| Uncertainty of b | **0.021** | | | | |
| Ordinate intercept a | **0.300** | | | | |
| Uncertainty of a | **0.668** | | | | |
| Expanded meas. uncertainty $W_{CM}$ | **16.63** | **%** | | | |
| **All comparisons, <18 µg/m³** | | | | | |
| Uncertainty between Reference | **0.51** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.32** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **246** | | | | |
| Slope b | **1.133** | | | | |
| Uncertainty of b | **0.024** | | | | |
| Ordinate intercept a | **-0.866** | | | | |
| Uncertainty of a | **0.237** | | | | |
| Expanded meas. uncertainty $W_{CM}$ | **22.55** | **%** | | | |

| Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 30 | µg/m³ |
| Status of measured values | Raw data | | Allowed uncertainty | 25 | % |
| **Cologne, Summer** | | | | | |
| Uncertainty between Reference | 0.66 | µg/m³ | | | |
| Uncertainty between Candidates | 0.12 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 81 | | | 82 | |
| Slope b | 1.119 | | | 1.116 | |
| Uncertainty of b | 0.034 | | | 0.035 | |
| Ordinate intercept a | -0.925 | | | -0.885 | |
| Uncertainty of a | 0.363 | | | 0.378 | |
| Expanded meas. uncertainty $W_{CM}$ | 20.11 | % | | 20.13 | % |
| **Cologne, Winter** | | | | | |
| Uncertainty between Reference | 0.54 | µg/m³ | | | |
| Uncertainty between Candidates | 0.55 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 51 | | | 50 | |
| Slope b | 1.051 | | | 1.014 | |
| Uncertainty of b | 0.014 | | | 0.014 | |
| Ordinate intercept a | 0.691 | | | 0.679 | |
| Uncertainty of a | 0.313 | | | 0.326 | |
| Expanded meas. uncertainty $W_{CM}$ | 17.05 | % | | 11.42 | % |
| **Bonn** | | | | | |
| Uncertainty between Reference | 0.62 | µg/m³ | | | |
| Uncertainty between Candidates | 0.70 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 50 | | | 50 | |
| Slope b | 1.114 | | | 1.070 | |
| Uncertainty of b | 0.025 | | | 0.027 | |
| Ordinate intercept a | -0.783 | | | -0.519 | |
| Uncertainty of a | 0.571 | | | 0.619 | |
| Expanded meas. uncertainty $W_{CM}$ | 21.21 | % | | 16.63 | % |
| **Bornheim** | | | | | |
| Uncertainty between Reference | 0.42 | µg/m³ | | | |
| Uncertainty between Candidates | 0.50 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 45 | | | 45 | |
| Slope b | 1.214 | | | 1.186 | |
| Uncertainty of b | 0.054 | | | 0.054 | |
| Ordinate intercept a | -1.487 | | | -1.606 | |
| Uncertainty of a | 0.644 | | | 0.643 | |
| Expanded meas. uncertainty $W_{CM}$ | 35.02 | % | | 29.11 | % |
| **Teddington, Winter** | | | | | |
| Uncertainty between Reference | 0.42 | µg/m³ | | | |
| Uncertainty between Candidates | 0.55 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 44 | | | 44 | |
| Slope b | 1.022 | | | 1.022 | |
| Uncertainty of b | 0.012 | | | 0.012 | |
| Ordinate intercept a | -0.007 | | | -0.154 | |
| Uncertainty of a | 0.237 | | | 0.220 | |
| Expanded meas. uncertainty $W_{CM}$ | 7.71 | % | | 6.65 | % |
| **Teddington, Summer** | | | | | |
| Uncertainty between Reference | 0.25 | µg/m³ | | | |
| Uncertainty between Candidates | 0.37 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 44 | | | 44 | |
| Slope b | 0.991 | | | 0.982 | |
| Uncertainty of b | 0.021 | | | 0.021 | |
| Ordinate intercept a | 0.483 | | | 0.418 | |
| Uncertainty of a | 0.246 | | | 0.243 | |
| Expanded meas. uncertainty $W_{CM}$ | 5.89 | % | | 5.68 | % |
| **All comparisons, ≥18 µg/m³** | | | | | |
| Uncertainty between Reference | 0.60 | µg/m³ | | | |
| Uncertainty between Candidates | 0.85 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 67 | | | 67 | |
| Slope b | 1.060 | | | 1.024 | |
| Uncertainty of b | 0.022 | | | 0.022 | |
| Ordinate intercept a | 0.117 | | | 0.443 | |
| Uncertainty of a | 0.681 | | | 0.68 | |
| Expanded meas. uncertainty $W_{CM}$ | 18.51 | % | | 15.51 | % |
| **All comparisons, <18 µg/m³** | | | | | |
| Uncertainty between Reference | 0.51 | µg/m³ | | | |
| Uncertainty between Candidates | 0.32 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 248 | | | 248 | |
| Slope b | 1.152 | | | 1.119 | |
| Uncertainty of b | 0.024 | | | 0.024 | |
| Ordinate intercept a | -0.929 | | | -0.827 | |
| Uncertainty of a | 0.241 | | | 0.239 | |
| Expanded meas. uncertainty $W_{CM}$ | 25.80 | % | | 20.34 | % |
| **All comparisons** | | | | | |
| Uncertainty between Reference | 0.53 | µg/m³ | | | |
| Uncertainty between Candidates | 0.48 | µg/m³ | | | |
| | **SN 0111** | | | **SN 0112** | |
| Number of data pairs | 315 | | | 315 | |
| Slope b | 1.075 | significant | | 1.045 | significant |
| Uncertainty of b | 0.009 | | | 0.009 | |
| Ordinate intercept a | -0.247 | not significant | | -0.154 | not significant |
| Uncertainty of a | 0.146 | | | 0.146 | |
| Expanded meas. uncertainty $W_{CM}$ | 16.71 | % | | 12.75 | % |

The results of the check of the five criteria given in chapter 6.1 Methodology of the equivalence check (modules 5.4.9 – 5.4.11) are as follows:

Criterion 1: More than 20 % of the data are greater than 17 µg/m³.

Criterion 2: The uncertainty between the candidates is less than 2.5 µg/m³.

Criterion 3: The uncertainty between the reference devices is less than 2.0 µg/m³.

Criterion 4: All expanded uncertainties except for the test site Bornheim, summer, are below 25 %.

Criterion 5: For both candidates, the slope is significantly greater than the permissible value for the evaluation of the complete dataset.

Other: For both candidates, the total slope is 1.060 and the intercept is -0.210 at an expanded overall uncertainty of 14.43 % for the complete dataset.

*Table 55: Overview of equivalence test of Fidas® 200 S for $PM_{10}$ (D+UK, PM_ENVIRO_0011)*

| | | | | | |
|---|---|---|---|---|---|
| **Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010** | | | | | |
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 50 | µg/m³ |
| Status of measured values | Raw data | | Allowed uncertainty | 25 | % |
| **All comparisons** | | | | | |
| Uncertainty between Reference | **0.58** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.67** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **316** | | | | |
| Slope b | **1.037** | significant | | | |
| Uncertainty of b | **0.009** | | | | |
| Ordinate intercept a | **-1.390** | significant | | | |
| Uncertainty of a | **0.216** | | | | |
| Expanded measured uncertainty WCM | **7.54** | **%** | | | |
| **All comparisons, ≥30 µg/m³** | | | | | |
| Uncertainty between Reference | **0.68** | **µg/m³** | | | |
| Uncertainty between Candidates | **1.19** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **44** | | | | |
| Slope b | **0.991** | | | | |
| Uncertainty of b | **0.035** | | | | |
| Ordinate intercept a | **0.704** | | | | |
| Uncertainty of a | **1.545** | | | | |
| Expanded measured uncertainty WCM | **10.92** | **%** | | | |
| **All comparisons, <30 µg/m³** | | | | | |
| Uncertainty between Reference | **0.56** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.57** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **272** | | | | |
| Slope b | **1.045** | | | | |
| Uncertainty of b | **0.018** | | | | |
| Ordinate intercept a | **-1.543** | | | | |
| Uncertainty of a | **0.311** | | | | |
| Expanded measured uncertainty WCM | **7.08** | **%** | | | |

| | | | | |
|---|---|---|---|---|
| **Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010** | | | | |
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 |
| | | | Limit value | 50 µg/m³ |
| Status of measured values | Raw data | | Allowed uncertainty | 25 % |
| **Cologne, Summer** | | | | |
| Uncertainty between Reference | 0.80 | µg/m³ | | |
| Uncertainty between Candidates | 0.27 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 81 | | 82 | |
| Slope b | 1.045 | | 1.028 | |
| Uncertainty of b | 0.028 | | 0.028 | |
| Ordinate intercept a | -1.637 | | -1.524 | |
| Uncertainty of a | 0.490 | | 0.489 | |
| Expanded measured uncertainty $W_{CM}$ | 6.98 | % | 6.56 | % |
| **Cologne, Winter** | | | | |
| Uncertainty between Reference | 0.53 | µg/m³ | | |
| Uncertainty between Candidates | 0.67 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 51 | | 50 | |
| Slope b | 1.064 | | 1.027 | |
| Uncertainty of b | 0.015 | | 0.015 | |
| Ordinate intercept a | -1.260 | | -1.284 | |
| Uncertainty of a | 0.399 | | 0.398 | |
| Expanded measured uncertainty $W_{CM}$ | 9.66 | % | 5.53 | % |
| **Bonn** | | | | |
| Uncertainty between Reference | 0.38 | µg/m³ | | |
| Uncertainty between Candidates | 0.90 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 50 | | 50 | |
| Slope b | 1.043 | | 1.004 | |
| Uncertainty of b | 0.027 | | 0.029 | |
| Ordinate intercept a | -0.082 | | 0.061 | |
| Uncertainty of a | 0.821 | | 0.865 | |
| Expanded measured uncertainty $W_{CM}$ | 11.98 | % | 9.29 | % |
| **Bornheim** | | | | |
| Uncertainty between Reference | 0.54 | µg/m³ | | |
| Uncertainty between Candidates | 0.87 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 47 | | 47 | |
| Slope b | 1.128 | | 1.083 | |
| Uncertainty of b | 0.040 | | 0.039 | |
| Ordinate intercept a | -1.986 | | -2.169 | |
| Uncertainty of a | 0.733 | | 0.720 | |
| Expanded measured uncertainty $W_{CM}$ | 19.05 | % | 10.63 | % |
| **Teddington, Winter** | | | | |
| Uncertainty between Reference | 0.48 | µg/m³ | | |
| Uncertainty between Candidates | 0.76 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 44 | | 44 | |
| Slope b | 0.999 | | 0.969 | |
| Uncertainty of b | 0.017 | | 0.016 | |
| Ordinate intercept a | -1.598 | | -1.580 | |
| Uncertainty of a | 0.441 | | 0.420 | |
| Expanded measured uncertainty $W_{CM}$ | 9.16 | % | 13.91 | % |
| **Teddington, Summer** | | | | |
| Uncertainty between Reference | 0.46 | µg/m³ | | |
| Uncertainty between Candidates | 0.56 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 45 | | 45 | |
| Slope b | 0.946 | | 0.944 | |
| Uncertainty of b | 0.029 | | 0.031 | |
| Ordinate intercept a | -0.090 | | -0.502 | |
| Uncertainty of a | 0.474 | | 0.507 | |
| Expanded measured uncertainty $W_{CM}$ | 12.26 | % | 14.26 | % |
| **All comparisons, ≥30 µg/m³** | | | | |
| Uncertainty between Reference | 0.68 | µg/m³ | | |
| Uncertainty between Candidates | 1.19 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 44 | | 44 | |
| Slope b | 1.021 | | 0.964 | |
| Uncertainty of b | 0.036 | | 0.036 | |
| Ordinate intercept a | 0.096 | | 1.252 | |
| Uncertainty of a | 1.574 | | 1.56 | |
| Expanded measured uncertainty $W_{CM}$ | 11.98 | % | 11.20 | % |
| **All comparisons, <30 µg/m³** | | | | |
| Uncertainty between Reference | 0.56 | µg/m³ | | |
| Uncertainty between Candidates | 0.57 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 274 | | 274 | |
| Slope b | 1.064 | | 1.028 | |
| Uncertainty of b | 0.019 | | 0.018 | |
| Ordinate intercept a | -1.597 | | -1.522 | |
| Uncertainty of a | 0.320 | | 0.308 | |
| Expanded measured uncertainty $W_{CM}$ | 9.38 | % | 6.49 | % |
| **All comparisons** | | | | |
| Uncertainty between Reference | 0.58 | µg/m³ | | |
| Uncertainty between Candidates | 0.67 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 318 | | 318 | |
| Slope b | 1.054 | significant | 1.020 | significant |
| Uncertainty of b | 0.010 | | 0.010 | |
| Ordinate intercept a | -1.420 | significant | -1.355 | significant |
| Uncertainty of a | 0.220 | | 0.216 | |
| Expanded measured uncertainty $W_{CM}$ | 9.13 | % | 7.47 | % |

The results of the check of the five criteria given in chapter 6.1 Methodology of the equivalence check (modules 5.4.9 – 5.4.11) are as follows:

Criterion 1: More than 20 % of the data are greater than 28 µg/m³.

Criterion 2: The uncertainty between the candidates is less than 2.5 µg/m³.

Criterion 3: The uncertainty between the reference devices is less than 2.0 µg/m³.

Criterion 4: All of the expanded uncertainties are below 25 %.

Criterion 5: For both candidates, the slope and the intercept are significantly greater than the permissible value for the evaluation of the complete dataset.

Other: For both candidates, the total slope is 1.037 and the intercept is -1.390 at an expanded overall uncertainty of 7.54 % for the complete dataset.

The January 2010 version of the Guide is ambiguous with respect to which slope and which intercept should be used to correct a candidate should it fail the test of equivalence. After consultation with the convenor (Mr Theo Hafkenscheid) of the EC working group responsible for setting up the Guide, it was decided that the requirements of the November 2005 version of the Guide are still valid, and that the slope and intercept from the orthogonal regression of all the paired data be used. These are stated additionally under "Other" in the above.

The 2006 UK Equivalence Report [10] has highlighted this was a flaw in the mathematics required for equivalence as per the November 2005 version of the Guide as it penalised instruments that were more accurate (Annex E Section 4.2 therein). This same flaw is copied in the January 2010 version. Hence, the Fidas® 200 S measuring system for $PM_{2.5}$ and $PM_{10}$ is indeed being penalised by the mathematics for being accurate. It is proposed that the same pragmatic approach is taken here that was previously undertaken in earlier studies.

Therefore, according to Table 54, the slope has to be corrected for $PM_{2.5}$ due to its determined significance for both candidates and the exceeded measurement uncertainty at the test site Bornheim, summer. For $PM_{10}$, the slope and the intercept have to be corrected due to their significance according to Table 55.

Nonetheless it should be noted that, even without application of correction factors, the determined uncertainties $W_{CM}$ for $PM_{10}$ are below the specified expanded relative uncertainty $W_{dqo}$ of 25 % for particulate matter for all datasets considered.

For $PM_{2.5}$:

The slope for the complete dataset is 1.060. Thus, an additional evaluation applying the respective calibration factor to the datasets is made in chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK).

For $PM_{10}$:

The slope for the complete dataset is 1.037. The intercept for the complete data set is -1.390. Thus, an additional evaluation applying the respective calibration factors to the datasets is made in chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK).

The revised January 2010 version of the Guide requires that, in order to monitor the processes in compliance with the guidelines, random checks shall be performed on a number of systems within a measuring network and that the number of measuring sites shall depend on the expanded uncertainty of the system. Either the network operator or the responsible authority of the member state is responsible for the appropriate realisation of the requirement mentioned above. However, TÜV Rheinland recommends that the expanded uncertainty for the complete dataset (here: uncorrected raw data) shall be referred to, i.e. 14.43 % for $PM_{2.5}$, which would require annual checks at 3 sites, and 7.54 %, for $PM_{10}$, which would require annual checks a 2 sites (Guide [5], Chapter 9.9.2, Table 6). Due to the necessary application of the corresponding calibration factors, this assessment should be made on the basis of the evaluation of the corrected datasets (refer to chapter 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK)).

## 7.6 Detailed presentation of test results

Table 56 and Table 57 present an overview of the uncertainties between the reference devices $u_{ref}$ obtained in the field tests.

*Table 56: Uncertainty between reference devices $u_{ref}$ for $PM_{2.5}$*

| **Reference devices** | **Test site** | **No. of values** | **Uncertainty $u_{bs}$** |
|---|---|---|---|
| No. | | | µg/m³ |
| 1 / 2 | Cologne, summer | 82 | 0.66 |
| 1 / 2 | Cologne, winter | 52 | 0.54 |
| 1 / 2 | Bonn, winter | 50 | 0.62 |
| 1 / 2 | Bornheim, summer | 47 | 0.42 |
| 1 / 2 | Teddington, winter | 44 | 0.42 |
| 1 / 2 | Teddington, summer | 44 | 0.25 |
| 1 / 2 | All test sites | 319 | 0.53 |

*Table 57: Uncertainty between reference devices $u_{ref}$ for $PM_{10}$*

| **Reference devices** | **Test site** | **No. of values** | **Uncertainty $u_{bs}$** |
|---|---|---|---|
| Nr. | | | µg/m³ |
| 1 / 2 | Cologne, summer | 82 | 0.80 |
| 1 / 2 | Cologne, winter | 52 | 0.53 |
| 1 / 2 | Bonn, winter | 50 | 0.38 |
| 1 / 2 | Bornheim, summer | 49 | 0.54 |
| 1 / 2 | Teddington, winter | 44 | 0.48 |
| 1 / 2 | Teddington, summer | 45 | 0.46 |
| 1 / 2 | All test sites | 322 | 0.58 |

The uncertainty between the reference devices $u_{ref}$ is < 2 µg/m³ for all test sites.

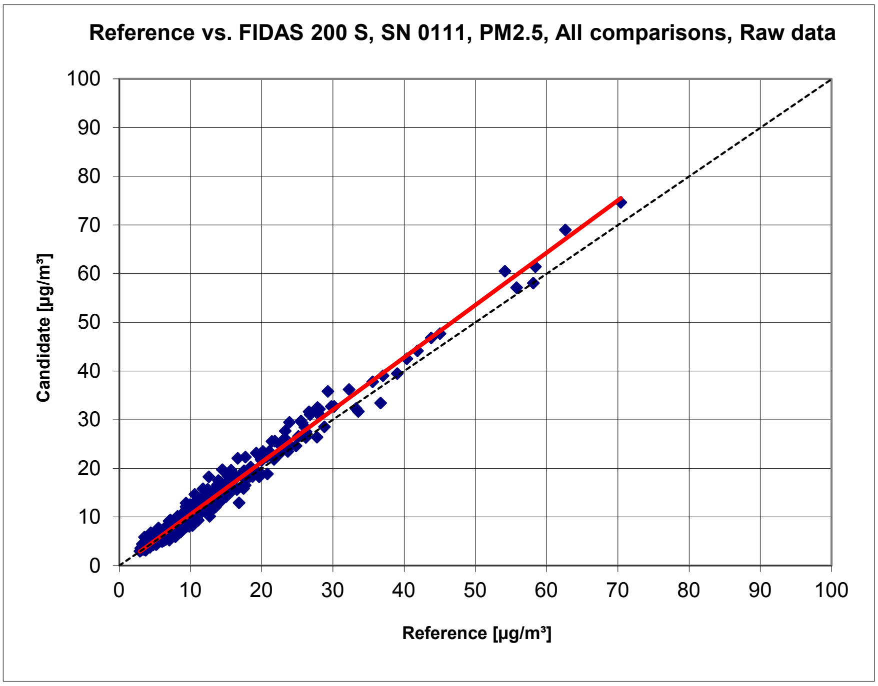



*Figure 112: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, all test sites (GER+UK), PM_ENVIRO_0011*

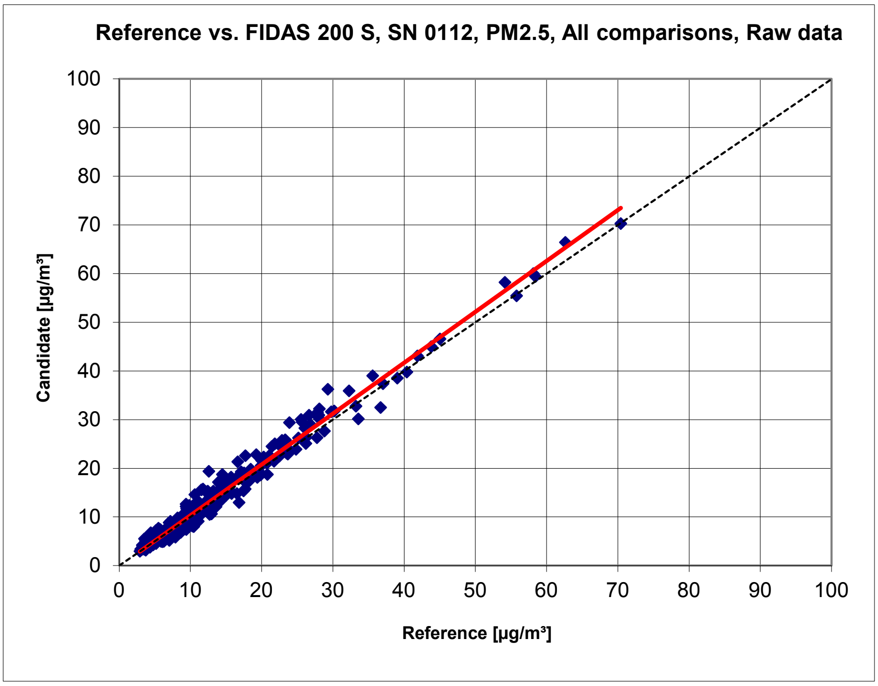



*Figure 113: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, all test sites (GER+UK), PM_ENVIRO_0011*

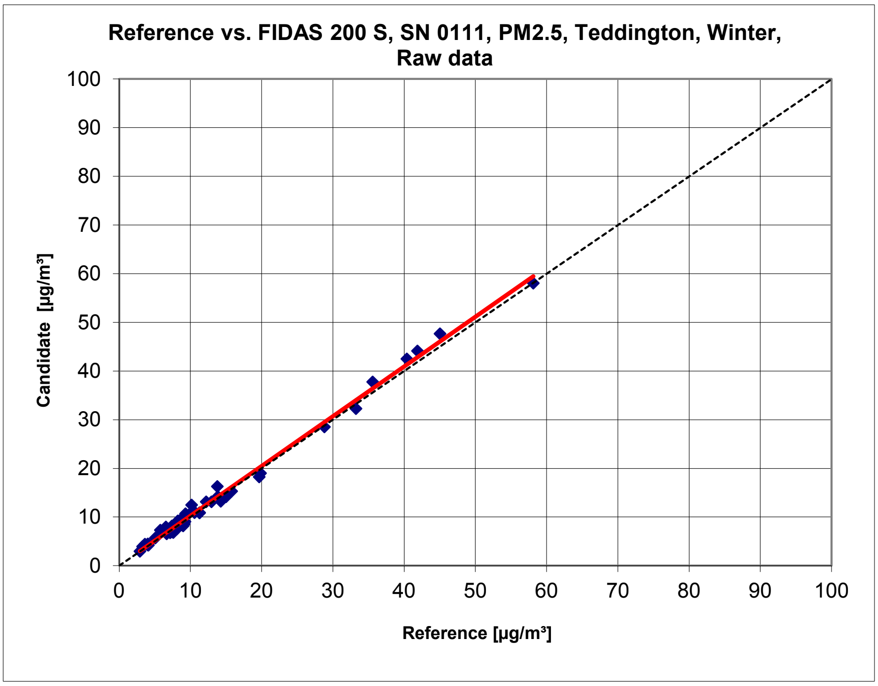



*Figure 114: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Teddington, winter, PM_ENVIRO_0011*

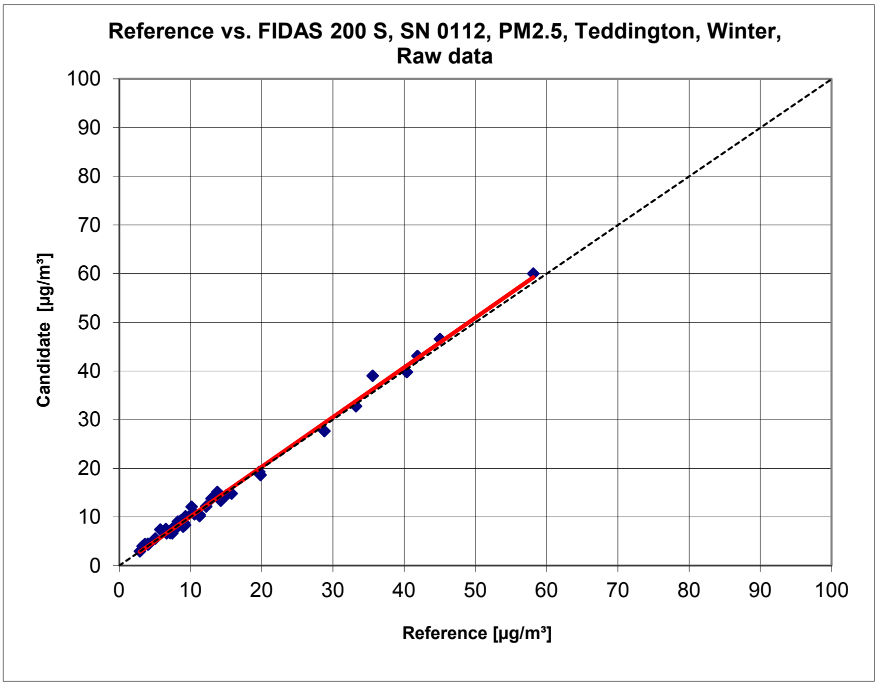



*Figure 115: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Teddington, winter, PM_ENVIRO_0011*

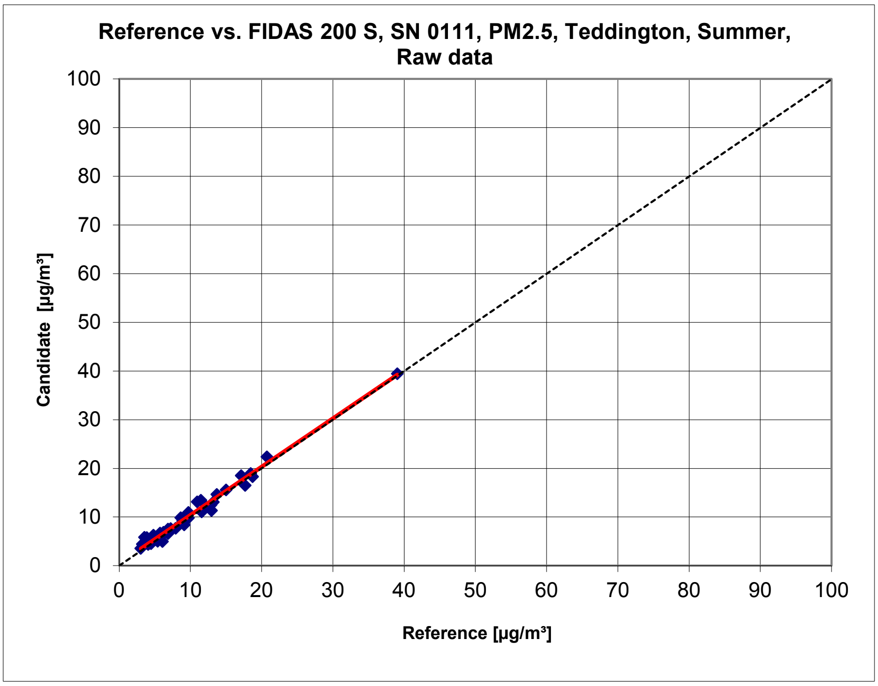



*Figure 116: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, Teddington, summer, PM_ENVIRO_0011*

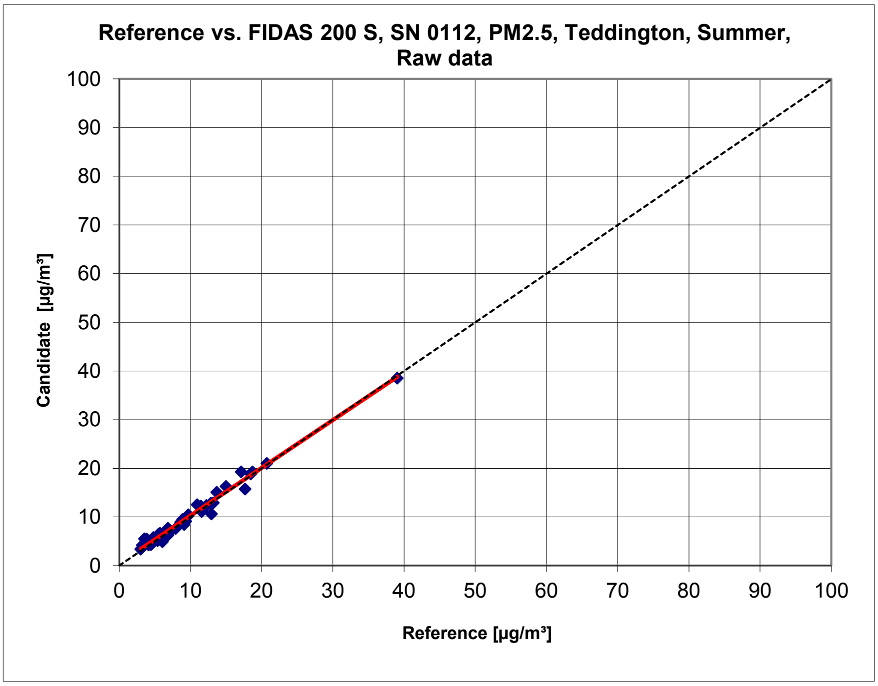



*Figure 117: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, Teddington, summer, PM_ENVIRO_0011*

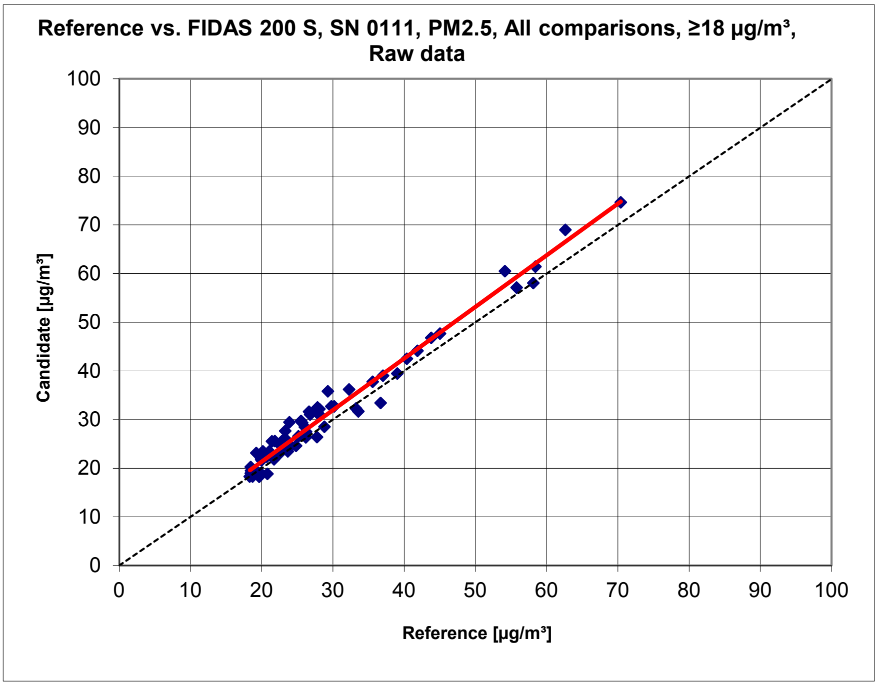



*Figure 118: Reference device vs. candidate, SN 0111, measured component $PM_{2.5}$, values ≥ 18 µg/m³ (GER+UK), PM_ENVIRO_0011*

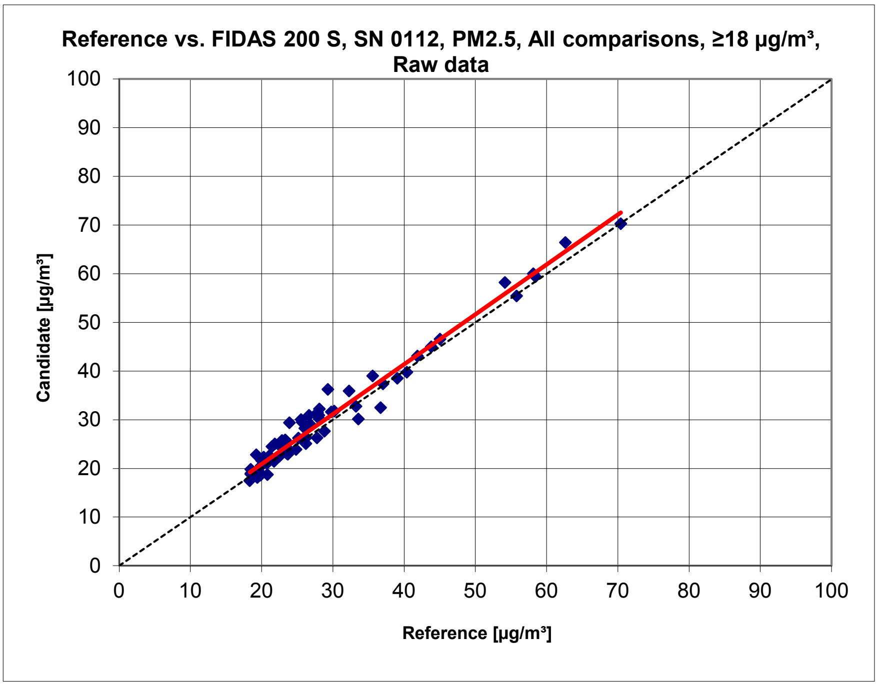



*Figure 119: Reference device vs. candidate, SN 0112, measured component $PM_{2.5}$, values ≥ 18 µg/m³ (GER+UK), PM_ENVIRO_0011*

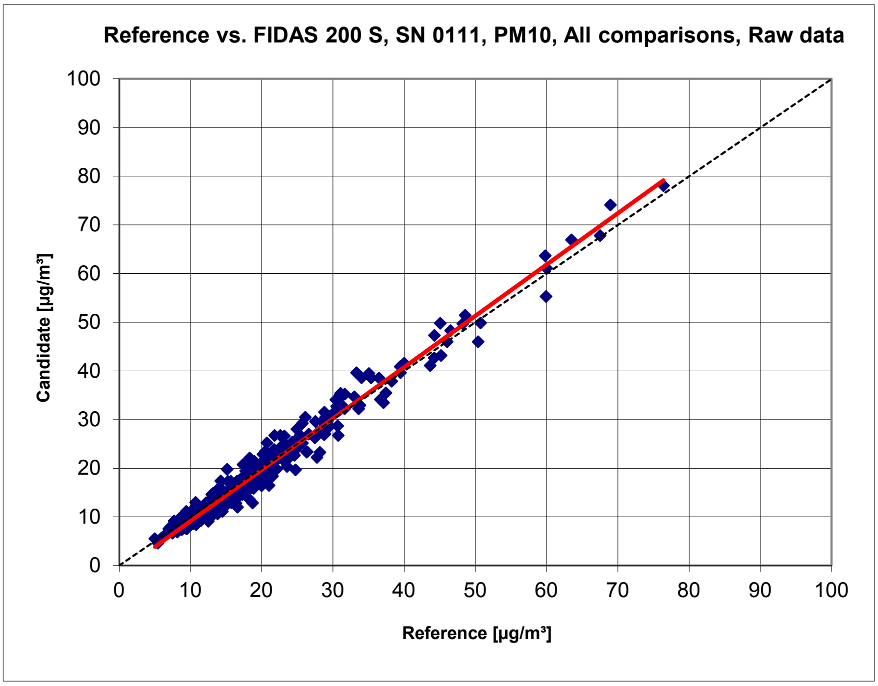



*Figure 120: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, all test sites (GER+UK), PM_ENVIRO_0011*

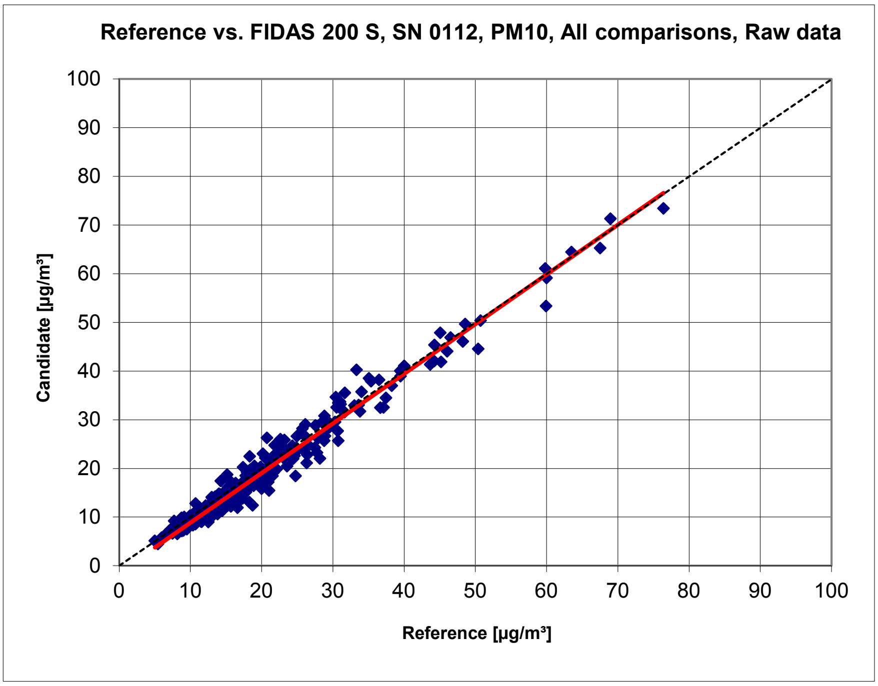



*Figure 121: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, all test sites (GER+UK), PM_ENVIRO_0011*

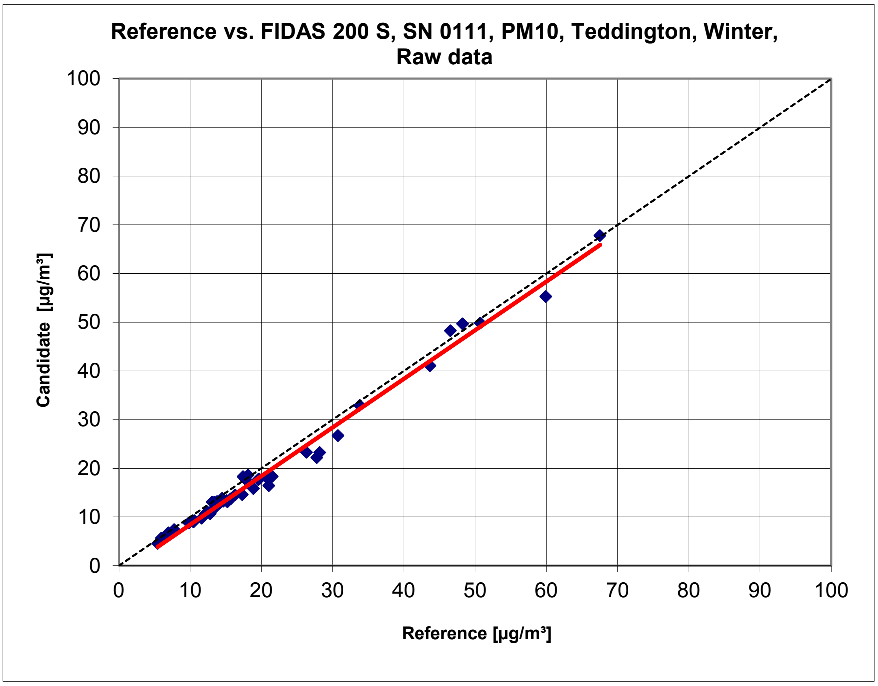



*Figure 122: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, Teddington, winter, PM_ENVIRO_0011*

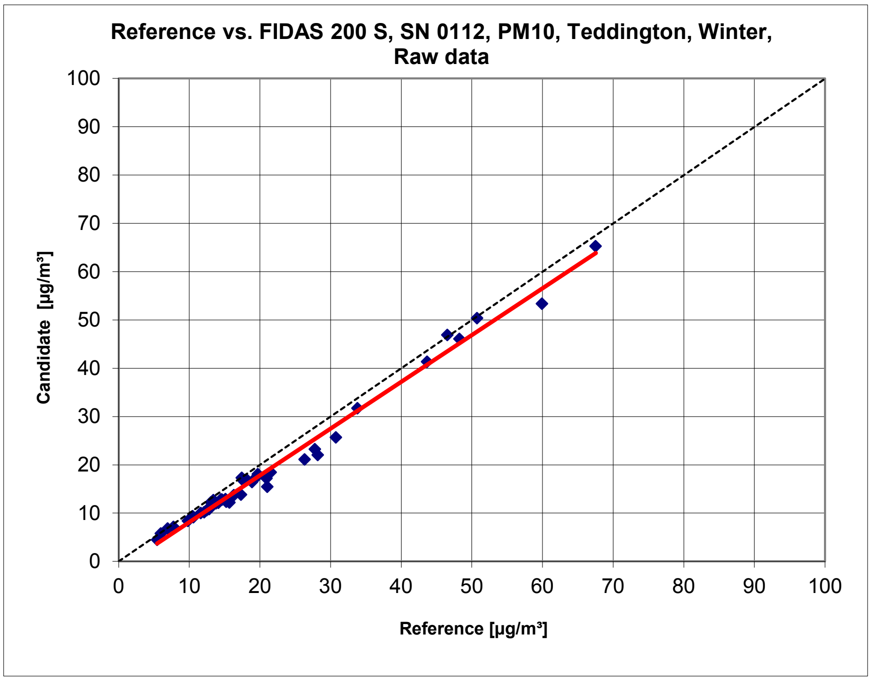



*Figure 123: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, Teddington, winter, PM_ENVIRO_0011*

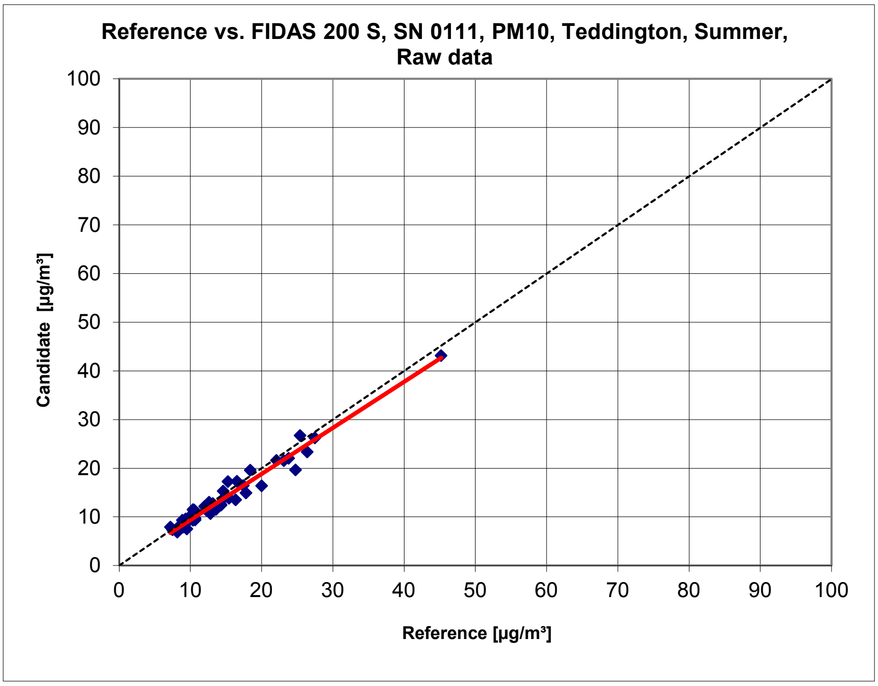



*Figure 124: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, Teddington, summer, PM_ENVIRO_0011*

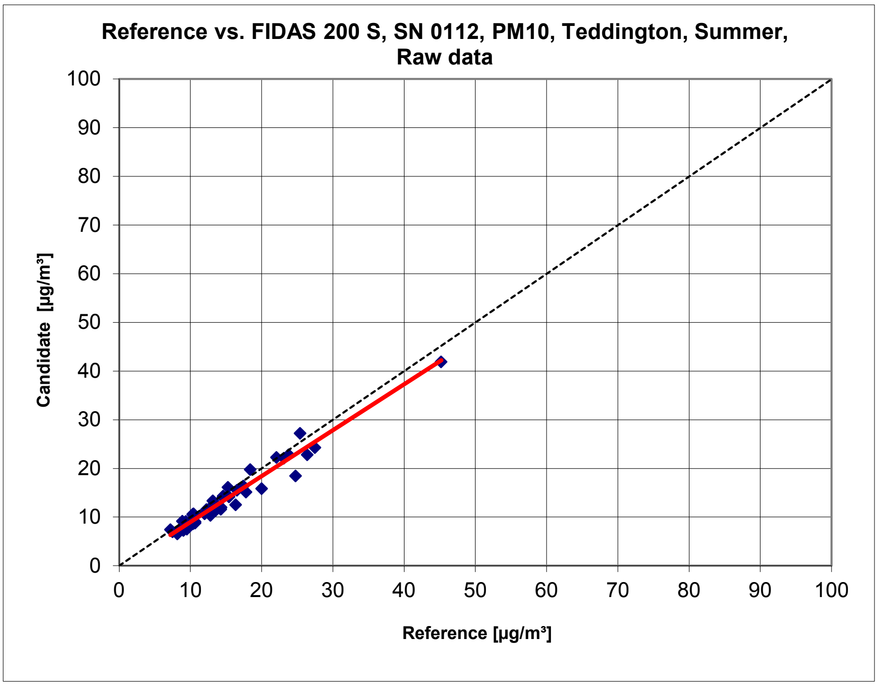



*Figure 125: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, Teddington, summer, PM_ENVIRO_0011*

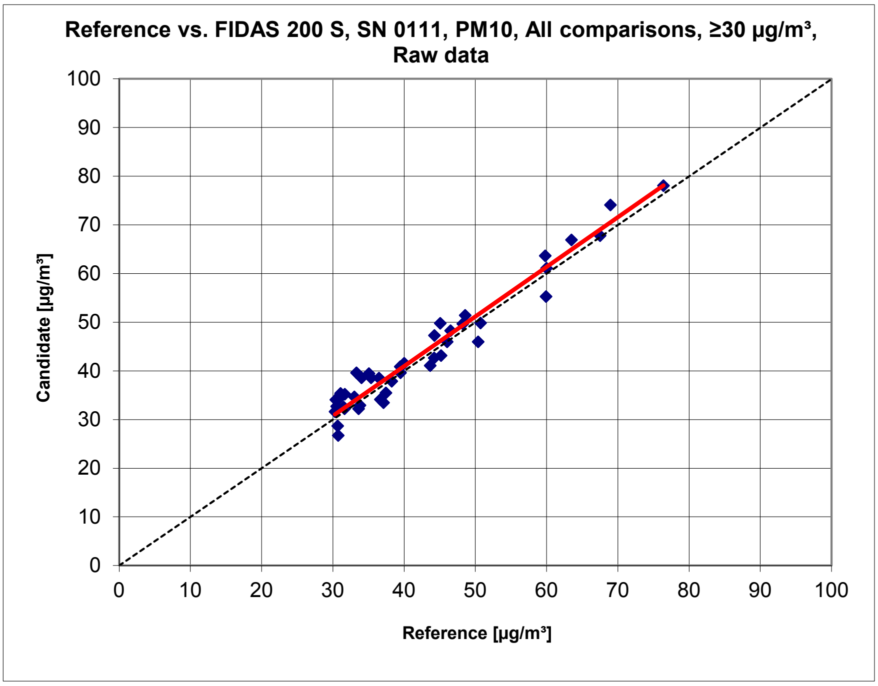



*Figure 126: Reference device vs. candidate, SN 0111, measured component $PM_{10}$, values ≥ 30 µg/m³ (GER+UK), PM_ENVIRO_0011*

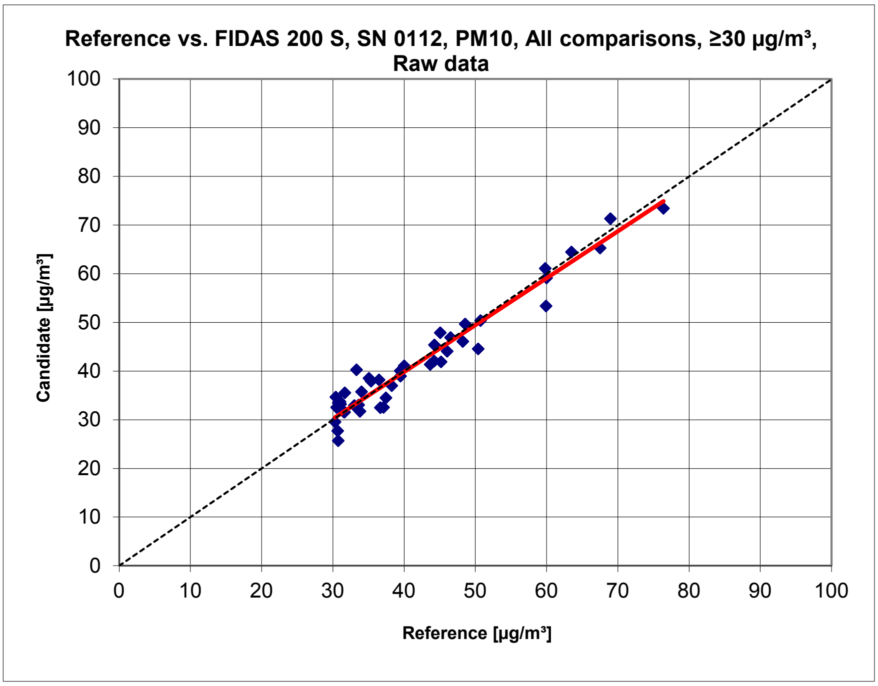



*Figure 127: Reference device vs. candidate, SN 0112, measured component $PM_{10}$, values ≥ 30 µg/m³ (GER+UK), PM_ENVIRO_0011*

## 7.1 5.4.11 Application of correction factors and terms (PM_ENVIRO_0011, GER+UK)

*If the maximum expanded uncertainty of the systems under test exceeds the data quality objectives according to Annex B of Standard VDI 4202, Sheet 1 (September 2010) for the test of $PM_{2.5}$ measuring systems, the application of factors and terms is allowed. Values corrected shall meet the requirements of chapter 9.5.3.2ff of the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods".*

*The tests were also carried out for the component $PM_{10}$.*

## 7.2 Equipment

No equipment is necessary to test this performance criterion.

## 7.3 Method

Refer to module 5.4.10.

## 7.4 Evaluation

If evaluation of the raw data according to module 5.4.10 leads to a case where $W_{CM} > W_{dqo}$, which means that the candidate systems is not regarded equivalent to the reference method, it is permitted to apply a correction factor or term resulting from the regression equation obtained from the complete dataset. The corrected values shall satisfy the requirements for all datasets or subsets (refer to module 5.4.10). Moreover, a correction factor may be applied even for $W_{CM} \leq W_{dqo}$ in order to improve the accuracy of the candidate systems.

Three different cases may occur:

a) Slope b not significantly different from 1: $|b-1| \leq 2u(b)$,
   intercept a significantly different from 0: $|a| > 2u(a)$

b) Slope b significantly different from 1: $|b-1| > 2u(b)$,
   intercept a not significantly different from 0: $|a| \leq 2u(a)$

c) Slope b significantly different from 1: $|b-1| > 2u(b)$
   intercept a significantly different from 0: $|a| > 2u(a)$

With respect to a)

The value of the intercept a may be used as a correction term to correct all input values $y_i$ according to the following equation.

$$y_{i,corr} = y_i - a$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u^2_{c\_s}(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + u^2(a)$$

with u(a) = uncertainty of the original intercept a, the value of which has been used to obtain $y_{i,corr}$.

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in annex B of [4]. RSS is determined analogue to the calculation in module 5.4.10.

With respect to b)

The value of the slope b may be used as a term to correct all input values $y_i$ according to the following equation.

$$y_{i,corr} = \frac{y_i}{b}$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u^2_{c\_s}(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + x_i^2 u^2(b)$$

with u(b) = uncertainty of the original slope b, the value of which has been used to obtain $y_{i,corr}$.

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in annex B of [4]. RSS is determined analogue to the calculation in module 5.4.10.

With respect to c)

The values of the slope b and of the intercept a may be used as correction terms to correct all input values $y_i$ according to the following equation.

$$y_{i,corr} = \frac{y_i - a}{b}$$

The resulting values of $y_{i,corr}$ may then be used to calculate the following new terms by linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u_{c\_s}^2(y_{i,corr}) = \frac{RSS}{(n-2)} - u^2(x_i) + [c + (d-1)x_i]^2 + x_i^2 u^2(b) + u^2(a)$$

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. $W_{CM} \leq W_{dqo} \rightarrow$ Candidate method is accepted as equivalent to the standard method.

2. $W_{CM} > W_{dqo} \rightarrow$ Candidate method is not accepted as equivalent to the standard method.

The specified expanded relative uncertainty $W_{dqo}$ for particulate matter is 25 % [8].

## 7.5 Assessment

Due to application of the correction factors, the candidates meet the requirements on data quality of ambient air quality measurements for all datasets for $PM_{2.5}$ and $PM_{10}$. For $PM_{10}$, the requirements are met even without application of correction factors. The corrections of slope and intercept nevertheless lead to a (slight) improvement of the expanded measurement uncertainties of the complete data set.

Performance criterion met? yes

The evaluation of the complete dataset for $PM_{2.5}$ shows a significant slope and for $PM_{10}$ a significant slope and intercept.

For $PM_{2.5}$:

The slope for the complete dataset is 1.060. The intercept for the complete dataset is -0.210 (refer to Table 54).

For $PM_{10}$:

The slope for the complete dataset is 1.037. The intercept for the complete dataset -1.390 (refer to Table 55).

For $PM_{2.5}$, a slope correction for the complete data set has been performed and all datasets were then re-evaluated using the corrected values.

For $PM_{10}$, a slope and a intercept correction for the complete data set has been performed and all datasets were then re-evaluated using the corrected values.

After correction, all datasets fulfil the requirements on data quality and the measurement uncertainties improve significantly for some of the sites.

The January 2010 version of the Guide requires that the systems are tested annually at a number of sites corresponding to the highest expanded uncertainty found during equivalence testing, if the AMS is operated within a network. The corresponding criterion for determining the number of test sites is divided into 5 % steps (Guide [4], chapter 9.9.2, Table 6). It should be noted that the highest expanded uncertainty determined for $PM_{2.5}$ lies in the range of <10 % after correction whereas it has been in the range of 10 % to 15 % before the correction. For $PM_{10}$, the highest expanded uncertainty determined lies in the range of <10 % before as well as after the correction.

The network operator or the responsible authority of the member state is responsible for the appropriate realisation of the required regular checks in networks mentioned above. However, TÜV Rheinland recommends to use the expanded uncertainty for the complete dataset, i.e. 14.43 % for $PM_{2.5}$: (uncorrected dataset) respectively 9.35 % (dataset after slope correction), which would require an annual test at 3 measurement sites (uncorrected) or 2 measurement sites (corrected); for $PM_{10}$: 7.54 % (uncorrected dataset) respectively 7.33 % (dataset after slope and intercept correction), which would require an annual test at 2 measurement sites (uncorrected and corrected).

## 7.6 Detailed presentation of test results

Table 58 and Table 59 present the results of the evaluations of the equivalence test after application of the correction factors on the complete dataset.

*Table 58: Summary of the results of the equivalence test, SN 0111 & SN 0112, measured component $PM_{2.5}$ after correction of slope, GER+UK, PM_ENVIRO_0011*

| Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010 | | | | |
|---|---|---|---|---|
| Candidate | FIDAS 200 S | SN | SN 0111 & SN 0112 | |
| | | Limit value | 30 | µg/m³ |
| Status of measured values | Slope corrected | Allowed uncertainty | 25 | % |
| | | | | |
| **All comparisons** | | | | |
| Uncertainty between Reference | **0.53** | **µg/m³** | | |
| Uncertainty between Candidates | **0.45** | **µg/m³** | | |
| | **SN 0111 & SN 0112** | | | |
| Number of data pairs | **313** | | | |
| Slope b | **0.999** | **not significant** | | |
| Uncertainty of b | **0.008** | | | |
| Ordinate intercept a | **-0.190** | **not significant** | | |
| Uncertainty of a | **0.136** | | | |
| Expanded meas. uncertainty $W_{CM}$ | **9.35** | **%** | | |
| **All comparisons, ≥18 µg/m³** | | | | |
| Uncertainty between Reference | **0.60** | **µg/m³** | | |
| Uncertainty between Candidates | **0.80** | **µg/m³** | | |
| | **SN 0111 & SN 0112** | | | |
| Number of data pairs | **67** | | | |
| Slope b | **0.981** | | | |
| Uncertainty of b | **0.020** | | | |
| Ordinate intercept a | **0.306** | | | |
| Uncertainty of a | **0.630** | | | |
| Expanded meas. uncertainty $W_{CM}$ | **12.51** | **%** | | |
| **All comparisons, <18 µg/m³** | | | | |
| Uncertainty between Reference | **0.51** | **µg/m³** | | |
| Uncertainty between Candidates | **0.31** | **µg/m³** | | |
| | **SN 0111 & SN 0112** | | | |
| Number of data pairs | **246** | | | |
| Slope b | **1.065** | | | |
| Uncertainty of b | **0.023** | | | |
| Ordinate intercept a | **-0.782** | | | |
| Uncertainty of a | **0.224** | | | |
| Expanded meas. uncertainty $W_{CM}$ | **11.34** | **%** | | |

| Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010 | | | | |
|---|---|---|---|---|
| Candidate | FIDAS 200 S | SN | SN 0111 & SN 0112 | |
| | | Limit value | 30 | µg/m³ |
| Status of measured values | Slope corrected | Allowed uncertainty | 25 | % |
| **Cologne, Summer** | | | | |
| Uncertainty between Reference | 0.66 | µg/m³ | | |
| Uncertainty between Candidates | 0.11 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 81 | | 82 | |
| Slope b | 1.053 | | 1.050 | |
| Uncertainty of b | 0.032 | | 0.033 | |
| Ordinate intercept a | -0.850 | | -0.810 | |
| Uncertainty of a | 0.342 | | 0.357 | |
| Expanded meas. uncertainty $W_{CM}$ | 10.46 | % | 10.77 | % |
| **Cologne, Winter** | | | | |
| Uncertainty between Reference | 0.54 | µg/m³ | | |
| Uncertainty between Candidates | 0.52 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 51 | | 50 | |
| Slope b | 0.991 | | 0.956 | |
| Uncertainty of b | 0.013 | | 0.013 | |
| Ordinate intercept a | 0.656 | | 0.645 | |
| Uncertainty of a | 0.296 | | 0.307 | |
| Expanded meas. uncertainty $W_{CM}$ | 8.50 | % | 9.43 | % |
| **Bonn** | | | | |
| Uncertainty between Reference | 0.62 | µg/m³ | | |
| Uncertainty between Candidates | 0.66 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 50 | | 50 | |
| Slope b | 1.050 | | 1.008 | |
| Uncertainty of b | 0.024 | | 0.026 | |
| Ordinate intercept a | -0.723 | | -0.471 | |
| Uncertainty of a | 0.539 | | 0.584 | |
| Expanded meas. uncertainty $W_{CM}$ | 12.32 | % | 12.33 | % |
| **Bornheim** | | | | |
| Uncertainty between Reference | 0.42 | µg/m³ | | |
| Uncertainty between Candidates | 0.47 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 45 | | 45 | |
| Slope b | 1.142 | | 1.115 | |
| Uncertainty of b | 0.051 | | 0.050 | |
| Ordinate intercept a | -1.370 | | -1.482 | |
| Uncertainty of a | 0.607 | | 0.607 | |
| Expanded meas. uncertainty $W_{CM}$ | 22.40 | % | 17.49 | % |
| **Teddington, Winter** | | | | |
| Uncertainty between Reference | 0.42 | µg/m³ | | |
| Uncertainty between Candidates | 0.52 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 44 | | 44 | |
| Slope b | 0.964 | | 0.963 | |
| Uncertainty of b | 0.012 | | 0.011 | |
| Ordinate intercept a | -0.004 | | -0.143 | |
| Uncertainty of a | 0.223 | | 0.208 | |
| Expanded meas. uncertainty $W_{CM}$ | 9.46 | % | 10.01 | % |
| **Teddington, Summer** | | | | |
| Uncertainty between Reference | 0.25 | µg/m³ | | |
| Uncertainty between Candidates | 0.35 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 44 | | 44 | |
| Slope b | 0.934 | | 0.926 | |
| Uncertainty of b | 0.020 | | 0.020 | |
| Ordinate intercept a | 0.461 | | 0.399 | |
| Uncertainty of a | 0.232 | | 0.229 | |
| Expanded meas. uncertainty $W_{CM}$ | 11.50 | % | 13.40 | % |
| **All comparisons, ≥18 µg/m³** | | | | |
| Uncertainty between Reference | 0.60 | µg/m³ | | |
| Uncertainty between Candidates | 0.80 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 67 | | 67 | |
| Slope b | 0.999 | | 0.965 | |
| Uncertainty of b | 0.020 | | 0.021 | |
| Ordinate intercept a | 0.134 | | 0.443 | |
| Uncertainty of a | 0.642 | | 0.65 | |
| Expanded meas. uncertainty $W_{CM}$ | 12.67 | % | 13.39 | % |
| **All comparisons, <18 µg/m³** | | | | |
| Uncertainty between Reference | 0.51 | µg/m³ | | |
| Uncertainty between Candidates | 0.31 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 248 | | 248 | |
| Slope b | 1.083 | | 1.052 | |
| Uncertainty of b | 0.023 | | 0.023 | |
| Ordinate intercept a | -0.841 | | -0.744 | |
| Uncertainty of a | 0.227 | | 0.226 | |
| Expanded meas. uncertainty $W_{CM}$ | 13.84 | % | 9.97 | % |
| **All comparisons** | | | | |
| Uncertainty between Reference | 0.53 | µg/m³ | | |
| Uncertainty between Candidates | 0.45 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 315 | | 315 | |
| Slope b | 1.014 | not significant | 0.985 | not significant |
| Uncertainty of b | 0.008 | | 0.008 | |
| Ordinate intercept a | -0.225 | not significant | -0.137 | not significant |
| Uncertainty of a | 0.137 | | 0.137 | |
| Expanded meas. uncertainty $W_{CM}$ | 9.50 | % | 10.17 | % |

*Table 59: Summary of the results of the equivalence test, SN 0111 & SN 0112, measured component $PM_{10}$ after correction of slope & intercept, GER+UK, PM_ENVIRO_0011*

| Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 50 | µg/m³ |
| Status of measured values | Slope & offset corrected | | Allowed uncertainty | 25 | % |
| | | | | | |
| **All comparisons** | | | | | |
| Uncertainty between Reference | **0.58** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.65** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **316** | | | | |
| Slope b | **1.000** | **not significant** | | | |
| Uncertainty of b | **0.009** | | | | |
| Ordinate intercept a | **0.010** | **not significant** | | | |
| Uncertainty of a | **0.208** | | | | |
| Expanded measured uncertainty WCM | **7.33** | **%** | | | |
| **All comparisons, ≥30 µg/m³** | | | | | |
| Uncertainty between Reference | **0.68** | **µg/m³** | | | |
| Uncertainty between Candidates | **1.15** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **44** | | | | |
| Slope b | **0.955** | | | | |
| Uncertainty of b | **0.034** | | | | |
| Ordinate intercept a | **2.060** | | | | |
| Uncertainty of a | **1.490** | | | | |
| Expanded measured uncertainty WCM | **10.68** | **%** | | | |
| **All comparisons, <30 µg/m³** | | | | | |
| Uncertainty between Reference | **0.56** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.55** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **272** | | | | |
| Slope b | **1.006** | | | | |
| Uncertainty of b | **0.018** | | | | |
| Ordinate intercept a | **-0.122** | | | | |
| Uncertainty of a | **0.300** | | | | |
| Expanded measured uncertainty WCM | **6.63** | **%** | | | |

| Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 50 | µg/m³ |
| Status of measured values | Slope & offset corrected | | Allowed uncertainty | 25 | % |
| **Cologne, Summer** | | | | | |
| Uncertainty between Reference | 0.80 | µg/m³ | | | |
| Uncertainty between Candidates | 0.26 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 81 | | | 82 | |
| Slope b | 1.007 | | | 0.990 | |
| Uncertainty of b | 0.027 | | | 0.027 | |
| Ordinate intercept a | -0.221 | | | -0.112 | |
| Uncertainty of a | 0.473 | | | 0.471 | |
| Expanded measured uncertainty $W_{CM}$ | 6.59 | % | | 7.00 | % |
| **Cologne, Winter** | | | | | |
| Uncertainty between Reference | 0.53 | µg/m³ | | | |
| Uncertainty between Candidates | 0.64 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 51 | | | 50 | |
| Slope b | 1.026 | | | 0.990 | |
| Uncertainty of b | 0.014 | | | 0.014 | |
| Ordinate intercept a | 0.130 | | | 0.107 | |
| Uncertainty of a | 0.385 | | | 0.384 | |
| Expanded measured uncertainty $W_{CM}$ | 8.19 | % | | 5.89 | % |
| **Bonn** | | | | | |
| Uncertainty between Reference | 0.38 | µg/m³ | | | |
| Uncertainty between Candidates | 0.87 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 50 | | | 50 | |
| Slope b | 1.005 | | | 0.968 | |
| Uncertainty of b | 0.026 | | | 0.028 | |
| Ordinate intercept a | 1.279 | | | 1.419 | |
| Uncertainty of a | 0.792 | | | 0.834 | |
| Expanded measured uncertainty $W_{CM}$ | 10.60 | % | | 9.15 | % |
| **Bornheim** | | | | | |
| Uncertainty between Reference | 0.54 | µg/m³ | | | |
| Uncertainty between Candidates | 0.84 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 47 | | | 47 | |
| Slope b | 1.086 | | | 1.043 | |
| Uncertainty of b | 0.038 | | | 0.038 | |
| Ordinate intercept a | -0.555 | | | -0.731 | |
| Uncertainty of a | 0.707 | | | 0.694 | |
| Expanded measured uncertainty $W_{CM}$ | 16.74 | % | | 9.15 | % |
| **Teddington, Winter** | | | | | |
| Uncertainty between Reference | 0.48 | µg/m³ | | | |
| Uncertainty between Candidates | 0.73 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 44 | | | 44 | |
| Slope b | 0.963 | | | 0.934 | |
| Uncertainty of b | 0.017 | | | 0.016 | |
| Ordinate intercept a | -0.195 | | | -0.179 | |
| Uncertainty of a | 0.426 | | | 0.405 | |
| Expanded measured uncertainty $W_{CM}$ | 10.41 | % | | 15.18 | % |
| **Teddington, Summer** | | | | | |
| Uncertainty between Reference | 0.46 | µg/m³ | | | |
| Uncertainty between Candidates | 0.54 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 45 | | | 45 | |
| Slope b | 0.912 | | | 0.910 | |
| Uncertainty of b | 0.028 | | | 0.029 | |
| Ordinate intercept a | 1.264 | | | 0.868 | |
| Uncertainty of a | 0.457 | | | 0.489 | |
| Expanded measured uncertainty $W_{CM}$ | 13.68 | % | | 15.62 | % |
| **All comparisons, ≥30 µg/m³** | | | | | |
| Uncertainty between Reference | 0.68 | µg/m³ | | | |
| Uncertainty between Candidates | 1.15 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 44 | | | 44 | |
| Slope b | 0.983 | | | 0.928 | |
| Uncertainty of b | 0.035 | | | 0.034 | |
| Ordinate intercept a | 1.474 | | | 2.590 | |
| Uncertainty of a | 1.518 | | | 1.50 | |
| Expanded measured uncertainty $W_{CM}$ | 11.17 | % | | 11.47 | % |
| **All comparisons, <30 µg/m³** | | | | | |
| Uncertainty between Reference | 0.56 | µg/m³ | | | |
| Uncertainty between Candidates | 0.55 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 274 | | | 274 | |
| Slope b | 1.025 | | | 0.990 | |
| Uncertainty of b | 0.018 | | | 0.017 | |
| Ordinate intercept a | -0.172 | | | -0.102 | |
| Uncertainty of a | 0.308 | | | 0.297 | |
| Expanded measured uncertainty $W_{CM}$ | 8.05 | % | | 6.99 | % |
| **All comparisons** | | | | | |
| Uncertainty between Reference | 0.58 | µg/m³ | | | |
| Uncertainty between Candidates | 0.65 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 318 | | | 318 | |
| Slope b | 1.016 | not significant | | 0.983 | not significant |
| Uncertainty of b | 0.009 | | | 0.009 | |
| Ordinate intercept a | -0.019 | not significant | | 0.043 | not significant |
| Uncertainty of a | 0.212 | | | 0.209 | |
| Expanded measured uncertainty $W_{CM}$ | 8.16 | % | | 8.01 | % |

# 8. Description of instrument modifications based on the statement of 27 September 2014

## 8.1 Qualification of the indoor version Fidas® 200

The measuring system Fidas® 200 S is designed for outdoor installation. This means, that the Fidas® control unit (incl. the aerosol sensor) is installed in a weatherproof cabinet (IP65, with heating and ventilation).

In order to increase the application range of the measuring system, an indoor version with the designation Fidas® 200 shall be approved, which can be installed directly in measuring stations / cabinets. For this instrument version, the weatherproof cabinet is obsolete - apart from that the measuring system is identical in construction with the version Fidas® 200 S.

In order to quantify possible influences of ambient temperature on the indoor version Fidas® 200, a new climate chamber test has been carried out with two complete measuring systems in the range of +5 °C to +40 °C. All test results fulfill the respective minimum requirements without problems. Based on the available documentation (Statement of TÜV Rheinland of 27 September 2014), the publication of the issue (Approval of indoor version Fidas® 200 as an additional instrument version) has been recommended during the 35th expert meeting “Test reports”. The official announcement in the Federal Gazette “Bundesanzeiger” has happened with announcement of Federal Environment Agency UBA of 25 February 2015 (BAnz AT 02.04.2015 B15, chapter IV, 14th notification).

**Technical documentation on the Qualification of the indoor version Fidas® 200**

The measuring system Fidas® 200 S is designed for outdoor installation. This means, that the Fidas® control unit (incl. the aerosol sensor) is installed in a weatherproof cabinet (IP65, with heating and ventilation).

In order to increase the application range of the measuring system, an indoor version with the designation Fidas® 200 shall be approved, which can be installed directly in measuring stations / cabinets. For this instrument version, the weatherproof cabinet is obsolete - apart from that the measuring system is identical in construction with the version Fidas® 200 S.

In order to quantify possible influences of ambient temperature on the indoor version Fidas® 200, a new climate chamber test has been carried out with two complete measuring systems in the range of +5 °C to +40 °C.

In order to test the dependence of zero point and measured values on the surrounding temperature, the complete measuring systems were operated within a climatic chamber (refer to Figure 128).

*Figure 128: Candidates Fidas® 200 in climate chamber*

For the zero point test particle free sampling air was applied to both measuring systems SN 5048 and SN 5049 by means of zero filters installed at the instrument inlets.

The reference point test comprised a check and evaluation of the peak position upon application of CalDust 1100 in order to test the stability of the sensitivity of both candidates SN 5048 and SN 5049.

The sensitivity test was carried out with monodisperse dust (CalDust 1100). When applying this calibration dust, the size distribution is expected to peak in channel 130 (this corresponds with a particle size of 0.93 µm). In order to make the quantification of deviations in the classification possible, the datasets obtained in the field test were used to calculate the effects of a peak shift of max. ±3 channels on a measured PM value. For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for $PM_{10}$ were defined. The concentration value to be expected depending on the peak shift was then calculated according to the matrix in chapter 4.2 Laboratory test.

The ambient temperature within the climatic chamber was altered in the sequence

20 °C – 5 °C – 20 °C – 40 °C – 20 °C.

The measured values at zero point (3 x 24 h per temperature level) and the measured values at reference point (3 x 24 h per temperature level) were recorded after an equilibration period of 24 h per temperature level.

The evaluation of the tests has been carried out as follows:

Zero point:

The measured concentration values obtained in the individual 24-hour measurements were collected and evaluated. The absolute deviation in µg/m³ per temperature level in relation to the default temperature of 20 °C is considered.

Reference value: $B_0$ = 2 µg/m³

Looking at the values that were output by the AMS, the maximum dependence of ambient temperature in the range of +5 °C to +40 °C at zero was 5.5 x $10^{-5}$ µg/m³ for $PM_{2.5}$ and 5.7 x $10^{-5}$ µg/m³ for $PM_{10}$

Performance criterion met? yes

Reference point:

The measured value's change in percentage for each temperature level in relation to the initial temperature of 20 °C is checked.

At the reference point, no deviations > -2.2 % for $PM_{2,5}$ rspectively > -2.2 % for $PM_{10}$ related to the base value at 20 °C could be determined for an ambient temperature in the range of +5 °C to +40 °C.

Performance criterion met? yes

Thus the indoor version Fidas® 200 fulfills the minimum requirements in the relevant ambient temperature in the range of +5 °C to +40 °C.

Detailed presentation of test results:

*Table 60: Dependence of zero point on ambient temperature, deviations in µg/m³, mean value of three measurements, $PM_{10}$, SN 5048 & SN 5049*

| Ambient temperature | | Deviation | |
|---|---|---|---|
| Start temperature | End temperature | SN 5048 | SN 5049 |
| °C | °C | µg/m³ | µg/m³ |
| 20 | 5 | 5.7E-05 | 7.9E-07 |
| 5 | 20 | 4.2E-05 | 0.0E+00 |
| 20 | 40 | -9.8E-06 | 0.0E+00 |
| 40 | 20 | -7.5E-06 | 0.0E+00 |

*Table 61: Dependence of zero point on ambient temperature, deviations in µg/m³, mean value of three measurements, $PM_{2,5}$, SN 5048 & SN 5049*

| Ambient temperature | | Deviation | |
|---|---|---|---|
| Start temperature | End temperature | SN 5048 | SN 5049 |
| °C | °C | µg/m³ | µg/m³ |
| 20 | 5 | 5.5E-05 | 7.9E-07 |
| 5 | 20 | 4.2E-05 | 0.0E+00 |
| 20 | 40 | -9.8E-06 | 0.0E+00 |
| 40 | 20 | -7.5E-06 | 0.0E+00 |

*Table 62: Dependence of sensitivity (CalDust 1100) on ambient temperature, deviation in %, mean value of three measurements, $PM_{10}$, SN 5048 & SN 5049*

| Ambient temperature | | Deviation | |
|---|---|---|---|
| Start temperature | End temperature | SN 5048 | SN 5049 |
| °C | °C | [%] | [%] |
| 20 | 5 | -2.2 | -1.9 |
| 5 | 20 | -0.9 | -0.5 |
| 20 | 40 | 1.0 | 0.6 |
| 40 | 20 | -0.1 | -0.5 |

*Table 63: Dependence of sensitivity (CalDust 1100) on ambient temperature, deviation in %, mean value of three measurements, $PM_{2,5}$, SN 5048 & SN 5049*

| Ambient temperature | | Deviation | |
|---|---|---|---|
| Start temperature | End temperature | SN 5048 | SN 5049 |
| °C | °C | [%] | [%] |
| 20 | 5 | -2.2 | -1.9 |
| 5 | 20 | -0.9 | -0.5 |
| 20 | 40 | 1.1 | 0.7 |
| 40 | 20 | -0.1 | -0.5 |

## 8.2 Qualification of hardware modifications „new LED“ and „additional digital output“

Since the initial certification, the following noteworthy modifications have been applied to the measuring system Fidas® 200 respectively Fidas® 200 S:

Modification #1 (Type 0):

An additional port for a digital signal (digital out, e.g. for threshold monitoring) is added to the rear side of the instrument.

The modification has been correctly classified as a Type 0 – modification and thus has got no impact on the measuring instrument. The modification is depicted in the following technical documentation.

Modification #2 (Type 1):

Due to discontinuation of the currently implemented LED in the Fidas-sensor, a respective new follow-up LED must be applied in the measuring instrument. The new LED of the company Osram of the type Ostar Stage Art.-Nr. LE ATB S2W is hereby the official follow-up LED for the currently implemented LED of the company Osram of the type Ostar Projektion Art.-Nr. LE B H3W. Regarding the light spectrum (dominant wave length), both LEDs are almost identical.

As the modification could potentially have an impact on the performance of the measuring instrument, the modification has been classified as a Type 1- modification. The company Palas has carried out extensive tests for the qualification of the new LED and it could be confirmed, that the application of the new LED has no impact on the performance of the measuring system. The performed investigations and evaluations of the data have been examined in detail during the 2014 surveillance audit and are described extensively in the following technical documentation.

Based on the available documentation and test results, no significant influence on the measuring system is to expect.

Based on the available documentation (Statement of TÜV Rheinland of 27 September 2014), the publication of the issue (Approval of new LED and additional digital output) has been recommended during the 35th expert meeting “Test reports”. The official announcement in the Federal Gazette “Bundesanzeiger” has happened with announcement of Federal Environment Agency UBA of 25 February 2015 (BAnz AT 02.04.2015 B15, chapter IV, 14th notification).

**Technical documentation for depiction of the additional digital output on the rear side of the instrument**

The measuring system receives an additional port for a digital output signal on the rear side of the instrument (refer to Figure 129). This modification has no impact on the measuring system.


*Figure 129: Rear side of instrument with additional port (marked in yellow)*

## Technical documentation for the qualification of the LED in the Fidas® – Sensor

Due to discontinuation of the currently implemented LED in the Fidas-sensor, a respective new follow-up LED must be applied in the measuring instrument. The new LED of the company Osram of the type Ostar Stage Art.-Nr. LE ATB S2W is hereby the official follow-up LED for the currently implemented LED of the company Osram of the type Ostar Projektion Art.-Nr. LE B H3W.

When choosing for the LED, special emphasis was put on as identical as possible optical data.

The currently implemented LED of the company Osram of the type Ostar Projektion Art.-Nr. LE B H3W operates in the relevant range with a dominant wavelength in a range between 456 nm and 469 nm (typical wavelength 464 nm).

The new LED of the company Osram of the type Ostar Stage Art.-Nr. LE ATB S2W operates in the relevant range with a dominant wavelength in a range between 462 nm and 466 nm

In order to ascertain, that the switch of the LED has got no significant influence on the measuring instrument, the company Palas has performed extensive tests for the following points:

a) Dependency on temperature – Comparison LED, old vs. LED, new
b) Comparison of PM measured values of instruments with new LED compared to the reference device SN 0108 (with old LED) at the aerosol test rig

Re a): Dependency on temperature – Comparison LED, old vs. LED, new

One instrument with the old LED and one instrument with the new LED have been operated in the climate chamber at ambient temperatures of -10 °C und +50 °C as well as between +5 °C und +60 °C and the LED temperatures were recorded. By offering CalDust1100, the peak position was determined at different LED-temperatures.

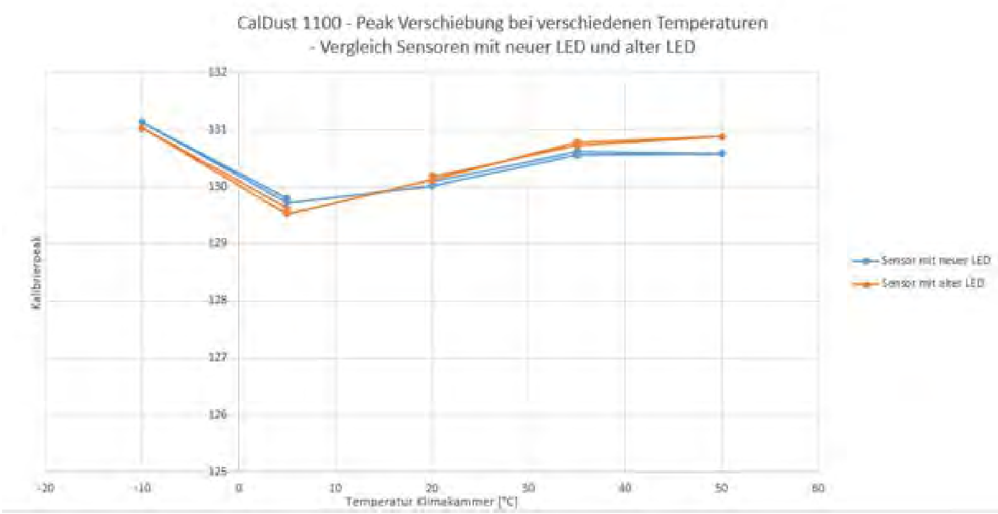



*Figure 130: Comparison of temperature behaviour between -10 °C and +50 °C, LED, old vs. LED, new*

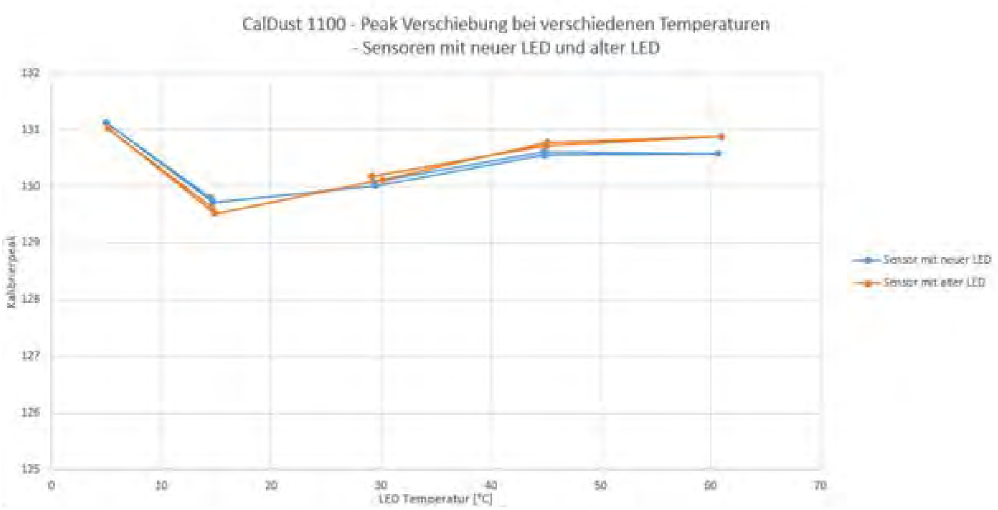



*Figure 131: Comparison of temperature behaviour between -+5 °C and +60 °C, LED, old vs. LED, new*

It is demonstrated, that there is no significant difference in the temperature behavior between the old LED and the new LED.

Re b): Comparison of PM measured values of instruments with new LED compared to the reference device SN 0108 (with old LED) at the aerosol test rig

In total 10 sensors with the new LED (always installed in one and the same instrument – thus other influences on the result, e.g. by the flow, are excluded and only the dependency on the sensor itself is measured) have been tested against the reference device SN 0108 (with old LED) at the aerosol test rig. For this, PM values in the range of 0 to approx. 180 µg/m³ $PM_{2,5}$ respectively 0 to 260 µg/m³ $PM_{10}$ have been offered to the instruments. Based on the comparison measurements, the slope (mean value of $PM_{2.5}$ and $PM_{10}$) between the instrument with the old LED and the instrument with the new LED has been determined.

| Sensor ID | Steigung |
|---|---|
| | |
| Fidas A 20.Aug.2014 | 1,01 |
| Fidas B 20.Aug.2014 | 1,02 |
| Fidas C 20.Aug.2014 | 0,98 |
| Fidas D 20.Aug.2014 | 1,01 |
| Fidas E 20.Aug.2014 | 1,03 |
| Fidas F 20.Aug.2014 | 1,03 |
| Fidas G 20.Aug.2014 | 1,01 |
| Fidas H 20.Aug.2014 | 1,00 |
| Fidas I 20.Aug.2014 | 1,00 |
| Fidas J 20.Aug.2014 | 0,97 |

Steigung = Slope

The results of the comparison measurements show, that the determined deviations between the candidates and the reference device show no significant deviation between candidates with new LED and the reference device with old LED. The determined slopes are all in the range of 0.97 – 1.03.

Based on the available documentation and test results, no significant influence on the measuring system is thus to expect.

## 8.3 New software

The measuring system has been tested and approved with the following software versions:

| | |
|---|---|
| Measuring system: | 100327 |
| Implemented evaluation algorithm: | PM_ENVIRO_0011 |
| Evaluation software PDAnalyze: | 1.010 (for evaluation on an external PC) |

The stated software version for the measuring system (in this case: 100327) is used for the operation of the Panel-PC. As there are - beyond the mentioned software version - 3 further software versions independently from each other implemented in the instrument (precisely on the boards SLA (Scattered light evaluation), MIO (multifunctional board, internal control of eg pump control) and Pt100 (control of IADS heater)), it was discussed during the 2014 surveillance audit to depict the software versions more precisely in a single and unique string.

The following general structure for the software string has been defined for the future:

FirmwarePanel.FirmwareSLA.FirmwareMIO.FirmwarePt100.EvaluationAlgorithm

The software implemented during the type approval test is then defined as follows:

100327.0007.0001.0001.0011

Since the initial certification of the measuring system, the firmware (Panel) and the firmware (SLA) have been modified. The firmware (MIO) and the firmware (Pt100) as well as the implemented evaluation algorithm remain unchanged.

For the firmware (Panel) the following modifications have been implemented:

a) Serial IO protocol extended (not covered by type approval test)
b) Digital alarm added
c) Automatic monitoring of calibration according to upcoming patent added (Add-On, not yet tested, thus not covered yet by type approval)
d) Cosmetic changes to the user interface
e) Calibration screen extended for flow calibration (-> increased usability)
f) Bug in Bayern/Hessen-Protocol fixed

g) Various modifications, which are only relevant for the measuring systems UF-CPC and Fidas mobile, but not for Fidas 200.
h) Additonal integration DiSC mini in Fidas Software Plug In
i) Modification of distribution presentation
j) E-Mail Alarm for Fidas – Bugfix for SMTP sending
k) Extension Fidas plugin to Horiba APDA (OEM-Version)
l) Start-Up-Manager extended to Horiba APDA (OEM-Version)
m) As an option calibration can be secured, so that calibration is only possible if 35 °C are really reached in a stable way.
n) Reworking of the depiction of the firmwareversion in one string

The modifications in the firmware (Panel) serve mainly for extension of functionality and increasement of safe operation.

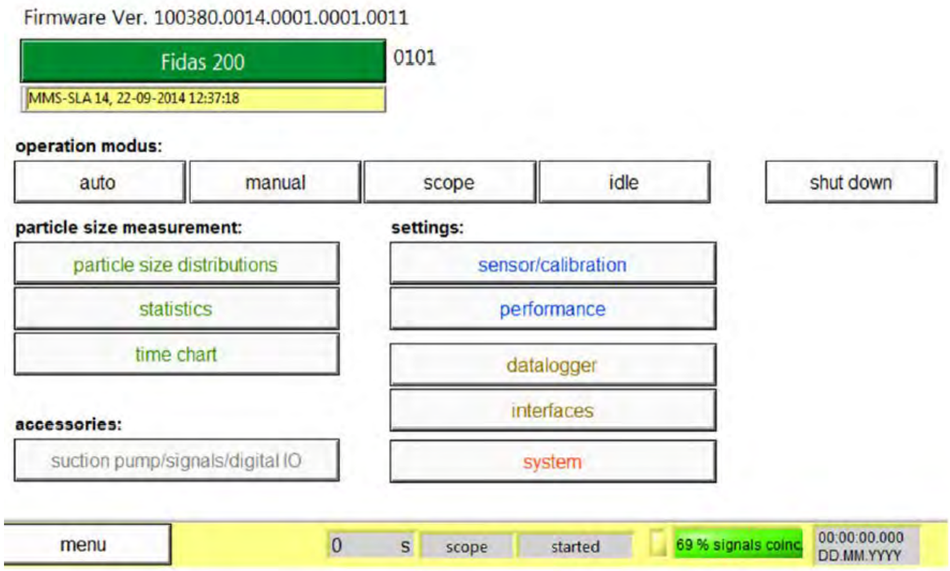
The current firmware version (Panel) is now 100380.

The modifications of the firmware (SLA) comprise additional modes for signal aquisition as well as new commands and are all not relevant for the measuring system Fidas 200 S respectively Fidas 200. It is to note, that the SLA board (and thus also the firmware) is used for all aerosol spectrometers and condensation nucleus counters of the company Palas GmbH.

The current firmware version (SLA) is now 0014.

The current software version is then defined as follows:

100380.0014.0001.0001.0011




The modification has been correctly classified as a Type 0 – modification and thus has got no impact on the measuring instrument. The respective documentation is available at the test institute.

Based on the available documentation (Statement of TÜV Rheinland of 27 September 2014), the publication of the issue (Approval of new software and new structure) has been recommended during the 35th expert meeting “Test reports”. The official announcement in the Federal Gazette “Bundesanzeiger” has happened with announcement of Federal Environment Agency UBA of 25 February 2015 (BAnz AT 02.04.2015 B15, chapter IV, 14th notification).

# 9. Recommendations for practical use

## 9.1 Works in the maintenance interval (4 weeks)

The following procedures are required to be carried out at regular intervals:

- Regular visual inspection / telemetrical monitoring
- Check of instrument status
  The instrument status may be controlled directly at the instrument or monitored on-line.
- The sensitivity of the particle sensor shall be checked with CalDust 1100 or MonoDust1500 once a month. Should the sensitivity of the particle sensor deviate from the nominal value 130 by more than ±1.5 channels (CalDust1100) respectively more than ±1.5 channels from the given nominal value (MonoDust1500) , it shall be readjusted with CalDust 1100; otherwise it shall be readjusted at least every 3 months.

As for the rest, the instructions and recommendations provided by the manufacturer shall be followed.

## 9.2 Further maintenance work

In addition to the regular maintenance work in the maintenance interval, the following procedures are necessary:

- As a matter of principle, the sampling head shall be cleaned according to the instructions provided by the manufacturer. Local concentrations of suspended particulate matter shall be taken into account (during type approval testing approx. every 3 months).
- The system's leak tightness shall be inspected every 3 months according to the manufacturer's information.
- A flow rate check shall be carried out every 3 months according to the manufacturer's information.
- The sensors of the weather station WS600-UMB shall be checked once a year (or when necessary) according to the specifications provided by the manufacturer.
- Cleaning the optical sensor is only required if the photomultiplier-voltage exceeds the calibration value obtained after the last cleaning or on delivery by more than 15 %.
- The filter shall be cleaned or changed if the suction pump capacity exceeds 50 %.

Further details are provided in the user manual.

Department of Environmental Protection/Air Pollution Control

| | | |
|---|---|---|
| Dipl.-Ing. Karsten Pletscher | Dipl.-Ing. Guido Baum | Dipl.-Ing. Ruth Steinhagen |

Cologne, 12 October 2016
936/21227195/C

# 10. Literature

[1] VDI Standard 4202, Part 1, "Performance criteria for type approval tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants", June 2002 & September 2010

[2] VDI Standard 4203, Part 3, "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", August 2004 & September 2010

[3] Standard EN 12341, "Air quality – Determination of the PM10 fraction of suspended particulate matter. Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341: 1998

[4] Standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005

[5] Guidance document "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version of January 2010

[6] Operator's manual Fidas® 200 S respectively Fidas® 200, comprising the manuals Fidas®, Fidas® Firmware, PDAnalyze Software, and Compact Weather Station WS600-UMB, Status 2014

[7] Operator's manual LVS3, Status 2000

[8] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

[9] Technical Specification CEN/TS 16450, "Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2.5)"; English version, May 2013

[10] Report "UK Equivalence Programme for Monitoring of Particulate Matter", Report No.: BV/AQ/AD202209/DH/2396 of 5 June 2006

[11] TÜV Rheinland Report No.: 936/21218896/A of 20 September 2013, Report on type approval testing of the Fidas® 200 S measuring system manufactured by PALAS GmbH for the components suspended particulate matter $PM_{10}$ and $PM_{2.5}$

5.1 Fidas® 200 S für Schwebstaub $PM_{10}$ und $PM_{2,5}$

Hersteller:
PALAS GmbH, Karlsruhe

Eignung:
Zur kontinuierlichen parallelen Immissionsmessung der $PM_{10}$- und der $PM_{2,5}$-Fraktion im Schwebstaub im stationären Einsatz

Messbereiche in der Eignungsprüfung:

| Komponente | Zertifizierungsbereich | Einheit |
|---|---|---|
| $PM_{10}$ | 0 – 10 000 | µg/m³ |
| $PM_{2,5}$ | 0 – 10 000 | µg/m³ |

Softwareversionen: Messsystem: 100327
Implementierter Auswertealgorithmus: PM_ENVIRO_0011
Auswertesoftware PDAnalyze: 1.010

Einschränkungen:
Keine

Hinweise:

1. Die Anforderungen gemäß des Leitfadens „Demonstration of Equivalence of Ambient Air Monitoring Methods" werden für die Messkomponenten $PM_{10}$ und $PM_{2,5}$ eingehalten.
2. Die Anforderungen an den Variationskoeffizienten $R^2$ gemäß Richtlinie EN 12341 wurden für den Standort Köln, Sommer für einen der beiden Prüflinge nicht eingehalten.
3. Die Empfindlichkeit des Partikelsensors muss monatlich mit CalDust 1100 überprüft werden.
4. Die Messeinrichtung ist mit dem gravimetrischen $PM_{10}$-Referenzverfahren nach DIN EN 12341 regelmäßig am Standort zu kalibrieren.
5. Die Messeinrichtung ist mit dem gravimetrischen $PM_{2,5}$-Referenzverfahren nach DIN EN 14907 regelmäßig am Standort zu kalibrieren.
6. Der Prüfbericht über die Eignungsprüfung ist im Internet unter www.qal1.de einsehbar.

Prüfinstitut: TÜV Rheinland Energie und Umwelt GmbH, Köln
Bericht-Nr.: 936/21218896/A vom 20. September 2013

Figure 132: Text for publication of type approval in Federal Gazette BAnz. AT 01.04.2014 B12, Chapter IV Number 5.1

## 14 Mitteilung zu der Bekanntmachung des Umweltbundesamtes vom 27. Februar 2014 (BAnz AT 01.04.2014 B12, Kapitel IV Nummer 5.1)

Die Messeinrichtung Fidas® 200 S für Schwebstaub $PM_{10}$ und $PM_{2,5}$ der Fa. PALAS GmbH ist auch als Indoor-Variante zur Installation an temperaturkontrollierten Orten unter der Bezeichnung Messeinrichtung Fidas® 200 für Schwebstaub $PM_{10}$ und $PM_{2,5}$ verfügbar.

Die Messeinrichtung erhält auf der Geräterückseite eine zusätzliche Buchse für ein digitales Ausgangssignal.

Die LED im Fidas® Sensor vom Typ Osram Ostar Projektion Art.-Nr. LE B H3W wurde abgekündigt und durch die LED vom Typ Osram Ostar Stage Art.-Nr. LE ATB S2W ersetzt.

Die Darstellung der Softwareversion der Messeinrichtung wurde überabeitet.

Die bislang bekanntgegebene Softwareversion der Messeinrichtung stellt sich nun wie folgt dar:

100327.0007.0001.0001.0011

Die aktuelle Softwareversion der Messeinrichtung lautet:

100380.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 27. September 2014

Figure 133: Text for publication of notification in Federal Gazette BAnz. AT 02.04.2015 B5, Chapter IV Notification 14

# 11. Annex

**Appendix 1** **Measured and calculated values**



**Appendix 2** **Filter weighing procedure**

**Appendix 3** **Manuals**

**Annex 1** **Detection limit** **Page 1 of 2**

Manufacturer Palas

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

Standards ZP Zero filter

| No. | Date | Measured values [µg/m³] SN 0111 | Date | Measured values [µg/m³] SN 0112 |
|---|---|---|---|---|
| 1 | 4/5/2012 | 0.0000000 | 4/5/2012 | 0.0000000 |
| 2 | 4/6/2012 | 0.0000000 | 4/6/2012 | 0.0000005 |
| 3 | 4/7/2012 | 0.0000000 | 4/7/2012 | 0.0000000 |
| 4 | 4/8/2012 | 0.0000000 | 4/8/2012 | 0.0000000 |
| 5 | 4/9/2012 | 0.0000000 | 4/9/2012 | 0.0000000 |
| 6 | 4/10/2012 | 0.0000008 | 4/10/2012 | 0.0000000 |
| 7 | 4/11/2012 | 0.0000000 | 4/11/2012 | 0.0000008 |
| 8 | 4/12/2012 | 0.0000008 | 4/12/2012 | 0.0000003 |
| 9 | 4/13/2012 | 0.0000000 | 4/13/2012 | 0.0000006 |
| 10 | 4/14/2012 | 0.0000000 | 4/14/2012 | 0.0000000 |
| 11 | 4/15/2012 | 0.0000177 | 4/15/2012 | 0.0000008 |
| 12 | 4/16/2012 | 0.0012831 | 4/16/2012 | 0.0000000 |
| 13 | 4/17/2012 | 0.0010071 | 4/17/2012 | 0.0000000 |
| 14 | 4/18/2012 | 0.0001465 | 4/18/2012 | 0.0000000 |
| 15 | 4/19/2012 | 0.0004303 | 4/19/2012 | 0.0000000 |
| | No. of values | 15 | No. of values | 15 |
| | Mean | 0.0001924 | Mean | 0.0000002 |
| | Standard deviation $s_{x0}$ | 0.0004064 | Standard deviation $s_{x0}$ | 0.0000003 |
| | Detection limit x | 8.7E-04 | Detection limit x | 6.6E-07 |

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

**Annex 1** **Detection limit** **Page 2 of 2**

Manufacturer Palas

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

Standards ZP Zero filter

| No. | Date | Measured values [µg/m³] SN 0111 | Date | Measured values [µg/m³] SN 0112 |
|---|---|---|---|---|
| 1 | 4/5/2012 | 0.0000003 | 4/5/2012 | 0.0000000 |
| 2 | 4/6/2012 | 0.0000000 | 4/6/2012 | 0.0000005 |
| 3 | 4/7/2012 | 0.0000000 | 4/7/2012 | 0.0000000 |
| 4 | 4/8/2012 | 0.0000000 | 4/8/2012 | 0.0000000 |
| 5 | 4/9/2012 | 0.0000000 | 4/9/2012 | 0.0000000 |
| 6 | 4/10/2012 | 0.0000000 | 4/10/2012 | 0.0000000 |
| 7 | 4/11/2012 | 0.0000008 | 4/11/2012 | 0.0000008 |
| 8 | 4/12/2012 | 0.0000000 | 4/12/2012 | 0.0000003 |
| 9 | 4/13/2012 | 0.0000008 | 4/13/2012 | 0.0000006 |
| 10 | 4/14/2012 | 0.0000000 | 4/14/2012 | 0.0000000 |
| 11 | 4/15/2012 | 0.0000000 | 4/15/2012 | 0.0000008 |
| 12 | 4/16/2012 | 0.0000177 | 4/16/2012 | 0.0000000 |
| 13 | 4/17/2012 | 0.0012831 | 4/17/2012 | 0.0000000 |
| 14 | 4/18/2012 | 0.0010071 | 4/18/2012 | 0.0000000 |
| 15 | 4/19/2012 | 0.0001465 | 4/19/2012 | 0.0000000 |
| | No. of values | 15 | No. of values | 15 |
| | Mean | 0.0001638 | Mean | 0.0000002 |
| | Standard deviation $s_{x0}$ | 0.0004036 | Standard deviation $s_{x0}$ | 0.0000003 |
| | Detection limit x | 8.7E-04 | Detection limit x | 6.6E-07 |

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

**Annex 2** **Dependence of zero point on ambient temperature (PM10)** **Page 1 of 2**

Manufacturer PALAS

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

Standards ZP Zero filter

| | | | Cycle 1 | | Cycle 2 | | Cycle 3 | |
|---|---|---|---|---|---|---|---|---|
| SN 0111 | No. | Temperature [°C] | Measured value [µg/m³] | Dev. [µg/m³] | Measured value [µg/m³] | Dev. [µg/m³] | Measured value [µg/m³] | Dev. [µg/m³] |
| ZP | 1 | 20 | 0.0000000 | - | 0.0000000 | - | 0.0000000 | - |
| | 2 | -20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| | 3 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| | 4 | 50 | 0.0000005 | 0.0000005 | 0.0000014 | 0.0000014 | 0.0000014 | 0.0000014 |
| | 5 | 20 | 0.0000000 | 0.0000000 | 0.0000008 | 0.0000008 | 0.0000000 | 0.0000000 |
| SN 0112 | No. | Temperature [°C] | Measured value [µg/m³] | Dev. [µg/m³] | Measured value [µg/m³] | Dev. [µg/m³] | Measured value [µg/m³] | Dev. [µg/m³] |
| ZP | 1 | 20 | 0.0000003 | - | 0.0000000 | - | 0.0000332 | - |
| | 2 | -20 | 0.0000000 | -0.0000003 | 0.0000017 | 0.0000017 | 0.0000000 | -0.0000332 |
| | 3 | 20 | 0.0000000 | -0.0000003 | 0.0000001 | 0.0000001 | 0.0000040 | -0.0000292 |
| | 4 | 50 | 0.0000000 | -0.0000003 | 0.0000000 | 0.0000000 | 0.0000000 | -0.0000332 |
| | 5 | 20 | 0.0000006 | 0.0000003 | 0.0000000 | 0.0000000 | 0.0000000 | -0.0000332 |

**Annex 2** **Dependence of zero point on ambient temperature (PM2.5)** **Page 2 of 2**

Manufacturer PALAS

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

Standards ZP Zero filter

| SN 0111 | No. | Temperature [°C] | Cycle 1 Measured value [µg/m³] | Dev. [µg/m³] | Cycle 2 Measured value [µg/m³] | Dev. [µg/m³] | Cycle 3 Measured value [µg/m³] | Dev. [µg/m³] |
|---|---|---|---|---|---|---|---|---|
| ZP | 1 | 20 | 0.0000000 | - | 0.0000000 | - | 0.0000000 | - |
| | 2 | -20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| | 3 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| | 4 | 50 | 0.0000005 | 0.0000005 | 0.0000014 | 0.0000014 | 0.0000014 | 0.0000014 |
| | 5 | 20 | 0.0000000 | 0.0000000 | 0.0000008 | 0.0000008 | 0.0000000 | 0.0000000 |

| SN 0112 | No. | Temperature [°C] | Measured value [µg/m³] | Dev. [µg/m³] | Measured value [µg/m³] | Dev. [µg/m³] | Measured value [µg/m³] | Dev. [µg/m³] |
|---|---|---|---|---|---|---|---|---|
| ZP | 1 | 20 | 0.0000003 | - | 0.0000000 | - | 0.0000332 | - |
| | 2 | -20 | 0.0000000 | -0.0000003 | 0.0000017 | 0.0000017 | 0.0000000 | -0.0000332 |
| | 3 | 20 | 0.0000000 | -0.0000003 | 0.0000001 | 0.0000001 | 0.0000040 | -0.0000292 |
| | 4 | 50 | 0.0000000 | -0.0000003 | 0.0000000 | 0.0000000 | 0.0000000 | -0.0000332 |
| | 5 | 20 | 0.0000006 | 0.0000003 | 0.0000000 | 0.0000000 | 0.0000000 | -0.0000332 |

**Annex 3** **Dependence of measured value on ambient temperature (PM10)** **Page 1 of 2**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Manufacturer | Palas | | | | | | | | | |
| | | | | | | Standards | | CalDust 1100 | | |
| Type | FIDAS 200 | | | | | | | | | |
| Serial-No. | SN 0111 / SN 0112 | | | | | | | | | |
| | | | Cycle 1 | | Cycle 2 | | Cycle 3 | | | |
| SN 0111 | No. | Temperature [°C] | Measured value | Dev. [%] | Measured value | Dev. [%] | Measured value | Dev. [%] | | |
| | 1 | 20 | 40.0 | - | 40.0 | - | 40.0 | - | | |
| | 2 | -20 | 38.2 | -4.4 | 38.2 | -4.4 | 38.2 | -4.4 | | |
| RP | 3 | 20 | 39.9 | -0.3 | 39.9 | -0.3 | 40.0 | 0.0 | | |
| | 4 | 50 | 39.4 | -1.4 | 39.7 | -0.9 | 39.7 | -0.9 | | |
| | 5 | 20 | 40.0 | 0.0 | 40.1 | 0.2 | 40.0 | 0.0 | | |
| SN 0112 | No. | Temperature [°C] | Measured value | Dev. [%] | Measured value | Dev. [%] | Measured value | Dev. [%] | | |
| | 1 | 20 | 40.0 | - | 40.0 | - | 40.0 | - | | |
| | 2 | -20 | 41.8 | 4.6 | 41.8 | 4.6 | 41.8 | 4.6 | | |
| RP | 3 | 20 | 40.0 | 0.0 | 40.0 | 0.0 | 40.1 | 0.2 | | |
| | 4 | 50 | 39.9 | -0.3 | 40.1 | 0.2 | 40.1 | 0.2 | | |
| | 5 | 20 | 40.0 | 0.0 | 40.1 | 0.2 | 40.1 | 0.2 | | |

**Annex 3** **Dependence of measured value on ambient temperature (PM2.5)** **Page 2 of 2**

Manufacturer Palas

Type FIDAS 200

Serial-No. SN 0111 / SN 0112

Standards CalDust 1100

| | | | Cycle 1 | | Cycle 2 | | Cycle 3 | |
|---|---|---|---|---|---|---|---|---|
| SN 0111 | No. | Temperature [°C] | Measured value | Dev. [%] | Measured value | Dev. [%] | Measured value | Dev. [%] |
| RP | 1 | 20 | 25.0 | - | 25.0 | - | 25.0 | - |
| | 2 | -20 | 23.9 | -4.4 | 23.9 | -4.4 | 23.9 | -4.4 |
| | 3 | 20 | 24.9 | -0.3 | 24.9 | -0.3 | 25.0 | 0.0 |
| | 4 | 50 | 24.6 | -1.5 | 24.8 | -0.9 | 24.8 | -0.9 |
| | 5 | 20 | 25.0 | 0.0 | 25.1 | 0.3 | 25.0 | 0.0 |
| SN 0112 | No. | Temperature [°C] | Measured value | Dev. [%] | Measured value | Dev. [%] | Measured value | Dev. [%] |
| RP | 1 | 20 | 25.0 | - | 25.0 | - | 25.0 | - |
| | 2 | -20 | 26.2 | 5.0 | 26.2 | 5.0 | 26.2 | 5.0 |
| | 3 | 20 | 25.0 | 0.0 | 25.0 | 0.0 | 25.1 | 0.3 |
| | 4 | 50 | 24.9 | -0.3 | 25.1 | 0.3 | 25.1 | 0.3 |
| | 5 | 20 | 25.0 | 0.0 | 25.1 | 0.3 | 25.1 | 0.3 |

**Annex 4** **Dependence of measured value on mains voltage (PM10)** **Page 1 of 2**

| | | | | | |
|---|---|---|---|---|---|
| Manufacturer | PALAS | | | | |
| | | | Standards | CalDust 1100 | |
| Type | FIDAS 200 | | | | |
| Serial-No. | SN 0111 / SN 0112 | | | | |

| SN 0111 | No. | Mains voltage [V] | Cycle 1 Measured value | Dev. [%] | Cycle 2 Measured value | Dev. [%] | Cycle 3 Measured value | Dev. [%] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| RP | 1 | 230 | 40.1 | - | 39.9 | - | 40.0 | - | | |
| | 2 | 210 | 40.0 | -0.2 | 40.0 | 0.3 | 40.0 | 0.0 | | |
| | 3 | 230 | 40.1 | 0.0 | 40.0 | 0.3 | 40.0 | 0.0 | | |
| | 4 | 245 | 40.1 | 0.0 | 40.1 | 0.5 | 40.1 | 0.2 | | |
| | 5 | 230 | 40.0 | -0.2 | 40.0 | 0.3 | 40.2 | 0.5 | | |
| **SN 0112** | **No.** | **Mains voltage [V]** | **Measured value** | **Dev. [%]** | **Measured value** | **Dev. [%]** | **Measured value** | **Dev. [%]** | | |
| RP | 1 | 230 | 40.1 | - | 40.0 | - | 40.0 | - | | |
| | 2 | 210 | 40.2 | 0.2 | 40.3 | 0.7 | 40.2 | 0.5 | | |
| | 3 | 230 | 40.4 | 0.7 | 40.3 | 0.7 | 40.3 | 0.7 | | |
| | 4 | 245 | 40.2 | 0.2 | 40.4 | 1.0 | 40.2 | 0.5 | | |
| | 5 | 230 | 40.1 | 0.0 | 39.7 | -0.9 | 40.3 | 0.7 | | |

**Annex 4** **Dependence of measured value on mains voltage (PM2.5)** **Page 2 of 2**

| | |
|---|---|
| Manufacturer | PALAS |
| Type | FIDAS 200 |
| Serial-No. | SN 0111 / SN 0112 |
| Standards | CalDust 1100 |

| | | | 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 |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 1 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM2,5 [µg/m³] | SN 0112 PM2,5 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5/14/2012 | | | | | | 12.9 | 13.0 | 20.1 | 20.3 | | Cologne, summer |
| 2 | 5/15/2012 | 6.8 | 7.2 | 11.7 | 10.0 | 64.1 | 7.0 | 7.0 | 10.5 | 10.5 | | |
| 3 | 5/16/2012 | 6.4 | 8.2 | 13.8 | 13.1 | 54.4 | 7.0 | 7.0 | 12.0 | 11.9 | | |
| 4 | 5/17/2012 | 6.5 | 7.6 | 12.4 | 11.6 | 58.9 | 6.8 | 6.9 | 11.1 | 11.1 | | |
| 5 | 5/18/2012 | | | 14.4 | 11.7 | | 8.8 | 9.0 | 13.8 | 13.9 | Outlier Ref. PM2,5 | |
| 6 | 5/19/2012 | | | | | | 9.2 | 9.4 | 13.5 | 13.5 | | |
| 7 | 5/20/2012 | 12.0 | 12.8 | 19.1 | 16.8 | 69.0 | 13.3 | 13.4 | 19.1 | 19.2 | | |
| 8 | 5/21/2012 | 27.7 | 28.6 | | | | 32.1 | 32.2 | 43.8 | 43.6 | Outlier Ref. PM10 | |
| 9 | 5/22/2012 | | | | | | 58.8 | 58.2 | 74.5 | 73.3 | | |
| 10 | 5/23/2012 | | | 45.2 | 43.3 | | 32.2 | 32.0 | 42.6 | 42.0 | Outlier Ref. PM2,5 | |
| 11 | 5/24/2012 | 10.7 | 9.1 | 19.7 | 17.0 | 54.1 | 11.1 | 11.2 | 22.1 | 22.4 | | |
| 12 | 5/25/2012 | 6.8 | 6.6 | 16.6 | 14.8 | 42.6 | 6.1 | 6.2 | 17.3 | 17.2 | | |
| 13 | 5/26/2012 | | | | | | 8.8 | 9.0 | 18.7 | 19.0 | | |
| 14 | 5/27/2012 | | | | | | 9.2 | 9.4 | 14.6 | 14.9 | | |
| 15 | 5/28/2012 | 12.2 | 12.3 | 20.6 | 19.8 | 60.5 | 15.1 | 15.2 | 22.8 | 23.0 | | |
| 16 | 5/29/2012 | 11.3 | 11.9 | 26.8 | 25.2 | 44.5 | | 15.5 | | 26.8 | SN 0111 accidentally switched off via remote control | |
| 17 | 5/30/2012 | 17.6 | 17.8 | 34.8 | 32.4 | 52.8 | 22.3 | 22.6 | 32.2 | 33.0 | | |
| 18 | 5/31/2012 | 11.6 | 12.0 | 22.6 | 21.2 | 53.8 | 15.8 | 15.7 | 23.1 | 22.8 | | |
| 19 | 6/1/2012 | 9.5 | 9.3 | 16.6 | 15.2 | 59.1 | 12.1 | 12.1 | 15.9 | 16.0 | | |
| 20 | 6/2/2012 | | | | | | 10.6 | 10.6 | 13.9 | 14.1 | | |
| 21 | 6/3/2012 | 10.7 | 10.6 | 16.7 | 16.0 | 65.0 | 14.6 | 14.5 | 16.9 | 16.9 | | |
| 22 | 6/4/2012 | 4.1 | 4.8 | 11.5 | 11.2 | 39.4 | 6.7 | 6.7 | 11.2 | 11.4 | | |
| 23 | 6/5/2012 | 5.7 | 4.8 | 14.2 | 13.2 | 38.2 | 7.1 | 7.2 | 11.4 | 11.6 | | |
| 24 | 6/6/2012 | | | | | | 6.7 | 6.8 | 10.1 | 10.1 | | |
| 25 | 6/7/2012 | 4.9 | 4.0 | 8.5 | 7.0 | 57.7 | 5.3 | 5.4 | 9.1 | 9.2 | | |
| 26 | 6/8/2012 | | | | | | 3.9 | 3.9 | 8.3 | 8.3 | | |
| 27 | 6/9/2012 | | | | | | 4.6 | 4.7 | 8.8 | 8.8 | | |
| 28 | 6/10/2012 | | | | | | | | | | Power failure | |
| 29 | 6/11/2012 | 4.2 | 8.1 | 9.4 | 8.2 | 70.2 | 5.7 | 5.7 | 10.0 | 9.8 | | |
| 30 | 6/12/2012 | 13.2 | 12.3 | 19.5 | 19.7 | 65.1 | 14.1 | 14.0 | 18.0 | 17.7 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 2 of 22**

| | | |
|---|---|---|
| Manufacturer | PALAS | PM10 and PM2.5 |
| Type of instrument | FIDAS 200 S | Measured values in µg/m³ (ACT) |
| Serial-No. | SN 0111 / SN 0112 | |

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 6/13/2012 | 9.7 | 10.0 | 21.2 | 20.7 | 47.0 | 12.4 | 12.3 | 17.7 | 17.8 | | Cologne, summer |
| 32 | 6/14/2012 | 11.7 | 13.0 | 22.9 | 21.4 | 55.9 | 14.8 | 14.9 | 19.8 | 19.8 | | |
| 33 | 6/15/2012 | | | | | | | | | | Inlet -> Zero filter | |
| 34 | 6/16/2012 | | | | | | | | | | Zero filter | |
| 35 | 6/17/2012 | | | | | | | | | | Zero filter | |
| 36 | 6/18/2012 | 11.2 | 10.9 | 17.1 | 15.8 | 67.3 | 10.8 | 10.8 | 15.4 | 15.5 | | |
| 37 | 6/19/2012 | 19.5 | 19.1 | 29.2 | 28.7 | 66.7 | 23.1 | 22.8 | 27.0 | 26.6 | | |
| 38 | 6/20/2012 | 13.5 | 13.0 | 18.8 | 18.3 | 71.5 | 15.5 | 15.3 | 18.9 | 18.5 | | |
| 39 | 6/21/2012 | 3.6 | 3.8 | 9.6 | 8.7 | 40.4 | 5.0 | 5.1 | 10.2 | 10.0 | | |
| 40 | 6/22/2012 | 5.3 | 7.1 | 13.4 | 13.4 | 46.2 | 6.5 | 6.5 | 11.6 | 11.6 | | |
| 41 | 6/23/2012 | | | | | | 6.9 | 7.0 | 10.5 | 10.6 | | |
| 42 | 6/24/2012 | 6.0 | 5.0 | 8.9 | 10.8 | 55.7 | 5.4 | 5.4 | 9.0 | 8.9 | | |
| 43 | 6/25/2012 | 10.0 | 11.3 | 15.2 | 16.5 | 67.1 | 9.6 | 9.5 | 14.7 | 14.4 | | |
| 44 | 6/26/2012 | 13.4 | 13.7 | | 19.8 | | 12.0 | 12.2 | 16.4 | 16.5 | | |
| 45 | 6/27/2012 | 11.8 | 11.8 | 17.6 | 18.7 | 64.9 | 12.4 | 12.1 | 18.2 | 17.7 | | |
| 46 | 6/28/2012 | 8.0 | 10.3 | 17.7 | 17.1 | 52.7 | 9.3 | 9.3 | 20.7 | 20.2 | | |
| 47 | 6/29/2012 | 10.4 | 10.8 | 22.9 | 23.5 | 45.8 | 12.6 | 12.7 | 26.6 | 25.8 | | |
| 48 | 6/30/2012 | | | | | | 8.3 | 8.3 | 17.8 | 17.3 | | |
| 49 | 7/1/2012 | 6.3 | 7.3 | 12.4 | 12.1 | 55.8 | 5.8 | 5.8 | 10.9 | 10.7 | | |
| 50 | 7/2/2012 | 6.7 | 8.5 | 11.5 | 12.3 | 64.2 | 6.9 | 6.9 | 10.8 | 10.6 | | |
| 51 | 7/3/2012 | 8.7 | 9.5 | 17.1 | 15.1 | 56.6 | 7.8 | 7.9 | 13.3 | 13.7 | | |
| 52 | 7/4/2012 | 9.9 | 10.6 | 15.8 | 16.8 | 62.9 | 10.4 | 10.4 | 16.0 | 15.7 | | |
| 53 | 7/5/2012 | 8.8 | 8.6 | 13.2 | 13.8 | 64.3 | 9.5 | 9.4 | 14.6 | 14.2 | | |
| 54 | 7/6/2012 | 7.0 | 5.8 | 10.8 | 10.4 | 60.0 | 5.3 | 5.3 | 9.8 | 9.8 | | |
| 55 | 7/7/2012 | | | | | | 4.6 | 4.6 | 8.0 | 7.9 | | |
| 56 | 7/8/2012 | 3.4 | 4.1 | 6.4 | 6.7 | 57.6 | 3.1 | 3.2 | 6.3 | 6.3 | | |
| 57 | 7/9/2012 | 7.2 | 7.7 | 12.4 | 12.1 | 60.4 | 8.0 | 8.0 | 12.2 | 12.1 | | |
| 58 | 7/10/2012 | 7.1 | 7.1 | 12.8 | 11.5 | 58.4 | 8.0 | 8.0 | 12.4 | 12.4 | | |
| 59 | 7/11/2012 | 3.7 | 2.9 | 7.0 | 8.1 | 43.9 | 3.3 | 3.4 | 6.7 | 6.6 | | |
| 60 | 7/12/2012 | 3.6 | 3.6 | 8.2 | 7.0 | 46.7 | 3.3 | 3.3 | 7.2 | 7.2 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 3 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 7/13/2012 | 3.2 | 3.1 | 6.6 | 6.5 | 47.9 | 3.2 | 3.2 | 6.4 | 6.4 | | Cologne, summer |
| 62 | 7/14/2012 | | | | | | 3.8 | 3.9 | 6.6 | 6.5 | | |
| 63 | 7/15/2012 | 6.0 | 7.1 | 12.0 | 11.3 | 56.6 | 6.3 | 6.5 | 10.2 | 10.2 | | |
| 64 | 7/16/2012 | 3.7 | 4.3 | 9.1 | 7.3 | 48.6 | 3.7 | 3.8 | 7.2 | 7.1 | | |
| 65 | 7/17/2012 | 5.4 | 5.7 | 12.6 | 13.1 | 43.0 | 7.7 | 7.7 | 12.2 | 12.0 | | |
| 66 | 7/18/2012 | 5.1 | 5.6 | 10.6 | 9.3 | 53.6 | 5.2 | 5.2 | 10.2 | 10.3 | | |
| 67 | 7/19/2012 | 5.4 | 5.6 | 14.5 | 13.8 | 39.2 | 6.5 | 6.5 | 12.6 | 12.3 | | |
| 68 | 7/20/2012 | | | | | | | | | | Zero filter | |
| 69 | 7/21/2012 | | | | | | | | | | Zero filter | |
| 70 | 7/22/2012 | | | | | | | | | | Zero filter | |
| 71 | 7/23/2012 | 8.1 | 6.3 | 13.0 | 12.6 | 56.5 | 6.4 | 6.5 | 11.0 | 11.3 | | |
| 72 | 7/24/2012 | 17.1 | 16.6 | 24.5 | 22.7 | 71.5 | 12.9 | 12.9 | 20.3 | 20.5 | | |
| 73 | 7/25/2012 | 27.6 | 28.0 | 39.0 | 37.6 | 72.6 | 26.4 | 26.3 | 37.8 | 37.0 | | |
| 74 | 7/26/2012 | 26.0 | 26.1 | 35.7 | 35.1 | 73.7 | 28.5 | 28.2 | 38.6 | 37.9 | | |
| 75 | 7/27/2012 | 22.3 | 22.7 | 31.6 | 31.4 | 71.4 | 23.0 | 22.5 | 32.5 | 31.6 | | |
| 76 | 7/28/2012 | | | | | | 18.6 | 18.2 | 24.3 | 23.8 | | |
| 77 | 7/29/2012 | 4.9 | 4.7 | 9.9 | 8.7 | 51.7 | 4.2 | 4.2 | 7.7 | 7.8 | | |
| 78 | 7/30/2012 | 5.8 | 6.1 | 12.3 | 12.8 | 47.4 | 5.0 | 5.0 | 9.1 | 9.0 | | |
| 79 | 7/31/2012 | 8.0 | 7.9 | 14.4 | 14.6 | 55.0 | 6.4 | 6.5 | 11.1 | 11.3 | | |
| 80 | 8/1/2012 | 10.2 | 10.4 | 16.5 | 17.1 | 61.3 | 8.2 | 8.1 | 15.4 | 15.0 | | |
| 81 | 8/2/2012 | 6.4 | 6.7 | 13.2 | 13.4 | 49.2 | 5.3 | 5.3 | 11.3 | 11.4 | | |
| 82 | 8/3/2012 | 6.7 | 7.0 | 14.4 | 15.5 | 45.9 | 6.6 | 6.6 | 12.2 | 12.3 | | |
| 83 | 8/4/2012 | | | | | | 7.6 | 7.6 | 10.9 | 10.8 | | |
| 84 | 8/5/2012 | 4.2 | 5.4 | 8.4 | 8.9 | 54.9 | 4.9 | 4.9 | 8.0 | 7.8 | | |
| 85 | 8/6/2012 | 4.0 | 4.0 | 8.1 | 9.6 | 44.9 | 3.6 | 3.6 | 7.4 | 7.1 | | |
| 86 | 8/7/2012 | 6.8 | 5.5 | 13.5 | 12.8 | 46.8 | 5.3 | 5.3 | 10.3 | 10.2 | | |
| 87 | 8/8/2012 | 10.4 | 9.0 | 16.2 | 16.6 | 59.2 | 8.7 | 8.6 | 12.8 | 12.7 | | |
| 88 | 8/9/2012 | 7.7 | 7.6 | 12.3 | 12.7 | 61.1 | 8.1 | 8.0 | 11.7 | 11.6 | | |
| 89 | 8/10/2012 | 8.6 | 8.7 | 13.3 | 14.3 | 62.7 | 6.9 | 6.9 | 10.6 | 10.6 | | |
| 90 | 8/11/2012 | | | | | | 6.0 | 5.9 | 8.9 | 8.7 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 4 of 22**

| | | |
|---|---|---|
| Manufacturer | PALAS | PM10 and PM2.5 |
| Type of instrument | FIDAS 200 S | Measured values in µg/m³ (ACT) |
| Serial-No. | SN 0111 / SN 0112 | |

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91 | 8/12/2012 | 6.2 | 5.6 | 10.0 | 10.0 | 59.1 | 5.4 | 5.4 | 9.7 | 9.7 | | Cologne, summer |
| 92 | 8/13/2012 | 9.7 | 9.2 | 15.4 | 16.8 | 58.6 | 8.2 | 8.2 | 15.0 | 14.8 | | |
| 93 | 8/14/2012 | 10.3 | 10.1 | 17.2 | 16.6 | 60.4 | 8.9 | 8.8 | 14.6 | 14.3 | | |
| 94 | 8/15/2012 | 10.1 | 10.4 | 19.5 | 20.0 | 51.7 | 9.8 | 9.7 | 20.2 | 19.4 | | |
| 95 | 8/16/2012 | 7.6 | 7.9 | 18.0 | 19.5 | 41.5 | 6.7 | 6.6 | 12.8 | 12.4 | | |
| 96 | 8/17/2012 | | | | | | | | | | Zero filter | |
| 97 | 8/18/2012 | | | | | | | | | | Zero filter | |
| 98 | 8/19/2012 | | | | | | | | | | Zero filter | |
| 99 | 8/20/2012 | 17.1 | 17.9 | 28.6 | 29.0 | 60.8 | 15.8 | 15.3 | 26.9 | 25.6 | | |
| 100 | 8/21/2012 | 18.3 | 19.8 | 29.3 | 29.3 | 65.1 | 19.3 | 18.7 | 29.6 | 28.3 | | |
| 101 | 8/22/2012 | 8.7 | 9.9 | 20.7 | 19.9 | 45.7 | 8.9 | 8.9 | 17.5 | 17.1 | | |
| 102 | 8/23/2012 | 7.6 | 8.3 | 14.5 | 13.8 | 56.1 | 5.9 | 5.8 | 11.7 | 11.3 | | |
| 103 | 8/24/2012 | 9.0 | 10.3 | 15.2 | 15.0 | 64.0 | 8.8 | 8.6 | 13.8 | 13.1 | | |
| 104 | 8/25/2012 | | | | | | 3.2 | 3.1 | 6.3 | 6.0 | | |
| 105 | 8/26/2012 | 6.6 | 7.3 | 12.0 | 11.1 | 60.0 | 7.6 | 7.4 | 10.3 | 10.1 | | |
| 106 | 8/27/2012 | 5.4 | 6.5 | 10.7 | 10.7 | 55.2 | 5.0 | 4.9 | 8.7 | 8.5 | | |
| 107 | 8/28/2012 | 8.2 | 7.9 | 14.7 | 16.9 | 50.9 | 6.5 | 6.4 | 12.9 | 12.3 | | |
| 108 | 8/29/2012 | 8.4 | 8.9 | 16.5 | 16.5 | 52.5 | 6.9 | 6.8 | 13.7 | 13.6 | | |
| 109 | 8/30/2012 | 5.6 | 6.1 | 14.2 | 14.4 | 40.8 | 6.6 | 6.5 | 12.3 | 12.0 | | |
| 110 | 8/31/2012 | 4.4 | 5.0 | 10.7 | 10.9 | 43.4 | 5.7 | 5.6 | 9.9 | 9.8 | | |
| 111 | 9/1/2012 | | | | | | 8.7 | 8.4 | 12.6 | 12.0 | | |
| 112 | 9/2/2012 | 10.3 | 11.9 | 18.7 | 17.9 | 60.7 | 9.3 | 9.1 | 13.6 | 13.0 | | |
| 113 | 11/19/2012 | | | | | | | | | | Zero filter | Cologne, winter |
| 114 | 11/20/2012 | | | | | | | | | | Zero filter | |
| 115 | 11/21/2012 | | | | | | | | | | | |
| 116 | 11/22/2012 | | | | | | 11.4 | 11.3 | 14.2 | 13.8 | | |
| 117 | 11/23/2012 | 15.3 | 15.1 | 19.6 | 19.6 | 77.8 | 16.8 | 16.3 | 20.4 | 19.7 | | |
| 118 | 11/24/2012 | | | | | | 15.0 | 14.8 | 19.2 | 19.0 | | |
| 119 | 11/25/2012 | 5.1 | 5.8 | 10.8 | 10.4 | 51.1 | 6.0 | 6.0 | 10.1 | 9.9 | | |
| 120 | 11/26/2012 | 6.1 | 6.9 | 11.0 | 11.6 | 57.4 | 7.2 | 7.2 | 11.0 | 10.8 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 5 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 121 | 11/27/2012 | 10.9 | 11.5 | 18.5 | 17.6 | 62.0 | 11.2 | 11.2 | 15.8 | 15.8 | | Cologne, winter |
| 122 | 11/28/2012 | 23.3 | 23.5 | 29.0 | 29.1 | 80.5 | 26.0 | 25.7 | 30.5 | 30.0 | | |
| 123 | 11/29/2012 | 9.0 | 9.3 | 14.2 | 14.4 | 64.0 | 10.3 | 10.2 | 14.7 | 14.6 | | |
| 124 | 11/30/2012 | 17.8 | 19.3 | 24.5 | 24.3 | 76.0 | 19.5 | 19.0 | 23.4 | 22.7 | | |
| 125 | 12/1/2012 | | | | | | 14.4 | 14.0 | 15.9 | 15.5 | | |
| 126 | 12/2/2012 | 10.0 | 11.0 | 14.8 | 14.6 | 71.2 | 11.8 | 11.6 | 14.6 | 14.3 | | |
| 127 | 12/3/2012 | 8.8 | 9.0 | 14.1 | 14.4 | 62.2 | 10.6 | 10.3 | 13.5 | 13.0 | | |
| 128 | 12/4/2012 | 8.3 | 7.6 | 11.6 | 11.6 | 68.3 | 9.1 | | 11.8 | | SN 0112 Fuse for heater burned | |
| 129 | 12/5/2012 | 8.7 | 8.5 | 12.1 | 12.5 | 69.8 | | 9.6 | | 12.1 | SN 0111 Fuse for heater burned | |
| 130 | 12/6/2012 | 9.5 | 10.3 | 16.5 | 16.1 | 60.7 | 12.5 | 12.2 | 16.7 | 16.0 | | |
| 131 | 12/7/2012 | 13.0 | 12.8 | 15.4 | 15.4 | 83.8 | 13.2 | 12.7 | 15.5 | 14.7 | | |
| 132 | 12/8/2012 | | | | | | 29.0 | | 31.5 | | SN 0112 Fuse for heater burned | |
| 133 | 12/9/2012 | 5.5 | 5.8 | 10.1 | 8.9 | 59.5 | 7.2 | | 9.8 | | SN 0112 Fuse for heater burned | |
| 134 | 12/10/2012 | 10.6 | 11.2 | 14.5 | 13.5 | 77.5 | 13.3 | 12.6 | 15.9 | 14.8 | | |
| 135 | 12/11/2012 | 17.3 | 17.7 | 23.6 | 22.8 | 75.4 | 19.2 | 18.3 | 23.7 | 22.6 | | |
| 136 | 12/12/2012 | 18.2 | 18.5 | 24.7 | 24.2 | 75.1 | 18.2 | 17.4 | 22.9 | 22.0 | | |
| 137 | 12/13/2012 | 23.4 | 23.7 | 29.3 | 28.2 | 82.0 | 24.3 | 23.0 | 27.8 | 26.4 | | |
| 138 | 12/14/2012 | 7.3 | 6.7 | 8.9 | 8.8 | 79.5 | 7.7 | 7.3 | 9.2 | 8.9 | | |
| 139 | 12/15/2012 | | | | | | 4.5 | 4.3 | 6.5 | 6.1 | | |
| 140 | 12/16/2012 | 5.4 | 5.9 | 9.7 | 9.5 | 58.9 | 6.9 | 6.6 | 9.2 | 8.7 | | |
| 141 | 12/17/2012 | 6.8 | 7.2 | 13.7 | 13.4 | 51.9 | 9.1 | 8.8 | 13.4 | 12.7 | | |
| 142 | 12/18/2012 | 12.9 | 13.3 | 20.1 | 20.5 | 64.5 | 15.0 | 14.3 | 19.0 | 18.1 | | |
| 143 | 12/19/2012 | 13.4 | 13.3 | 18.3 | 18.0 | 73.7 | 15.4 | 14.6 | 18.1 | 17.3 | | |
| 144 | 12/20/2012 | 11.6 | 11.6 | 14.1 | 13.6 | 83.8 | 12.3 | 11.7 | 13.8 | 13.2 | | |
| 145 | 12/21/2012 | 11.7 | 10.8 | 18.1 | 17.8 | 62.7 | 13.7 | 12.9 | 17.2 | 16.2 | | |
| 146 | 12/22/2012 | | | | | | 4.4 | 4.2 | 6.4 | 6.0 | | |
| 147 | 12/23/2012 | | | | | | 4.0 | 3.9 | 6.3 | 6.0 | | |
| 148 | 12/24/2012 | | | | | | 7.8 | 7.8 | 14.6 | 14.2 | | |
| 149 | 12/25/2012 | | | | | | 2.5 | 2.4 | 3.9 | 3.8 | | |
| 150 | 12/26/2012 | | | | | | 5.5 | 5.4 | 9.3 | 8.9 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 6 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 151 | 12/27/2012 | | | | | | 12.3 | 12.1 | 16.3 | 16.1 | | Cologne, winter |
| 152 | 12/28/2012 | | | | | | 5.1 | 5.0 | 7.0 | 6.7 | | |
| 153 | 12/29/2012 | | | | | | 4.1 | 4.0 | 5.9 | 5.7 | | |
| 154 | 12/30/2012 | | | | | | 5.7 | 5.5 | 8.7 | 8.4 | | |
| 155 | 12/31/2012 | | | | | | | | | | Power failure | |
| 156 | 1/1/2013 | | | | | | | | | | Power failure | |
| 157 | 1/2/2013 | 9.7 | 9.3 | 16.1 | 15.0 | 60.9 | 12.2 | 11.7 | 15.7 | 14.9 | | |
| 158 | 1/3/2013 | 11.9 | 13.1 | 19.4 | 18.6 | 65.6 | 15.7 | 15.3 | 21.4 | 20.5 | | |
| 159 | 1/4/2013 | 9.5 | 9.9 | 13.8 | 13.0 | 72.5 | 11.6 | 11.3 | 14.3 | 13.9 | | |
| 160 | 1/5/2013 | | | | | | 18.7 | 18.5 | 21.2 | 20.8 | | |
| 161 | 1/6/2013 | 26.7 | 26.6 | 37.5 | 37.4 | 71.3 | 31.6 | 30.9 | 35.4 | 34.5 | | |
| 162 | 1/7/2013 | 17.6 | 19.4 | 24.6 | 25.0 | 74.5 | 20.2 | 19.8 | 23.8 | 23.3 | | |
| 163 | 1/8/2013 | 13.6 | 14.7 | 19.6 | 20.1 | 71.4 | 17.1 | 16.8 | 20.7 | 20.3 | | |
| 164 | 1/9/2013 | 11.6 | 13.3 | 18.9 | 19.7 | 64.5 | 15.3 | 15.0 | 19.6 | 18.9 | | |
| 165 | 1/10/2013 | 13.6 | 14.7 | 21.9 | 21.5 | 65.1 | 15.8 | 15.5 | 19.5 | 19.2 | | |
| 166 | 1/11/2013 | | | | | | | | | | Zero filter | |
| 167 | 1/12/2013 | | | | | | | | | | Zero filter | |
| 168 | 1/13/2013 | | | | | | | | | | Zero filter | |
| 169 | 1/14/2013 | 24.9 | 24.8 | 28.4 | 29.4 | 86.0 | 24.6 | 23.9 | 27.5 | 26.6 | | |
| 170 | 1/15/2013 | 33.4 | 33.8 | 36.3 | 37.1 | 91.5 | 31.6 | 30.1 | 34.1 | 32.5 | | |
| 171 | 1/16/2013 | 58.5 | 58.4 | 63.7 | 63.3 | 92.0 | 61.4 | 59.4 | 66.9 | 64.4 | | |
| 172 | 1/17/2013 | 55.4 | 56.2 | 60.2 | 59.8 | 93.0 | 57.1 | 55.4 | 61.0 | 59.1 | | |
| 173 | 1/18/2013 | 17.4 | 17.5 | 19.0 | 18.6 | 92.7 | 18.2 | 17.6 | 20.1 | 19.6 | | |
| 174 | 1/19/2013 | 21.1 | 21.1 | 22.6 | 23.0 | 92.4 | 23.2 | 22.6 | 24.5 | 23.8 | | |
| 175 | 1/20/2013 | 29.7 | 30.0 | 30.9 | 31.2 | 96.2 | 32.7 | 31.6 | 35.0 | 33.6 | | |
| 176 | 1/21/2013 | 44.9 | 42.8 | 45.4 | 44.8 | 97.2 | 46.7 | 45.0 | 49.7 | 47.8 | | |
| 177 | 1/22/2013 | 53.5 | 54.9 | 61.5 | 58.2 | 90.5 | 60.5 | 58.2 | 63.6 | 61.1 | Outlier Ref. PM10 - not discarded | |
| 178 | 1/23/2013 | 62.1 | 63.2 | 69.2 | 68.8 | 90.8 | 69.0 | 66.4 | 74.0 | 71.3 | | |
| 179 | 1/24/2013 | 23.6 | 24.5 | 27.8 | 28.1 | 86.1 | 24.5 | 23.5 | 27.3 | 26.1 | | |
| 180 | 1/25/2013 | 19.6 | 19.3 | 21.2 | 20.4 | 93.3 | 18.9 | 18.1 | 20.5 | 19.5 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 7 of 22**

| | |
|---|---|
| Manufacturer | PALAS |
| Type of instrument | FIDAS 200 S |
| Serial-No. | SN 0111 / SN 0112 |

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 181 | 1/26/2013 | 26.6 | 25.9 | 28.3 | 28.4 | 92.5 | 26.3 | 25.1 | 27.8 | 26.5 | | Cologne, winter |
| 182 | 1/27/2013 | 9.1 | 9.2 | 15.0 | 15.0 | 61.1 | 10.6 | 10.2 | 14.8 | 14.2 | | |
| 183 | 1/28/2013 | 5.7 | 5.9 | 8.9 | 7.9 | 68.6 | 6.2 | 5.9 | 8.4 | 8.0 | | |
| 184 | 1/29/2013 | 3.4 | 3.9 | 5.5 | 4.5 | 72.0 | 4.1 | 3.7 | 5.5 | 5.1 | | |
| 185 | 1/30/2013 | 6.4 | 6.8 | 15.2 | 14.8 | 43.8 | 7.4 | 7.2 | 13.5 | 12.7 | | |
| 186 | 1/31/2013 | 8.0 | 8.5 | 20.3 | 19.2 | 41.6 | 10.1 | 9.8 | 17.2 | 16.4 | | |
| 187 | 2/1/2013 | 9.2 | 9.4 | 11.9 | 10.9 | 81.4 | 9.3 | 8.8 | 10.9 | 10.4 | | |
| 188 | 2/2/2013 | | | | | | 6.9 | 6.7 | 11.9 | 11.3 | | |
| 189 | 2/3/2013 | | | | | | 8.7 | 8.2 | 10.6 | 10.0 | | |
| 190 | 2/4/2013 | | | | | | 9.4 | 9.0 | 14.5 | 13.7 | | |
| 191 | 2/5/2013 | | | | | | | | | | Zero filter | |
| 192 | 2/6/2013 | | | | | | | | | | Zero filter | |
| 193 | 2/27/2013 | | | | | | | | | | Zero filter | Bonn, winter |
| 194 | 2/28/2013 | | | | | | | | | | Zero filter | |
| 195 | 3/1/2013 | 24.9 | 23.0 | 36.3 | 36.7 | 65.6 | 29.4 | 29.4 | 38.5 | 38.1 | | |
| 196 | 3/2/2013 | | | | | | 34.3 | 34.1 | 43.3 | 42.7 | | |
| 197 | 3/3/2013 | 22.1 | 23.2 | 29.3 | 29.8 | 76.6 | 24.7 | 24.5 | 28.6 | 28.4 | | |
| 198 | 3/4/2013 | 19.6 | 20.5 | 28.2 | 28.7 | 70.2 | 21.6 | 21.6 | 29.6 | 29.5 | | |
| 199 | 3/5/2013 | 28.4 | 27.7 | 40.2 | 39.9 | 70.1 | 31.0 | 30.9 | 41.6 | 41.1 | | |
| 200 | 3/6/2013 | 25.8 | 24.5 | 39.3 | 39.7 | 63.8 | 26.5 | 26.2 | 39.6 | 38.9 | | |
| 201 | 3/7/2013 | 28.0 | 28.3 | 39.5 | 39.5 | 71.2 | 30.9 | 30.1 | 40.9 | 40.0 | | |
| 202 | 3/8/2013 | 28.8 | 27.0 | 35.4 | 34.8 | 79.5 | 32.4 | 31.4 | 39.4 | 38.5 | | |
| 203 | 3/9/2013 | | | | | | 12.1 | 11.8 | 15.6 | 15.1 | | |
| 204 | 3/10/2013 | 21.8 | 22.0 | 23.1 | 22.3 | 96.5 | 25.6 | 25.0 | 26.7 | 26.0 | | |
| 205 | 3/11/2013 | 27.6 | 28.1 | 31.2 | 30.3 | 90.6 | 31.5 | 30.7 | 34.1 | 33.4 | | |
| 206 | 3/12/2013 | 15.6 | 15.6 | 17.8 | 17.7 | 87.9 | 16.1 | 15.3 | 19.4 | 18.5 | | |
| 207 | 3/13/2013 | 36.7 | 36.7 | 50.8 | 50.0 | 72.9 | 33.4 | 32.5 | 45.9 | 44.5 | | |
| 208 | 3/14/2013 | 19.6 | 19.2 | 27.5 | 27.6 | 70.3 | 19.2 | 18.7 | 29.6 | 28.8 | | |
| 209 | 3/15/2013 | 22.0 | 21.5 | 31.7 | 31.7 | 68.7 | 21.8 | 21.4 | 32.2 | 31.5 | | |
| 210 | 3/16/2013 | | | | | | 14.4 | 14.2 | 25.2 | 25.1 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 8 of 22**

| | |
|---|---|
| Manufacturer | PALAS |
| Type of instrument | FIDAS 200 S |
| Serial-No. | SN 0111 / SN 0112 |

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 211 | 3/17/2013 | 7.0 | 7.4 | 11.0 | 10.5 | 67.2 | 9.4 | 9.1 | 12.9 | 12.8 | | Bonn, winter |
| 212 | 3/18/2013 | 7.7 | 8.2 | 17.4 | 17.2 | 45.9 | 9.0 | 8.7 | 17.4 | 16.7 | | |
| 213 | 3/19/2013 | 9.5 | 9.9 | 17.1 | 16.8 | 57.5 | 11.0 | 10.5 | 17.2 | 16.1 | | |
| 214 | 3/20/2013 | 21.3 | 20.9 | 25.2 | 24.5 | 84.7 | 23.4 | 22.1 | 25.7 | 24.3 | | |
| 215 | 3/21/2013 | 37.5 | 36.6 | 46.3 | 45.9 | 80.5 | 39.0 | 37.4 | 45.9 | 44.0 | | |
| 216 | 3/22/2013 | 21.4 | 21.6 | 26.0 | 26.3 | 82.2 | 25.5 | 24.5 | 30.4 | 29.0 | | |
| 217 | 3/23/2013 | | | | | | 25.3 | 24.4 | 28.3 | 27.5 | | |
| 218 | 3/24/2013 | 15.1 | 15.9 | 19.7 | 18.8 | 80.6 | 17.5 | 16.8 | 20.8 | 20.0 | | |
| 219 | 3/25/2013 | 20.1 | 20.6 | 26.0 | 25.6 | 78.9 | 23.2 | 22.3 | 29.2 | 28.1 | | |
| 220 | 3/26/2013 | 15.7 | 15.3 | 21.1 | 20.4 | 74.7 | 16.9 | 16.2 | 22.9 | 22.1 | | |
| 221 | 3/27/2013 | 26.6 | 25.9 | 33.3 | 32.8 | 79.5 | 27.5 | 26.3 | 34.6 | 32.9 | | |
| 222 | 3/28/2013 | | | | | | 51.4 | 48.7 | 59.1 | 55.8 | | |
| 223 | 3/29/2013 | 71.1 | 69.8 | 76.5 | 76.3 | 92.2 | 74.6 | 70.3 | 78.0 | 73.4 | | |
| 224 | 3/30/2013 | | | | | | | | | | Zero filter | |
| 225 | 3/31/2013 | | | | | | | | | | Zero filter | |
| 226 | 4/1/2013 | | | | | | | | | | Zero filter | |
| 227 | 4/2/2013 | 20.2 | 20.2 | 24.7 | 25.2 | 81.0 | 23.4 | 22.0 | 28.0 | 26.6 | | |
| 228 | 4/3/2013 | 27.2 | 26.5 | 31.4 | 30.8 | 86.3 | 31.0 | 29.0 | 35.3 | 33.2 | | |
| 229 | 4/4/2013 | 29.5 | 29.1 | 33.5 | 33.2 | 88.0 | 35.8 | 36.2 | 39.6 | 40.2 | | |
| 230 | 4/5/2013 | 25.8 | 25.4 | 30.8 | 30.0 | 84.1 | 29.7 | 30.0 | 34.1 | 34.6 | | |
| 231 | 4/6/2013 | | | | | | 25.8 | 26.0 | 30.2 | 30.3 | | |
| 232 | 4/7/2013 | 23.0 | 22.8 | 30.9 | 30.2 | 74.9 | 25.5 | 25.7 | 32.7 | 32.5 | | |
| 233 | 4/8/2013 | 26.3 | 25.1 | 31.7 | 31.7 | 81.0 | 29.3 | 29.4 | 35.2 | 35.5 | | |
| 234 | 4/9/2013 | 16.5 | 16.5 | 21.6 | 21.0 | 77.4 | 18.1 | 18.0 | 21.3 | 21.2 | | |
| 235 | 4/10/2013 | 12.2 | 12.2 | 17.9 | 17.8 | 68.4 | 12.3 | 12.1 | 16.7 | 16.2 | | |
| 236 | 4/11/2013 | 9.4 | 8.8 | 15.9 | 15.7 | 57.4 | 7.5 | 7.4 | 13.6 | 13.2 | | |
| 237 | 4/12/2013 | 6.2 | 6.3 | 10.4 | 10.4 | 60.4 | 5.1 | 4.9 | 9.5 | 8.8 | | |
| 238 | 4/13/2013 | | | | | | 6.5 | 6.4 | 10.9 | 10.4 | | |
| 239 | 4/14/2013 | 7.2 | 6.9 | 11.9 | 11.1 | 61.4 | 5.2 | 5.2 | 9.2 | 9.1 | | |
| 240 | 4/15/2013 | 18.5 | 16.8 | 31.2 | 30.2 | 57.3 | 18.1 | 17.6 | 28.7 | 27.6 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 9 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 241 | 4/16/2013 | 12.7 | 11.2 | 21.1 | 20.7 | 57.2 | 12.3 | 12.0 | 20.8 | 20.3 | | Bonn, winter |
| 242 | 4/17/2013 | 9.9 | 9.8 | 19.5 | 19.7 | 50.2 | 8.0 | 8.0 | 19.1 | 18.6 | | |
| 243 | 4/18/2013 | 9.4 | 8.7 | 21.4 | 21.5 | 42.2 | 8.3 | 8.3 | 20.7 | 20.3 | | |
| 244 | 4/19/2013 | 10.3 | 10.3 | 21.0 | 20.8 | 49.4 | 11.7 | 11.5 | 20.6 | 19.8 | | |
| 245 | 4/20/2013 | | | | | | 13.5 | 13.3 | 20.8 | 20.1 | | |
| 246 | 4/21/2013 | 24.4 | 23.0 | 36.7 | 37.6 | 63.8 | 23.4 | 22.9 | 33.4 | 32.5 | | |
| 247 | 4/22/2013 | 31.0 | 29.4 | 44.7 | 43.9 | 68.3 | 32.7 | 31.7 | 47.2 | 45.3 | | |
| 248 | 4/23/2013 | 11.0 | 10.4 | 18.2 | 18.8 | 57.6 | 9.8 | 9.4 | 19.5 | 18.6 | | |
| 249 | 4/24/2013 | 14.3 | 12.7 | 24.2 | 24.4 | 55.6 | 13.3 | 12.8 | 25.3 | 24.6 | | |
| 250 | 4/25/2013 | 13.8 | 12.1 | 23.3 | 23.6 | 55.3 | 11.9 | 11.5 | 24.7 | 23.8 | | |
| 251 | 4/26/2013 | | | | | | | | | | Zero filter | |
| 252 | 4/27/2013 | | | | | | | | | | Zero filter | |
| 253 | 4/28/2013 | | | | | | | | | | Zero filter | |
| 254 | 4/29/2013 | 14.3 | 12.9 | 20.6 | 21.4 | 64.9 | 12.7 | 12.1 | 20.5 | 19.3 | | |
| 255 | 4/30/2013 | | | | | | 16.0 | 15.2 | 24.5 | 23.1 | | |
| 256 | 5/1/2013 | 16.9 | 18.2 | 21.4 | 22.2 | 80.7 | 19.5 | 18.1 | 23.8 | 21.9 | | |
| 257 | 5/2/2013 | | | | | | 20.0 | 18.6 | 27.7 | 25.7 | | |
| 258 | 5/3/2013 | 23.2 | 23.4 | 33.7 | 34.4 | 68.5 | 27.6 | 25.8 | 38.5 | 35.7 | | |
| 259 | 5/4/2013 | 20.2 | 19.7 | 30.1 | 30.6 | 65.7 | 21.9 | 20.5 | 31.6 | 29.5 | | |
| 260 | 5/5/2013 | 9.6 | 9.3 | 14.0 | 14.8 | 65.4 | 7.9 | 7.4 | 13.2 | 12.3 | | |
| 261 | 5/14/2013 | | | | | | | | | | Zero filter | Bornheim, summer |
| 262 | 5/15/2013 | | | | | | | | | | Zero filter | |
| 263 | 5/16/2013 | 21.0 | 20.7 | 24.5 | 24.7 | 84.6 | 18.8 | 18.7 | 22.6 | 22.5 | | |
| 264 | 5/17/2013 | 16.1 | 15.5 | 18.3 | 19.4 | 83.8 | 15.3 | 15.1 | 17.3 | 17.1 | | |
| 265 | 5/18/2013 | | | | | | 9.5 | 9.7 | 12.3 | 12.3 | | |
| 266 | 5/19/2013 | | | | | | 18.9 | 18.8 | 22.6 | 22.2 | | |
| 267 | 5/20/2013 | 11.3 | 10.3 | 13.9 | 14.7 | 75.2 | 11.2 | 11.0 | 14.3 | 13.9 | | |
| 268 | 5/21/2013 | | 5.4 | 8.3 | 8.8 | | 4.9 | 4.9 | 8.2 | 8.2 | Power failure Ref. PM2,5 Device#1 | |
| 269 | 5/22/2013 | | | | | | 6.9 | 6.9 | 11.1 | 10.8 | | |
| 270 | 5/23/2013 | | | | | | 5.5 | 5.5 | 7.4 | 7.2 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 10 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 271 | 5/24/2013 | | | 10.1 | 10.7 | | 5.9 | 5.8 | 8.6 | 8.3 | Power failure Ref. PM2,5 Device#1 | Bornheim, summer |
| 272 | 5/25/2013 | | | | | | 10.5 | 10.5 | 14.1 | 14.0 | | |
| 273 | 5/26/2013 | | 6.6 | 12.9 | 13.4 | | 7.9 | 7.6 | 11.1 | 10.7 | Power failure Ref. PM2,5 Device#1 | |
| 274 | 5/27/2013 | 11.7 | 11.0 | 16.9 | 17.6 | 65.7 | 10.6 | 10.5 | 16.4 | 16.0 | | |
| 275 | 5/28/2013 | 8.7 | 7.7 | 12.8 | 12.2 | 65.8 | 6.8 | 6.7 | 11.7 | 11.4 | | |
| 276 | 5/29/2013 | | | | | | 4.1 | 3.9 | 6.1 | 5.6 | | |
| 277 | 5/30/2013 | | | | | | 9.1 | 8.7 | 11.1 | 10.5 | | |
| 278 | 5/31/2013 | | | | | | 16.7 | 15.6 | 22.9 | 21.5 | | |
| 279 | 6/1/2013 | | | | | | 15.7 | 14.9 | 19.3 | 18.3 | | |
| 280 | 6/2/2013 | 5.3 | 5.0 | 10.8 | 10.7 | 47.7 | 4.9 | 4.8 | 8.9 | 8.7 | | |
| 281 | 6/3/2013 | 8.0 | 7.0 | 14.5 | 14.5 | 51.5 | 8.0 | 7.8 | 13.5 | 12.9 | | |
| 282 | 6/4/2013 | 9.5 | 9.5 | 18.2 | 18.4 | 51.9 | 11.6 | 11.0 | 17.9 | 16.8 | | |
| 283 | 6/5/2013 | 9.1 | 9.3 | 17.2 | 18.8 | 51.2 | 9.8 | 9.3 | 19.0 | 17.6 | | |
| 284 | 6/6/2013 | 10.8 | 10.2 | 17.0 | 17.5 | 60.8 | 8.5 | 8.0 | 16.9 | 15.8 | | |
| 285 | 6/7/2013 | 17.0 | 16.1 | 28.6 | 29.9 | 56.6 | 15.6 | 14.8 | 30.6 | 29.1 | | |
| 286 | 6/8/2013 | | | | | | 17.6 | 16.5 | 25.3 | 23.7 | | |
| 287 | 6/9/2013 | 14.0 | 13.6 | 20.1 | 21.3 | 66.9 | 16.6 | 15.2 | 20.7 | 19.1 | | |
| 288 | 6/10/2013 | 16.1 | 15.4 | 26.1 | 27.1 | 59.1 | 19.6 | 18.2 | 27.0 | 24.7 | | |
| 289 | 6/11/2013 | 13.0 | 12.2 | 20.8 | 20.7 | 60.7 | 18.2 | 19.4 | 25.2 | 26.3 | | |
| 290 | 6/12/2013 | 7.1 | 6.4 | 14.6 | 14.0 | 47.4 | 7.4 | 7.8 | 17.3 | 17.4 | | |
| 291 | 6/13/2013 | 5.6 | 5.4 | 13.4 | 12.7 | 42.1 | 5.1 | 5.3 | 14.5 | 14.1 | | |
| 292 | 6/14/2013 | 5.0 | 5.7 | 10.8 | 10.8 | 49.3 | 4.4 | 4.7 | 8.4 | 8.7 | | |
| 293 | 6/15/2013 | 5.1 | 5.3 | 10.6 | 10.2 | 50.0 | 4.3 | 4.5 | 8.7 | 8.7 | | |
| 294 | 6/16/2013 | 7.3 | 7.6 | 16.7 | 16.6 | 44.8 | 7.0 | 7.4 | 11.9 | 11.9 | | |
| 295 | 6/17/2013 | 12.2 | 13.3 | 21.3 | 20.9 | 60.3 | 10.1 | 10.5 | 19.0 | 18.8 | | |
| 296 | 6/18/2013 | 17.8 | 17.3 | 28.6 | 29.1 | 60.9 | 18.7 | 19.0 | 31.5 | 30.8 | | |
| 297 | 6/19/2013 | 31.9 | 32.7 | 48.7 | 48.5 | 66.5 | 36.2 | 35.9 | 51.4 | 49.7 | | |
| 298 | 6/20/2013 | 8.7 | 10.1 | 15.5 | 14.9 | 62.1 | 12.8 | 12.6 | 19.7 | 18.7 | | |
| 299 | 6/21/2013 | 4.2 | 4.5 | 7.2 | 6.8 | 62.2 | 3.7 | 3.8 | 7.5 | 7.1 | | |
| 300 | 6/22/2013 | 3.3 | 4.1 | 5.7 | 5.9 | 63.8 | | | | | Zero filter | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 11 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301 | 6/23/2013 | 3.1 | 3.0 | 4.6 | 5.5 | 59.8 | | | | | Zero filter | Bornheim, summer |
| 302 | 6/24/2013 | 8.7 | 8.0 | 13.9 | 13.2 | 61.6 | 9.8 | 9.6 | 13.5 | 13.0 | | |
| 303 | 6/25/2013 | 6.3 | 6.6 | 12.9 | 12.7 | 50.4 | 7.2 | 7.0 | 11.2 | 10.9 | | |
| 304 | 6/26/2013 | 9.1 | 9.4 | 14.6 | 14.5 | 63.4 | 9.0 | 8.8 | 13.1 | 12.4 | | |
| 305 | 6/27/2013 | 9.8 | 9.6 | 14.2 | 13.8 | 69.5 | 9.9 | 9.5 | 14.0 | 13.1 | | |
| 306 | 6/28/2013 | 8.8 | 8.7 | 14.2 | 14.7 | 60.4 | 9.4 | 8.9 | 15.5 | 14.7 | | |
| 307 | 6/29/2013 | 6.0 | 5.8 | 11.7 | 11.5 | 50.8 | 5.4 | 5.0 | 9.9 | 9.0 | | |
| 308 | 6/30/2013 | 7.4 | 6.9 | 14.6 | 14.4 | 49.3 | 6.9 | 6.5 | 13.1 | 11.9 | | |
| 309 | 7/1/2013 | 7.7 | 7.6 | 13.4 | 13.2 | 57.5 | 8.0 | 7.4 | 14.8 | 13.1 | | |
| 310 | 7/2/2013 | 7.9 | 7.9 | 12.5 | 12.0 | 64.9 | 7.8 | 7.3 | 12.9 | 11.8 | | |
| 311 | 7/3/2013 | 3.6 | 3.8 | 9.0 | 9.9 | 39.1 | 4.6 | 4.2 | 11.1 | 9.6 | | |
| 312 | 7/4/2013 | 7.5 | 7.9 | 13.5 | 13.6 | 56.8 | 8.0 | 7.2 | 13.3 | 11.9 | | |
| 313 | 7/5/2013 | 12.9 | 13.1 | 20.9 | 19.9 | 63.8 | 14.8 | 13.2 | 21.7 | 19.0 | | |
| 314 | 7/6/2013 | 13.3 | 13.1 | 18.7 | 18.5 | 71.0 | 15.2 | 13.8 | 20.3 | 18.3 | | |
| 315 | 7/7/2013 | 11.3 | 10.7 | 14.9 | 14.4 | 75.0 | 10.9 | 9.8 | 15.0 | 13.2 | | |
| 316 | 7/8/2013 | 11.3 | 10.6 | 16.3 | 16.1 | 67.7 | 10.1 | 9.0 | 16.4 | 14.4 | | |
| 317 | 7/9/2013 | 14.2 | 14.5 | 24.9 | 22.6 | 60.5 | 15.9 | 14.1 | 24.5 | 21.1 | | |
| 318 | 7/10/2013 | 9.7 | 10.2 | 19.1 | 17.5 | 54.6 | 11.8 | 10.4 | 19.9 | 17.0 | | |
| 319 | 7/11/2013 | 13.6 | 14.3 | 26.6 | 24.9 | 54.1 | 17.5 | 17.1 | 25.1 | 24.0 | | |
| 320 | 7/12/2013 | 16.5 | 16.8 | | | | 22.0 | 21.3 | 30.3 | 28.8 | Outlier Ref. PM10 | |
| 321 | 7/13/2013 | 15.3 | 15.3 | 20.4 | 20.7 | 74.5 | 18.3 | 17.5 | 23.4 | 22.1 | | |
| 322 | 7/14/2013 | 14.5 | 14.5 | 22.2 | 21.5 | 66.5 | 19.7 | 18.7 | 26.7 | 24.7 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 12 of 22**

Manufacturer PALAS

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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5/14/2012 | - | - | | | - | 21.3 | 21.5 | | Cologne, summer |
| 2 | 5/15/2012 | - | - | 12.1 | 10.5 | - | 10.9 | 10.9 | | |
| 3 | 5/16/2012 | - | - | 14.1 | 13.5 | - | 12.4 | 12.2 | | |
| 4 | 5/17/2012 | - | - | 13.1 | 12.3 | - | 11.7 | 11.7 | | |
| 5 | 5/18/2012 | - | - | 15.3 | 12.5 | - | 14.7 | 14.8 | Outlier Ref. PM2,5 | |
| 6 | 5/19/2012 | - | - | | | - | 14.6 | 14.6 | | |
| 7 | 5/20/2012 | - | - | 20.7 | 18.4 | - | 20.7 | 20.8 | | |
| 8 | 5/21/2012 | - | - | | | - | 48.0 | 47.9 | Outlier Ref. PM10 | |
| 9 | 5/22/2012 | - | - | | | - | 80.9 | 79.6 | | |
| 10 | 5/23/2012 | - | - | 48.2 | 46.4 | - | 45.6 | 45.0 | Outlier Ref. PM2,5 | |
| 11 | 5/24/2012 | - | - | 21.2 | 18.3 | - | 23.8 | 24.2 | | |
| 12 | 5/25/2012 | - | - | 17.8 | 15.9 | - | 18.6 | 18.5 | | |
| 13 | 5/26/2012 | - | - | | | - | 20.2 | 20.5 | | |
| 14 | 5/27/2012 | - | - | | | - | 15.8 | 16.1 | | |
| 15 | 5/28/2012 | - | - | 22.2 | 21.5 | - | 24.7 | 24.9 | | |
| 16 | 5/29/2012 | - | - | 28.8 | 27.2 | - | | 28.8 | SN 0111 accidentally switched off via remote control | |
| 17 | 5/30/2012 | - | - | 37.2 | 34.9 | - | 34.5 | 35.4 | | |
| 18 | 5/31/2012 | - | - | 23.9 | 22.7 | - | 24.6 | 24.3 | | |
| 19 | 6/1/2012 | - | - | 17.5 | 16.1 | - | 16.8 | 16.9 | | |
| 20 | 6/2/2012 | - | - | | | - | 14.7 | 15.0 | | |
| 21 | 6/3/2012 | - | - | 17.6 | 17.0 | - | 17.9 | 17.9 | | |
| 22 | 6/4/2012 | - | - | 12.1 | 11.8 | - | 11.9 | 12.0 | | |
| 23 | 6/5/2012 | - | - | 15.0 | 14.0 | - | 12.2 | 12.3 | | |
| 24 | 6/6/2012 | - | - | | | - | 10.9 | 10.9 | | |
| 25 | 6/7/2012 | - | - | 9.2 | 7.6 | - | 9.9 | 10.0 | | |
| 26 | 6/8/2012 | - | - | | | - | 8.9 | 8.9 | | |
| 27 | 6/9/2012 | - | - | | | - | 9.4 | 9.4 | | |
| 28 | 6/10/2012 | - | - | | | - | | | Power failure | |
| 29 | 6/11/2012 | - | - | 10.1 | 8.8 | - | 10.7 | 10.6 | | |
| 30 | 6/12/2012 | - | - | 20.8 | 21.3 | - | 19.2 | 19.0 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 13 of 22**

| | | |
|---|---|---|
| Manufacturer | PALAS | |
| Type of instrument | FIDAS 200 S | PM10<br>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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 6/13/2012 | - | - | 22.3 | 21.9 | - | 18.8 | 18.7 | | Cologne, summer |
| 32 | 6/14/2012 | - | - | 24.3 | 22.8 | - | 21.1 | 21.1 | | |
| 33 | 6/15/2012 | - | - | | | - | | | Inlet -> Zero filter | |
| 34 | 6/16/2012 | - | - | | | - | | | Zero filter | |
| 35 | 6/17/2012 | - | - | | | - | | | Zero filter | |
| 36 | 6/18/2012 | - | - | 18.3 | 16.9 | - | 16.6 | 16.6 | | |
| 37 | 6/19/2012 | - | - | 31.1 | 30.8 | - | 29.1 | 28.5 | | |
| 38 | 6/20/2012 | - | - | 20.2 | 19.7 | - | 20.3 | 19.8 | | |
| 39 | 6/21/2012 | - | - | 10.3 | 9.4 | - | 10.9 | 10.8 | | |
| 40 | 6/22/2012 | - | - | 14.2 | 14.3 | - | 12.3 | 12.3 | | |
| 41 | 6/23/2012 | - | - | | | - | 11.2 | 11.3 | | |
| 42 | 6/24/2012 | - | - | 9.4 | 11.5 | - | 9.6 | 9.5 | | |
| 43 | 6/25/2012 | - | - | 16.0 | 17.5 | - | 15.7 | 15.2 | | |
| 44 | 6/26/2012 | - | - | 0.0 | 21.2 | - | 17.7 | 17.6 | | |
| 45 | 6/27/2012 | - | - | 19.0 | 20.2 | - | 19.9 | 19.0 | | |
| 46 | 6/28/2012 | - | - | 19.4 | 18.9 | - | 22.6 | 22.3 | | |
| 47 | 6/29/2012 | - | - | 24.7 | 25.4 | - | 28.7 | 27.9 | | |
| 48 | 6/30/2012 | - | - | | | - | 19.1 | 18.7 | | |
| 49 | 7/1/2012 | - | - | 13.1 | 12.9 | - | 11.7 | 11.4 | | |
| 50 | 7/2/2012 | - | - | 12.2 | 13.1 | - | 11.6 | 11.3 | | |
| 51 | 7/3/2012 | - | - | 18.5 | 16.4 | - | 14.6 | 14.8 | | |
| 52 | 7/4/2012 | - | - | 17.3 | 18.4 | - | 17.5 | 17.2 | | |
| 53 | 7/5/2012 | - | - | 14.5 | 15.2 | - | 15.9 | 15.5 | | |
| 54 | 7/6/2012 | - | - | 11.7 | 11.3 | - | 10.6 | 10.6 | | |
| 55 | 7/7/2012 | - | - | | | - | 8.7 | 8.6 | | |
| 56 | 7/8/2012 | - | - | 6.9 | 7.2 | - | 6.8 | 6.8 | | |
| 57 | 7/9/2012 | - | - | 13.4 | 13.1 | - | 13.1 | 13.0 | | |
| 58 | 7/10/2012 | - | - | 13.7 | 12.4 | - | 13.3 | 13.3 | | |
| 59 | 7/11/2012 | - | - | 7.4 | 8.6 | - | 7.1 | 7.1 | | |
| 60 | 7/12/2012 | - | - | 8.8 | 7.5 | - | 7.7 | 7.7 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 14 of 22**

| | | | |
|---|---|---|---|
| Manufacturer | PALAS | | PM10 |
| Type of instrument | FIDAS 200 S | | Measured values in µg/m³ (STD) |
| Serial-No. | SN 0111 / SN 0112 | | |

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/Nm³] | Ref 2. PM10 [µg/Nm³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/Nm³] | SN 0112 PM10 [µg/Nm³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 7/13/2012 | - | - | 7.1 | 7.0 | - | 6.8 | 6.9 | | Cologne, summer |
| 62 | 7/14/2012 | - | - | | | - | 7.0 | 7.0 | | |
| 63 | 7/15/2012 | - | - | 12.6 | 11.9 | - | 10.8 | 10.8 | | |
| 64 | 7/16/2012 | - | - | 9.6 | 7.8 | - | 7.7 | 7.5 | | |
| 65 | 7/17/2012 | - | - | 13.4 | 13.9 | - | 13.1 | 12.8 | | |
| 66 | 7/18/2012 | - | - | 11.5 | 10.2 | - | 11.0 | 11.1 | | |
| 67 | 7/19/2012 | - | - | 15.4 | 14.7 | - | 13.4 | 13.1 | | |
| 68 | 7/20/2012 | - | - | | | - | | | Zero filter | |
| 69 | 7/21/2012 | - | - | | | - | | | Zero filter | |
| 70 | 7/22/2012 | - | - | | | - | | | Zero filter | |
| 71 | 7/23/2012 | - | - | 13.9 | 13.5 | - | 12.0 | 12.0 | | |
| 72 | 7/24/2012 | - | - | 26.6 | 24.8 | - | 22.3 | 22.3 | | |
| 73 | 7/25/2012 | - | - | 42.6 | 41.2 | - | 41.6 | 40.5 | | |
| 74 | 7/26/2012 | - | - | 39.1 | 38.6 | - | 42.2 | 41.6 | | |
| 75 | 7/27/2012 | - | - | | | - | 35.3 | 34.6 | | |
| 76 | 7/28/2012 | - | - | | | - | 26.0 | 25.7 | | |
| 77 | 7/29/2012 | - | - | 10.6 | 9.3 | - | 8.2 | 8.3 | | |
| 78 | 7/30/2012 | - | - | 13.0 | 13.6 | - | 9.7 | 9.5 | | |
| 79 | 7/31/2012 | - | - | 15.3 | 15.7 | - | 12.0 | 12.1 | | |
| 80 | 8/1/2012 | - | - | 18.1 | 18.9 | - | 16.8 | 16.5 | | |
| 81 | 8/2/2012 | - | - | 14.2 | 14.5 | - | 12.2 | 12.2 | | |
| 82 | 8/3/2012 | - | - | | | - | 13.2 | 13.3 | | |
| 83 | 8/4/2012 | - | - | | | - | 11.7 | 11.7 | | |
| 84 | 8/5/2012 | - | - | 9.0 | 9.7 | - | 8.6 | 8.4 | | |
| 85 | 8/6/2012 | - | - | 8.7 | 10.3 | - | 7.9 | 7.6 | | |
| 86 | 8/7/2012 | - | - | 14.3 | 13.6 | - | 11.0 | 10.8 | | |
| 87 | 8/8/2012 | - | - | 17.3 | 17.7 | - | 13.6 | 13.5 | | |
| 88 | 8/9/2012 | - | - | 13.0 | 13.6 | - | 12.5 | 12.3 | | |
| 89 | 8/10/2012 | - | - | | | - | 11.3 | 11.2 | | |
| 90 | 8/11/2012 | - | - | | | - | 9.6 | 9.3 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** 

| | | |
|---|---|---|
| Manufacturer | PALAS | |
| Type of instrument | FIDAS 200 S | PM10<br>Measured values in µg/m³ (STD) |
| Serial-No. | SN 0111 / SN 0112 | |

| No. | Date | Ref. 1<br>PM2,5<br>[µg/m³] | Ref. 2<br>PM2,5<br>[µg/m³] | Ref. 1<br>PM10<br>[µg/Nm³] | Ref 2.<br>PM10<br>[µg/Nm³] | Ratio<br>PM2,5/PM10<br>[%] | SN 0111<br>PM10<br>[µg/Nm³] | SN 0112<br>PM10<br>[µg/Nm³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|
| 91 | 8/12/2012 | - | - | 10.8 | 10.9 | - | 10.5 | 10.4 | | Cologne, summer |
| 92 | 8/13/2012 | - | - | 16.8 | 18.3 | - | 16.4 | 16.1 | | |
| 93 | 8/14/2012 | - | - | 18.7 | 18.1 | - | 16.0 | 15.7 | | |
| 94 | 8/15/2012 | - | - | 21.4 | 22.0 | - | 22.0 | 21.0 | | |
| 95 | 8/16/2012 | - | - | 19.3 | 21.1 | - | 14.0 | 13.5 | | |
| 96 | 8/17/2012 | - | - | | | - | | | Zero filter | |
| 97 | 8/18/2012 | - | - | | | - | | | Zero filter | |
| 98 | 8/19/2012 | - | - | | | - | | | Zero filter | |
| 99 | 8/20/2012 | - | - | 31.0 | 31.6 | - | 29.3 | 28.0 | | |
| 100 | 8/21/2012 | - | - | 31.9 | 32.0 | - | 32.1 | 30.4 | | |
| 101 | 8/22/2012 | - | - | 22.1 | 21.4 | - | 19.0 | 18.5 | | |
| 102 | 8/23/2012 | - | - | 15.6 | 14.9 | - | 12.7 | 12.2 | | |
| 103 | 8/24/2012 | - | - | 16.5 | 16.4 | - | 15.0 | 14.2 | | |
| 104 | 8/25/2012 | - | - | | | - | 6.7 | 6.3 | | |
| 105 | 8/26/2012 | - | - | 12.7 | 11.8 | - | 11.0 | 10.8 | | |
| 106 | 8/27/2012 | - | - | 11.5 | 11.5 | - | 9.4 | 9.2 | | |
| 107 | 8/28/2012 | - | - | 15.8 | 18.2 | - | 13.9 | 13.3 | | |
| 108 | 8/29/2012 | - | - | 17.8 | 17.9 | - | 14.7 | 14.5 | | |
| 109 | 8/30/2012 | - | - | 15.2 | 15.4 | - | 13.0 | 12.6 | | |
| 110 | 8/31/2012 | - | - | 11.2 | 11.5 | - | 10.4 | 10.2 | | |
| 111 | 9/1/2012 | - | - | | | - | 13.3 | 12.7 | | |
| 112 | 9/2/2012 | - | - | 19.8 | 19.0 | - | 14.4 | 13.9 | | |
| 113 | 11/19/2012 | - | - | | | - | | | Zero filter | Cologne, winter |
| 114 | 11/20/2012 | - | - | | | - | | | Zero filter | |
| 115 | 11/21/2012 | - | - | | | - | | | | |
| 116 | 11/22/2012 | - | - | | | - | 14.6 | 14.3 | | |
| 117 | 11/23/2012 | - | - | 20.2 | 20.3 | - | 21.1 | 20.3 | | |
| 118 | 11/24/2012 | - | - | | | - | 20.2 | 20.0 | | |
| 119 | 11/25/2012 | - | - | 11.2 | 10.9 | - | 10.5 | 10.4 | | |
| 120 | 11/26/2012 | - | - | 11.5 | 12.2 | - | 11.6 | 11.3 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 16 of 22**

| | |
|---|---|
| Manufacturer | PALAS |
| Type of instrument | FIDAS 200 S |
| 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 121 | 11/27/2012 | - | - | 19.2 | 18.4 | - | 16.5 | 16.4 | | Cologne, winter |
| 122 | 11/28/2012 | - | - | 30.0 | 30.2 | - | 31.7 | 31.2 | | |
| 123 | 11/29/2012 | - | - | 14.6 | 14.8 | - | 15.1 | 15.1 | | |
| 124 | 11/30/2012 | - | - | 24.7 | 24.7 | - | 23.7 | 23.0 | | |
| 125 | 12/1/2012 | - | - | | | - | 16.3 | 15.8 | | |
| 126 | 12/2/2012 | - | - | 15.1 | 15.0 | - | 14.9 | 14.6 | | |
| 127 | 12/3/2012 | - | - | 14.5 | 14.8 | - | 13.9 | 13.4 | | |
| 128 | 12/4/2012 | - | - | 12.0 | 12.1 | - | 12.2 | | SN 0112 Fuse for heater burned | |
| 129 | 12/5/2012 | - | - | 12.3 | 12.8 | - | | 12.4 | SN 0111 Fuse for heater burned | |
| 130 | 12/6/2012 | - | - | 16.7 | 16.3 | - | 16.9 | 16.2 | | |
| 131 | 12/7/2012 | - | - | 15.4 | 15.5 | - | 15.5 | 14.7 | | |
| 132 | 12/8/2012 | - | - | | | - | 31.1 | | SN 0112 Fuse for heater burned | |
| 133 | 12/9/2012 | - | - | 10.4 | 9.1 | - | 10.0 | | SN 0112 Fuse for heater burned | |
| 134 | 12/10/2012 | - | - | 14.6 | 13.7 | - | 16.0 | 14.8 | | |
| 135 | 12/11/2012 | - | - | 23.4 | 22.7 | - | 23.6 | 22.6 | | |
| 136 | 12/12/2012 | - | - | 24.6 | 24.3 | - | 23.0 | 22.3 | | |
| 137 | 12/13/2012 | - | - | 29.7 | 28.7 | - | 28.2 | 27.4 | | |
| 138 | 12/14/2012 | - | - | 9.3 | 9.2 | - | 9.7 | 9.3 | | |
| 139 | 12/15/2012 | - | - | | | - | 6.8 | 6.4 | | |
| 140 | 12/16/2012 | - | - | 10.1 | 9.9 | - | 9.6 | 9.1 | | |
| 141 | 12/17/2012 | - | - | 14.2 | 13.9 | - | 13.9 | 13.1 | | |
| 142 | 12/18/2012 | - | - | 20.5 | 21.0 | - | 19.5 | 18.4 | | |
| 143 | 12/19/2012 | - | - | 18.5 | 18.3 | - | 18.4 | 17.6 | | |
| 144 | 12/20/2012 | - | - | 14.3 | 13.9 | - | 14.1 | 13.5 | | |
| 145 | 12/21/2012 | - | - | 18.5 | 18.4 | - | 17.7 | 16.9 | | |
| 146 | 12/22/2012 | - | - | | | - | 6.7 | 6.3 | | |
| 147 | 12/23/2012 | - | - | | | - | 6.6 | 6.4 | | |
| 148 | 12/24/2012 | - | - | | | - | 15.5 | 14.9 | | |
| 149 | 12/25/2012 | - | - | | | - | 4.1 | 3.9 | | |
| 150 | 12/26/2012 | - | - | | | - | 9.7 | 9.2 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 17 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/Nm³] | Ref 2. PM10 [µg/Nm³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/Nm³] | SN 0112 PM10 [µg/Nm³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|
| 151 | 12/27/2012 | - | - | | | - | 16.9 | 16.6 | | Cologne, winter |
| 152 | 12/28/2012 | - | - | | | - | 7.2 | 7.0 | | |
| 153 | 12/29/2012 | - | - | | | - | 6.1 | 5.9 | | |
| 154 | 12/30/2012 | - | - | | | - | 9.0 | 8.7 | | |
| 155 | 12/31/2012 | - | - | | | - | | | Power failure | |
| 156 | 1/1/2013 | - | - | | | - | | | Power failure | |
| 157 | 1/2/2013 | - | - | 16.4 | 15.3 | - | 16.0 | 15.2 | | |
| 158 | 1/3/2013 | - | - | 19.8 | 19.1 | - | 21.9 | 20.9 | | |
| 159 | 1/4/2013 | - | - | 14.0 | 13.3 | - | 14.6 | 14.2 | | |
| 160 | 1/5/2013 | - | - | | | - | 21.7 | 21.2 | | |
| 161 | 1/6/2013 | - | - | 38.2 | 38.4 | - | 36.4 | 35.3 | | |
| 162 | 1/7/2013 | - | - | 25.0 | 25.7 | - | 24.5 | 23.9 | | |
| 163 | 1/8/2013 | - | - | 20.0 | 20.6 | - | 21.4 | 20.8 | | |
| 164 | 1/9/2013 | - | - | 19.2 | 20.2 | - | 20.1 | 19.4 | | |
| 165 | 1/10/2013 | - | - | 22.3 | 22.0 | - | 20.1 | 19.6 | | |
| 166 | 1/11/2013 | - | - | | | - | | | Zero filter | |
| 167 | 1/12/2013 | - | - | | | - | | | Zero filter | |
| 168 | 1/13/2013 | - | - | | | - | | | Zero filter | |
| 169 | 1/14/2013 | - | - | 28.4 | 29.5 | - | 27.6 | 26.7 | | |
| 170 | 1/15/2013 | - | - | 36.5 | 37.6 | - | 34.5 | 32.7 | | |
| 171 | 1/16/2013 | - | - | 63.6 | 63.6 | - | 66.9 | 64.4 | | |
| 172 | 1/17/2013 | - | - | 59.9 | 59.9 | - | 60.9 | 59.4 | | |
| 173 | 1/18/2013 | - | - | 19.2 | 18.9 | - | 20.4 | 20.0 | | |
| 174 | 1/19/2013 | - | - | 22.9 | 23.4 | - | 24.9 | 24.2 | | |
| 175 | 1/20/2013 | - | - | 31.5 | 32.0 | - | 35.7 | 34.2 | | |
| 176 | 1/21/2013 | - | - | 45.8 | 45.8 | - | 50.8 | 48.7 | | |
| 177 | 1/22/2013 | - | - | 62.3 | 59.3 | - | 64.7 | 61.9 | Outlier Ref. PM10 - not discarded | |
| 178 | 1/23/2013 | - | - | 69.6 | 69.6 | - | 75.1 | 71.8 | | |
| 179 | 1/24/2013 | - | - | 27.7 | 28.1 | - | 27.3 | 26.1 | | |
| 180 | 1/25/2013 | - | - | 21.1 | 20.5 | - | 20.5 | 19.6 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 18 of 22**

| | |
|---|---|
| Manufacturer | PALAS |
| Type of instrument | FIDAS 200 S |
| Serial-No. | SN 0111 / SN 0112 |

PM10
Measured values in µg/m³ (STD)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/Nm³] | Ref 2. PM10 [µg/Nm³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/Nm³] | SN 0112 PM10 [µg/Nm³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|
| 181 | 1/26/2013 | - | - | 28.5 | 28.7 | - | 28.0 | 26.7 | | Cologne, winter |
| 182 | 1/27/2013 | - | - | 15.3 | 15.4 | - | 15.2 | 14.5 | | |
| 183 | 1/28/2013 | - | - | 9.2 | 8.2 | - | 8.6 | 8.2 | | |
| 184 | 1/29/2013 | - | - | 5.8 | 4.8 | - | 5.8 | 5.4 | | |
| 185 | 1/30/2013 | - | - | 15.8 | 15.6 | - | 14.2 | 13.4 | | |
| 186 | 1/31/2013 | - | - | 21.0 | 20.0 | - | 17.9 | 17.1 | | |
| 187 | 2/1/2013 | - | - | 12.3 | 11.4 | - | 11.4 | 10.7 | | |
| 188 | 2/2/2013 | - | - | | | - | 12.2 | 11.6 | | |
| 189 | 2/3/2013 | - | - | | | - | 10.9 | 10.3 | | |
| 190 | 2/4/2013 | - | - | | | - | 15.2 | 14.4 | | |
| 191 | 2/5/2013 | - | - | | | - | | | Zero filter | |
| 192 | 2/6/2013 | - | - | | | - | | | Zero filter | |
| 193 | 2/27/2013 | - | - | | | - | | | Zero filter | Bonn, winter |
| 194 | 2/28/2013 | - | - | | | - | | | Zero filter | |
| 195 | 3/1/2013 | - | - | 36.6 | 37.1 | - | 38.9 | 38.5 | | |
| 196 | 3/2/2013 | - | - | | | - | 43.7 | 43.1 | | |
| 197 | 3/3/2013 | - | - | 29.5 | 30.2 | - | 28.9 | 28.7 | | |
| 198 | 3/4/2013 | - | - | 28.9 | 29.7 | - | 30.5 | 30.4 | | |
| 199 | 3/5/2013 | - | - | 41.8 | 41.8 | - | 43.4 | 42.9 | | |
| 200 | 3/6/2013 | - | - | 41.5 | 42.3 | - | 42.1 | 41.4 | | |
| 201 | 3/7/2013 | - | - | 41.9 | 42.3 | - | 43.7 | 42.8 | | |
| 202 | 3/8/2013 | - | - | 37.8 | 37.4 | - | 42.3 | 41.3 | | |
| 203 | 3/9/2013 | - | - | 0.0 | 0.0 | - | 16.6 | 16.1 | | |
| 204 | 3/10/2013 | - | - | 23.6 | 22.9 | - | 27.4 | 26.7 | | |
| 205 | 3/11/2013 | - | - | 31.5 | 30.8 | - | 34.5 | 33.8 | | |
| 206 | 3/12/2013 | - | - | 17.9 | 17.9 | - | 19.5 | 18.6 | | |
| 207 | 3/13/2013 | - | - | 51.3 | 50.9 | - | 46.4 | 44.9 | | |
| 208 | 3/14/2013 | - | - | 27.5 | 27.9 | - | 29.7 | 28.9 | | |
| 209 | 3/15/2013 | - | - | 32.0 | 32.3 | - | 32.7 | 32.0 | | |
| 210 | 3/16/2013 | - | - | | | - | 26.1 | 25.9 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 19 of 22**

Manufacturer PALAS
Type of instrument FIDAS 200 S
Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/Nm³] | Ref 2. PM10 [µg/Nm³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/Nm³] | SN 0112 PM10 [µg/Nm³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|
| 211 | 3/17/2013 | - | - | 11.4 | 11.0 | - | 13.5 | 13.3 | | Bonn, winter |
| 212 | 3/18/2013 | - | - | 18.2 | 18.1 | - | 18.3 | 17.6 | | |
| 213 | 3/19/2013 | - | - | 17.7 | 17.5 | - | 18.0 | 16.8 | | |
| 214 | 3/20/2013 | - | - | 25.8 | 25.2 | - | 26.4 | 24.8 | | |
| 215 | 3/21/2013 | - | - | 46.4 | 46.3 | - | 46.2 | 44.3 | | |
| 216 | 3/22/2013 | - | - | 26.4 | 26.8 | - | 31.0 | 29.5 | | |
| 217 | 3/23/2013 | - | - | | | - | 28.7 | 27.8 | | |
| 218 | 3/24/2013 | - | - | 19.9 | 19.1 | - | 21.1 | 20.3 | | |
| 219 | 3/25/2013 | - | - | 26.2 | 25.9 | - | 29.6 | 28.5 | | |
| 220 | 3/26/2013 | - | - | 21.4 | 20.8 | - | 23.3 | 22.5 | | |
| 221 | 3/27/2013 | - | - | 33.9 | 33.6 | - | 35.4 | 33.6 | | |
| 222 | 3/28/2013 | - | - | | | - | 60.6 | 57.2 | | |
| 223 | 3/29/2013 | - | - | 78.1 | 77.4 | - | 79.3 | 74.6 | | |
| 224 | 3/30/2013 | - | - | | | - | | | Zero filter | |
| 225 | 3/31/2013 | - | - | | | - | | | Zero filter | |
| 226 | 4/1/2013 | - | - | | | - | | | Zero filter | |
| 227 | 4/2/2013 | - | - | 25.2 | 25.8 | - | 28.7 | 27.2 | | |
| 228 | 4/3/2013 | - | - | 31.9 | 31.5 | - | 36.0 | 33.8 | | |
| 229 | 4/4/2013 | - | - | 34.3 | 34.2 | - | 40.7 | 41.4 | | |
| 230 | 4/5/2013 | - | - | 31.5 | 30.8 | - | 34.9 | 35.5 | | |
| 231 | 4/6/2013 | - | - | | | - | 30.7 | 30.8 | | |
| 232 | 4/7/2013 | - | - | 31.7 | 31.2 | - | 33.6 | 33.4 | | |
| 233 | 4/8/2013 | - | - | 32.9 | 33.1 | - | 36.7 | 37.0 | | |
| 234 | 4/9/2013 | - | - | 22.6 | 22.2 | - | 22.4 | 22.3 | | |
| 235 | 4/10/2013 | - | - | 18.7 | 18.8 | - | 17.6 | 17.1 | | |
| 236 | 4/11/2013 | - | - | 16.9 | 16.9 | - | 14.5 | 14.1 | | |
| 237 | 4/12/2013 | - | - | 11.0 | 11.1 | - | 10.1 | 9.3 | | |
| 238 | 4/13/2013 | - | - | | | - | 11.4 | 10.9 | | |
| 239 | 4/14/2013 | - | - | 12.6 | 11.9 | - | 9.8 | 9.7 | | |
| 240 | 4/15/2013 | - | - | 33.0 | 32.3 | - | 30.6 | 29.5 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 20 of 22**

| | |
|---|---|
| Manufacturer | PALAS |
| Type of instrument | FIDAS 200 S |
| Serial-No. | SN 0111 / SN 0112 |

PM10
Measured values in µg/m³ (STD)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/Nm³] | Ref 2. PM10 [µg/Nm³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/Nm³] | SN 0112 PM10 [µg/Nm³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|
| 241 | 4/16/2013 | - | - | 22.4 | 22.2 | - | 22.2 | 21.7 | | Bonn, winter |
| 242 | 4/17/2013 | - | - | 20.9 | 21.2 | - | 20.5 | 20.0 | | |
| 243 | 4/18/2013 | - | - | 22.6 | 22.9 | - | 22.0 | 21.5 | | |
| 244 | 4/19/2013 | - | - | 21.7 | 21.7 | - | 21.4 | 20.5 | | |
| 245 | 4/20/2013 | - | - | | | - | 21.5 | 20.8 | | |
| 246 | 4/21/2013 | - | - | 38.2 | 39.4 | - | 34.9 | 34.0 | | |
| 247 | 4/22/2013 | - | - | 46.8 | 46.4 | - | 49.7 | 47.7 | | |
| 248 | 4/23/2013 | - | - | 19.0 | 19.8 | - | 20.5 | 19.5 | | |
| 249 | 4/24/2013 | - | - | 25.7 | 26.0 | - | 26.9 | 26.1 | | |
| 250 | 4/25/2013 | - | - | 24.9 | 25.4 | - | 26.6 | 25.6 | | |
| 251 | 4/26/2013 | - | - | | | - | | | Zero filter | |
| 252 | 4/27/2013 | - | - | | | - | | | Zero filter | |
| 253 | 4/28/2013 | - | - | | | - | | | Zero filter | |
| 254 | 4/29/2013 | - | - | 21.5 | 22.6 | - | 21.4 | 20.2 | | |
| 255 | 4/30/2013 | - | - | | | - | 25.6 | 24.1 | | |
| 256 | 5/1/2013 | - | - | 22.4 | 23.4 | - | 25.1 | 23.1 | | |
| 257 | 5/2/2013 | - | - | | | - | 29.4 | 27.4 | | |
| 258 | 5/3/2013 | - | - | 35.6 | 36.7 | - | 41.0 | 38.0 | | |
| 259 | 5/4/2013 | - | - | 31.7 | 32.5 | - | 33.5 | 31.3 | | |
| 260 | 5/5/2013 | - | - | 14.8 | 15.7 | - | 14.0 | 13.0 | | |
| 261 | 5/14/2013 | - | - | | | - | | | Zero filter | Bornheim, summer |
| 262 | 5/15/2013 | - | - | | | - | | | Zero filter | |
| 263 | 5/16/2013 | - | - | 26.2 | 26.6 | - | 24.2 | 24.1 | | |
| 264 | 5/17/2013 | - | - | 19.3 | 20.5 | - | 18.2 | 18.0 | | |
| 265 | 5/18/2013 | - | - | | | - | 13.0 | 13.0 | | |
| 266 | 5/19/2013 | - | - | | | - | 24.4 | 23.9 | | |
| 267 | 5/20/2013 | - | - | 14.6 | 15.6 | - | 15.1 | 14.6 | | |
| 268 | 5/21/2013 | - | - | 8.7 | 9.4 | - | 8.6 | 8.7 | Power failure Ref. PM2,5 Device#1 | |
| 269 | 5/22/2013 | - | - | | | - | 11.5 | 11.3 | | |
| 270 | 5/23/2013 | - | - | | | - | 7.6 | 7.5 | | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 21 of 22**

| | | | |
|---|---|---|---|
| Manufacturer | PALAS | | 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 271 | 5/24/2013 | - | - | 10.5 | 11.1 | - | 8.9 | 8.6 | Power failure Ref. PM2,5 Device#1 | Bornheim, summer |
| 272 | 5/25/2013 | - | - | | | - | 14.8 | 14.7 | | |
| 273 | 5/26/2013 | - | - | 13.4 | 14.0 | - | 11.6 | 11.2 | Power failure Ref. PM2,5 Device#1 | |
| 274 | 5/27/2013 | - | - | 18.0 | 18.7 | - | 17.5 | 17.0 | | |
| 275 | 5/28/2013 | - | - | 13.8 | 13.3 | - | 12.7 | 12.4 | | |
| 276 | 5/29/2013 | - | - | | | - | 6.4 | 5.9 | | |
| 277 | 5/30/2013 | - | - | | | - | 11.8 | 11.2 | | |
| 278 | 5/31/2013 | - | - | | | - | 24.6 | 23.0 | | |
| 279 | 6/1/2013 | - | - | | | - | 20.3 | 19.1 | | |
| 280 | 6/2/2013 | - | - | 11.3 | 11.3 | - | 9.3 | 9.1 | | |
| 281 | 6/3/2013 | - | - | 15.0 | 15.1 | - | 14.0 | 13.4 | | |
| 282 | 6/4/2013 | - | - | 19.2 | 19.5 | - | 18.9 | 17.7 | | |
| 283 | 6/5/2013 | - | - | 18.4 | 20.2 | - | 20.4 | 18.9 | | |
| 284 | 6/6/2013 | - | - | 18.2 | 18.9 | - | 18.3 | 17.0 | | |
| 285 | 6/7/2013 | - | - | 30.8 | 32.3 | - | 33.1 | 31.5 | | |
| 286 | 6/8/2013 | - | - | | | - | 27.5 | 25.7 | | |
| 287 | 6/9/2013 | - | - | 21.4 | 22.8 | - | 22.1 | 20.4 | | |
| 288 | 6/10/2013 | - | - | 27.6 | 28.9 | - | 28.6 | 26.2 | | |
| 289 | 6/11/2013 | - | - | 22.2 | 22.3 | - | 27.0 | 28.2 | | |
| 290 | 6/12/2013 | - | - | 15.7 | 15.1 | - | 18.7 | 18.8 | | |
| 291 | 6/13/2013 | - | - | 14.2 | 13.6 | - | 15.5 | 15.0 | | |
| 292 | 6/14/2013 | - | - | 11.5 | 11.5 | - | 8.9 | 9.2 | | |
| 293 | 6/15/2013 | - | - | 11.3 | 10.9 | - | 9.3 | 9.3 | | |
| 294 | 6/16/2013 | - | - | 17.9 | 17.7 | - | 12.8 | 12.8 | | |
| 295 | 6/17/2013 | - | - | 23.3 | 22.8 | - | 20.8 | 20.6 | | |
| 296 | 6/18/2013 | - | - | 31.5 | 32.1 | - | 34.8 | 34.0 | | |
| 297 | 6/19/2013 | - | - | 53.8 | 53.8 | - | 56.9 | 55.0 | | |
| 298 | 6/20/2013 | - | - | 16.8 | 16.1 | - | 21.4 | 20.3 | | |
| 299 | 6/21/2013 | - | - | 7.7 | 7.3 | - | 8.1 | 7.6 | | |
| 300 | 6/22/2013 | - | - | 6.1 | 6.4 | - | | | Zero filter | |

**Annex 5** **$PM_{10}$-measured values from field test sites, related to standard conditions [EN 12431]** **Page 22 of 22**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10
Measured values in µg/m³ (STD)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/Nm³] | Ref 2. PM10 [µg/Nm³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/Nm³] | SN 0112 PM10 [µg/Nm³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|
| 301 | 6/23/2013 | - | - | 4.9 | 5.8 | - | | | Zero filter | Bornheim, summer |
| 302 | 6/24/2013 | - | - | 14.6 | 13.9 | - | 14.3 | 13.7 | | |
| 303 | 6/25/2013 | - | - | 13.5 | 13.2 | - | 11.7 | 11.3 | | |
| 304 | 6/26/2013 | - | - | 15.3 | 15.2 | - | 13.6 | 12.9 | | |
| 305 | 6/27/2013 | - | - | 14.9 | 14.5 | - | 14.7 | 13.8 | | |
| 306 | 6/28/2013 | - | - | 15.0 | 15.6 | - | 16.3 | 15.5 | | |
| 307 | 6/29/2013 | - | - | 12.3 | 12.2 | - | 10.5 | 9.5 | | |
| 308 | 6/30/2013 | - | - | 15.5 | 15.4 | - | 13.9 | 12.7 | | |
| 309 | 7/1/2013 | - | - | 14.3 | 14.2 | - | 15.9 | 14.0 | | |
| 310 | 7/2/2013 | - | - | 13.6 | 13.0 | - | 14.0 | 12.9 | | |
| 311 | 7/3/2013 | - | - | 9.7 | 10.6 | - | 11.9 | 10.3 | | |
| 312 | 7/4/2013 | - | - | 14.4 | 14.6 | - | 14.2 | 12.7 | | |
| 313 | 7/5/2013 | - | - | 22.2 | 21.2 | - | 23.1 | 20.2 | | |
| 314 | 7/6/2013 | - | - | 20.0 | 19.9 | - | 21.7 | 19.6 | | |
| 315 | 7/7/2013 | - | - | 16.0 | 15.5 | - | 16.1 | 14.2 | | |
| 316 | 7/8/2013 | - | - | 17.6 | 17.3 | - | 17.7 | 15.5 | | |
| 317 | 7/9/2013 | - | - | 26.9 | 24.5 | - | 26.5 | 22.9 | | |
| 318 | 7/10/2013 | - | - | 20.4 | 18.8 | - | 21.3 | 18.2 | | |
| 319 | 7/11/2013 | - | - | 28.1 | 26.3 | - | 26.5 | 25.3 | | |
| 320 | 7/12/2013 | - | - | | | - | 32.1 | 30.5 | Outlier Ref. PM10 | |
| 321 | 7/13/2013 | - | - | 21.7 | 22.0 | - | 24.9 | 23.5 | | |
| 322 | 7/14/2013 | - | - | 23.7 | 23.0 | - | 28.5 | 26.4 | | |

**Annex 6** **Ambient conditions from field test sites** **Page 1 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5/14/2012 | Cologne, summer | 15.4 | 22.1 | 1006 | 52.7 | 0.9 | 144 | 0.9 |
| 2 | 5/15/2012 | | 9.2 | 15.7 | 1006 | 76.3 | 1.2 | 119 | 6.0 |
| 3 | 5/16/2012 | | 8.9 | 14.6 | 1016 | 65.0 | 1.1 | 138 | 1.2 |
| 4 | 5/17/2012 | | 14.4 | 18.8 | 1008 | 46.4 | 0.9 | 177 | 0.0 |
| 5 | 5/18/2012 | | 15.4 | 20.0 | 1003 | 72.3 | 0.6 | 187 | 0.0 |
| 6 | 5/19/2012 | | 19.3 | 24.9 | 1002 | 65.9 | 0.2 | 231 | 0.0 |
| 7 | 5/20/2012 | | 19.5 | 27.8 | 997 | 70.6 | 0.2 | 148 | 0.3 |
| 8 | 5/21/2012 | | 21.2 | 26.4 | 993 | 68.1 | 0.4 | 135 | 0.0 |
| 9 | 5/22/2012 | | 21.5 | 27.6 | 1005 | 72.2 | 0.5 | 110 | 0.0 |
| 10 | 5/23/2012 | | 20.3 | 26.0 | 1015 | 76.0 | 0.2 | 176 | 0.0 |
| 11 | 5/24/2012 | | 23.2 | 31.5 | 1017 | 50.4 | 0.7 | 159 | 0.0 |
| 12 | 5/25/2012 | | 21.2 | 28.6 | 1016 | 39.9 | 1.0 | 177 | 0.0 |
| 13 | 5/26/2012 | | 21.3 | 28.1 | 1013 | 46.2 | 0.6 | 187 | 0.0 |
| 14 | 5/27/2012 | | 21.4 | 28.1 | 1010 | 51.8 | 0.3 | 200 | 0.0 |
| 15 | 5/28/2012 | | 21.7 | 27.8 | 1007 | 53.4 | 0.8 | 108 | 0.0 |
| 16 | 5/29/2012 | | 20.4 | 25.4 | 1008 | 57.7 | 0.9 | 104 | 0.0 |
| 17 | 5/30/2012 | | 19.8 | 24.7 | 1011 | 61.7 | 0.7 | 140 | 0.0 |
| 18 | 5/31/2012 | | 17.1 | 24.4 | 1009 | 76.1 | 0.9 | 130 | 13.3 |
| 19 | 6/1/2012 | | 15.0 | 18.4 | 1011 | 68.6 | 0.8 | 107 | 0.0 |
| 20 | 6/2/2012 | | 15.2 | 20.2 | 1006 | 58.2 | 0.7 | 151 | 3.0 |
| 21 | 6/3/2012 | | 11.9 | 15.2 | 1002 | 87.2 | 0.3 | 154 | 6.8 |
| 22 | 6/4/2012 | | 12.2 | 20.2 | 1006 | 80.4 | 0.9 | 125 | 7.2 |
| 23 | 6/5/2012 | | 14.2 | 19.0 | 1007 | 60.8 | 0.5 | 167 | 6.5 |
| 24 | 6/6/2012 | | 16.0 | 20.0 | 1000 | 78.5 | 0.4 | 165 | 5.0 |
| 25 | 6/7/2012 | | 19.7 | 24.5 | 996 | 69.4 | 1.1 | 178 | 0.3 |
| 26 | 6/8/2012 | | 17.5 | 23.1 | 1003 | 58.9 | 2.7 | 189 | 0.3 |
| 27 | 6/9/2012 | | 15.5 | 19.9 | 1006 | 57.5 | 1.6 | 166 | 0.0 |
| 28 | 6/10/2012 | | 17.8 | 26.6 | 1000 | 56.8 | 0.3 | 184 | 0.0 |
| 29 | 6/11/2012 | | 15.5 | 19.9 | 995 | 81.8 | 0.4 | 151 | 26.6 |
| 30 | 6/12/2012 | | 16.4 | 21.1 | 1000 | 72.0 | 0.8 | 116 | 0.0 |

**Annex 6** **Ambient conditions from field test sites** **Page 2 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 31 | 6/13/2012 | Cologne, summer | 13.9 | 15.4 | 1010 | 71.0 | 0.2 | 114 | 0.0 |
| 32 | 6/14/2012 | | 16.4 | 20.9 | 1010 | 65.0 | 0.2 | 174 | 0.3 |
| 34 | 6/15/2012 | | 17.8 | 21.8 | 1007 | 79.2 | 0.4 | 152 | 11.6 |
| 34 | 6/16/2012 | | 15.7 | 18.1 | 1010 | 82.0 | 0.6 | 155 | 1.8 |
| 35 | 6/17/2012 | | 18.4 | 24.1 | 1011 | 61.8 | 0.6 | 133 | 0.0 |
| 36 | 6/18/2012 | | 18.9 | 24.9 | 1011 | 69.1 | 0.7 | 137 | 0.0 |
| 37 | 6/19/2012 | | 18.6 | 21.4 | 1010 | 73.9 | 0.1 | 149 | 7.5 |
| 38 | 6/20/2012 | | 18.6 | 23.0 | 1006 | 82.1 | 0.3 | 135 | 2.1 |
| 39 | 6/21/2012 | | 19.0 | 24.6 | 1005 | 76.2 | 0.4 | 151 | 12.7 |
| 40 | 6/22/2012 | | 17.0 | 21.9 | 1013 | 64.6 | 1.2 | 161 | 0.6 |
| 41 | 6/23/2012 | | 18.6 | 23.4 | 1014 | 59.4 | 0.7 | 138 | 0.0 |
| 42 | 6/24/2012 | | 15.7 | 20.0 | 1006 | 76.5 | 1.6 | 162 | 6.9 |
| 43 | 6/25/2012 | | 15.5 | 19.9 | 1012 | 71.5 | 0.8 | 124 | 0.6 |
| 44 | 6/26/2012 | | 19.1 | 24.2 | 1014 | 61.4 | 0.5 | 138 | 0.0 |
| 45 | 6/27/2012 | | 20.3 | 23.2 | 1009 | 82.7 | 0.3 | 136 | 0.3 |
| 46 | 6/28/2012 | | 24.9 | 32.0 | 1001 | 68.1 | 0.7 | 172 | 10.0 |
| 47 | 6/29/2012 | | 19.7 | 27.4 | 1004 | 84.5 | 0.2 | 146 | 29.5 |
| 48 | 6/30/2012 | | 21.2 | 26.0 | 1006 | 67.3 | 0.6 | 152 | 0.0 |
| 49 | 7/1/2012 | | 17.3 | 23.2 | 1012 | 64.9 | 0.4 | 150 | 0.0 |
| 50 | 7/2/2012 | | 17.5 | 21.9 | 1012 | 71.0 | 0.2 | 183 | 0.0 |
| 51 | 7/3/2012 | | 22.2 | 27.7 | 1009 | 59.9 | 0.2 | 163 | 0.0 |
| 52 | 7/4/2012 | | 24.0 | 28.8 | 1004 | 60.6 | 0.5 | 171 | 0.0 |
| 53 | 7/5/2012 | | 23.6 | 30.6 | 1002 | 68.8 | 0.4 | 189 | 0.0 |
| 54 | 7/6/2012 | | 21.0 | 27.2 | 1005 | 63.9 | 0.7 | 167 | 0.0 |
| 55 | 7/7/2012 | | 20.6 | 25.9 | 1003 | 65.6 | 0.2 | 157 | 5.9 |
| 56 | 7/8/2012 | | 18.8 | 22.6 | 1002 | 72.1 | 1.6 | 170 | 9.8 |
| 57 | 7/9/2012 | | 19.8 | 25.2 | 1006 | 65.8 | 0.5 | 144 | 0.0 |
| 58 | 7/10/2012 | | 18.4 | 24.8 | 1005 | 77.5 | 0.5 | 145 | 8.0 |
| 59 | 7/11/2012 | | 16.1 | 21.6 | 1006 | 70.2 | 1.2 | 163 | 1.5 |
| 60 | 7/12/2012 | | 17.2 | 22.2 | 1005 | 66.6 | 0.9 | 150 | 11.3 |

**Annex 6** **Ambient conditions from field test sites** **Page 3 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 61 | 7/13/2012 | Cologne, summer | 16.0 | 22.7 | 996 | 83.8 | 0.8 | 133 | implausible |
| 62 | 7/14/2012 | | 16.3 | 19.5 | 1001 | 74.9 | 1.4 | 110 | 3.0 |
| 63 | 7/15/2012 | | 14.6 | 17.5 | 1011 | 81.4 | 0.9 | 106 | 9.8 |
| 64 | 7/16/2012 | | 16.0 | 18.9 | 1014 | 77.8 | 1.8 | 130 | implausible |
| 65 | 7/17/2012 | | 17.8 | 22.2 | 1014 | 79.3 | 1.3 | 108 | implausible |
| 66 | 7/18/2012 | | 21.0 | 28.2 | 1003 | 60.9 | 1.9 | 128 | implausible |
| 67 | 7/19/2012 | | 17.0 | 21.6 | 1005 | 73.5 | 1.6 | 114 | implausible |
| 68 | 7/20/2012 | | 16.1 | 20.1 | 1010 | 80.0 | 0.2 | 117 | 8.6 |
| 69 | 7/21/2012 | | 15.0 | 19.5 | 1017 | 69.3 | 0.4 | 175 | 0.0 |
| 70 | 7/22/2012 | | 17.6 | 24.8 | 1021 | 62.3 | 0.1 | 202 | 0.0 |
| 71 | 7/23/2012 | | 20.6 | 27.2 | 1016 | 56.2 | 0.6 | 161 | 0.0 |
| 72 | 7/24/2012 | | 23.7 | 31.4 | 1009 | 60.7 | 0.2 | 166 | 0.0 |
| 73 | 7/25/2012 | | 25.3 | 32.0 | 1008 | 59.5 | 0.1 | 124 | 0.0 |
| 74 | 7/26/2012 | | 26.1 | 32.7 | 1008 | 59.4 | 0.4 | 138 | 0.0 |
| 75 | 7/27/2012 | | 23.3 | 34.6 | 1002 | 76.6 | 0.4 | 151 | 12.4 |
| 76 | 7/28/2012 | | 19.3 | 23.1 | 1002 | 83.5 | 0.1 | 137 | 15.4 |
| 77 | 7/29/2012 | | 17.8 | 23.3 | 1008 | 64.0 | 0.9 | 143 | 6.5 |
| 78 | 7/30/2012 | | 16.6 | 21.8 | 1011 | 69.1 | 0.5 | 144 | 1.2 |
| 79 | 7/31/2012 | | 18.4 | 22.2 | 1010 | 67.4 | 0.2 | 171 | 0.0 |
| 80 | 8/1/2012 | | 25.4 | 31.1 | 1003 | 57.8 | 0.9 | 182 | 0.0 |
| 81 | 8/2/2012 | | 20.5 | 25.0 | 1008 | 69.7 | 0.4 | 143 | 0.0 |
| 82 | 8/3/2012 | | 20.5 | 25.9 | 1008 | 67.8 | 0.3 | 161 | 1.8 |
| 83 | 8/4/2012 | | 20.1 | 26.8 | 1005 | 74.3 | 0.3 | 162 | 3.6 |
| 84 | 8/5/2012 | | 19.3 | 25.8 | 1002 | 81.7 | 0.5 | 159 | 8.9 |
| 85 | 8/6/2012 | | 19.2 | 23.6 | 1008 | 64.4 | 1.8 | 149 | 0.0 |
| 86 | 8/7/2012 | | 17.3 | 20.9 | 1015 | 66.3 | 0.6 | 137 | 0.0 |
| 87 | 8/8/2012 | | 19.2 | 22.6 | 1017 | 72.0 | 0.3 | 118 | 0.0 |
| 88 | 8/9/2012 | | 18.7 | 24.6 | 1018 | 65.8 | 0.6 | 136 | 0.0 |
| 89 | 8/10/2012 | | 17.3 | 23.9 | 1018 | 64.3 | 0.5 | 150 | 0.0 |
| 90 | 8/11/2012 | | 18.7 | 24.4 | 1012 | 61.4 | 0.4 | 174 | 0.0 |

**Annex 6** **Ambient conditions from field test sites** **Page 4 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 91 | 8/12/2012 | Cologne, summer | 20.8 | 26.6 | 1007 | 53.4 | 0.8 | 170 | 0.0 |
| 92 | 8/13/2012 | | 23.0 | 28.9 | 1006 | 57.3 | 0.4 | 188 | 0.0 |
| 93 | 8/14/2012 | | 22.6 | 29.6 | 1006 | 69.6 | 0.3 | 156 | 1.5 |
| 94 | 8/15/2012 | | 24.4 | 33.2 | 1005 | 62.6 | 0.8 | 148 | 8.0 |
| 95 | 8/16/2012 | | 22.0 | 28.2 | 1012 | 58.4 | 0.5 | 149 | 0.0 |
| 96 | 8/17/2012 | | 24.3 | 30.8 | 1012 | 55.0 | 0.5 | 169 | implausible |
| 97 | 8/18/2012 | | 27.8 | 35.8 | 1010 | 53.2 | 0.7 | 170 | 0.0 |
| 98 | 8/19/2012 | | 30.7 | 39.5 | 1008 | 53.8 | 0.7 | 149 | 0.0 |
| 99 | 8/20/2012 | | 24.4 | 31.1 | 1012 | 70.9 | 0.2 | 154 | 1.2 |
| 100 | 8/21/2012 | | 24.3 | 31.1 | 1008 | 64.2 | 0.3 | 123 | 0.6 |
| 101 | 8/22/2012 | | 19.4 | 25.9 | 1010 | 60.8 | 0.5 | 139 | 0.0 |
| 102 | 8/23/2012 | | 20.7 | 27.4 | 1004 | 53.8 | 0.4 | 158 | 3.0 |
| 103 | 8/24/2012 | | 20.1 | 26.0 | 999 | 70.6 | 0.3 | 136 | 7.1 |
| 104 | 8/25/2012 | | 20.5 | 25.7 | 1000 | 61.1 | 2.3 | 194 | 4.4 |
| 105 | 8/26/2012 | | 15.7 | 18.5 | 1010 | 83.5 | 0.8 | 148 | 2.7 |
| 106 | 8/27/2012 | | 20.3 | 26.0 | 1010 | 59.3 | 0.5 | 177 | 0.0 |
| 107 | 8/28/2012 | | 21.0 | 26.8 | 1010 | 65.6 | 0.5 | 160 | 0.0 |
| 108 | 8/29/2012 | | 22.3 | 29.9 | 1008 | 62.7 | 0.8 | 148 | 0.0 |
| 109 | 8/30/2012 | | 18.7 | 23.4 | 1009 | 63.3 | 0.8 | 153 | 1.2 |
| 110 | 8/31/2012 | | No weather data available | | | | | | |
| 111 | 9/1/2012 | | | | | | | | |
| 112 | 9/2/2012 | | | | | | | | |
| 113 | 11/19/2012 | Cologne, winter | No weather data available | | | | | | |
| 114 | 11/20/2012 | | | | | | | | |
| 115 | 11/21/2012 | | | | | | | | |
| 116 | 11/22/2012 | | 8.2 | 13.4 | 1013 | 79.5 | 0.6 | 150 | 0.0 |
| 117 | 11/23/2012 | | 8.5 | 9.6 | 1010 | 88.3 | 0.1 | 147 | 9.3 |
| 118 | 11/24/2012 | | 11.6 | 14.7 | 1005 | 78.5 | 0.9 | 156 | 0.3 |
| 119 | 11/25/2012 | | 8.8 | 13.7 | 1004 | 70.3 | 1.4 | 161 | 0.3 |
| 120 | 11/26/2012 | | 8.9 | 9.8 | 997 | 83.3 | 0.3 | 150 | 5.9 |

**Annex 6** **Ambient conditions from field test sites** **Page 5 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 121 | 11/27/2012 | Cologne, winter | 7.5 | 10.6 | 998 | 81.2 | 0.1 | 125 | 0.3 |
| 122 | 11/28/2012 | | 6.0 | 7.4 | 997 | 81.3 | 1.8 | 84 | 0.0 |
| 123 | 11/29/2012 | | 4.0 | 5.3 | 999 | 81.0 | 1.0 | 80 | 0.0 |
| 124 | 11/30/2012 | | 1.6 | 4.7 | 1005 | 83.8 | 0.1 | 157 | 0.0 |
| 125 | 12/1/2012 | | 2.9 | 5.8 | 1003 | 83.1 | 0.7 | 156 | 5.1 |
| 126 | 12/2/2012 | | 3.9 | 5.3 | 1006 | 82.3 | 1.3 | 146 | 0.3 |
| 127 | 12/3/2012 | | 3.7 | 5.8 | 997 | 87.7 | 0.5 | 158 | 7.2 |
| 128 | 12/4/2012 | | 4.5 | 6.6 | 993 | 84.3 | 1.0 | 114 | 5.7 |
| 129 | 12/5/2012 | | 2.1 | 4.2 | 999 | 85.7 | 0.8 | 120 | 4.2 |
| 130 | 12/6/2012 | | 0.9 | 4.1 | 1005 | 79.9 | 0.7 | 151 | 0.0 |
| 131 | 12/7/2012 | | -2.6 | 0.0 | 1001 | 89.4 | 0.0 | 108 | 0.0 |
| 132 | 12/8/2012 | | -2.6 | 1.9 | 1016 | 86.2 | 0.0 | 125 | 0.9 |
| 134 | 12/9/2012 | | 4.0 | 4.9 | 1002 | 87.0 | 1.8 | 149 | 16.1 |
| 134 | 12/10/2012 | | 1.9 | 4.6 | 1010 | 81.4 | 2.6 | 78 | 1.8 |
| 135 | 12/11/2012 | | -0.2 | 1.4 | 1018 | 74.8 | 0.8 | 128 | 0.0 |
| 136 | 12/12/2012 | | -0.5 | 4.7 | 1010 | 71.4 | 0.5 | 136 | 0.0 |
| 137 | 12/13/2012 | | 0.9 | 3.8 | 1000 | 75.6 | 0.5 | 148 | 0.0 |
| 138 | 12/14/2012 | | 7.1 | 9.5 | 988 | 82.4 | 1.3 | 157 | 4.2 |
| 139 | 12/15/2012 | | 8.7 | 12.1 | 995 | 78.6 | 1.2 | 173 | 4.7 |
| 140 | 12/16/2012 | | 7.2 | 11.0 | 997 | 85.2 | 0.4 | 151 | 7.4 |
| 141 | 12/17/2012 | | 7.2 | 10.1 | 999 | 85.4 | 0.1 | 141 | 3.0 |
| 142 | 12/18/2012 | | 6.2 | 7.6 | 1011 | 88.1 | 0.0 | 145 | 0.9 |
| 143 | 12/19/2012 | | 4.2 | 6.3 | 1014 | 85.6 | 0.3 | 154 | 0.0 |
| 144 | 12/20/2012 | | 2.8 | 4.2 | 1003 | 85.8 | 1.4 | 150 | 7.2 |
| 145 | 12/21/2012 | | 6.0 | 7.6 | 1007 | 91.2 | 0.0 | 153 | 2.1 |
| 146 | 12/22/2012 | | 8.7 | 13.3 | 1001 | 89.0 | 1.0 | 148 | 25.7 |
| 147 | 12/23/2012 | | 10.6 | 14.5 | 1001 | 87.5 | 0.8 | 139 | 8.4 |
| 148 | 12/24/2012 | | 11.8 | 13.8 | 995 | 76.0 | 0.7 | 155 | 2.4 |
| 149 | 12/25/2012 | | 9.4 | 11.8 | 996 | 77.1 | 2.1 | 162 | 4.2 |
| 150 | 12/26/2012 | | 9.1 | 10.9 | 1000 | 76.1 | 2.3 | 165 | 4.2 |

**Annex 6** **Ambient conditions from field test sites** **Page 6 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 151 | 12/27/2012 | Cologne, winter | 7.3 | 10.9 | 1004 | 86.2 | 0.5 | 129 | 9.8 |
| 152 | 12/28/2012 | | 8.4 | 10.0 | 1015 | 85.1 | 0.5 | 157 | 1.8 |
| 153 | 12/29/2012 | | 10.4 | 12.2 | 1005 | 72.7 | 2.2 | 168 | 0.3 |
| 154 | 12/30/2012 | | 8.6 | 9.9 | 1009 | 72.5 | 2.6 | 171 | 3.3 |
| 155 | 12/31/2012 | | 9.9 | 11.2 | 1000 | 71.3 | 3.3 | 177 | 2.1 |
| 156 | 1/1/2013 | | 6.1 | 8.9 | 1006 | 82.0 | 0.7 | 143 | 3.0 |
| 157 | 1/2/2013 | | 7.5 | 9.4 | 1020 | 79.6 | 0.8 | 155 | 1.8 |
| 158 | 1/3/2013 | | 10.6 | 11.0 | 1026 | 88.3 | 0.6 | 126 | 2.4 |
| 159 | 1/4/2013 | | 9.1 | 10.8 | 1027 | 89.3 | 0.7 | 120 | 0.9 |
| 160 | 1/5/2013 | | 8.4 | 9.2 | 1025 | 86.1 | 0.3 | 126 | 0.0 |
| 161 | 1/6/2013 | | 9.1 | 9.7 | 1022 | 86.6 | 0.4 | 115 | 0.0 |
| 162 | 1/7/2013 | | 8.2 | 10.2 | 1020 | 80.0 | 0.3 | 143 | 0.0 |
| 163 | 1/8/2013 | | 7.6 | 8.9 | 1017 | 78.6 | 0.3 | 141 | 0.0 |
| 164 | 1/9/2013 | | 5.8 | 6.3 | 1010 | 87.0 | 0.2 | 136 | 6.3 |
| 165 | 1/10/2013 | | 4.0 | 7.6 | 1006 | 80.2 | 0.7 | 129 | 2.4 |
| 166 | 1/11/2013 | | -1.4 | 2.3 | 1011 | 78.3 | 0.0 | 153 | 0.0 |
| 167 | 1/12/2013 | | -1.5 | 2.6 | 1010 | 70.1 | 0.1 | 141 | 0.0 |
| 168 | 1/13/2013 | | -0.6 | 2.7 | 1009 | 70.0 | 0.2 | 145 | 0.0 |
| 169 | 1/14/2013 | | -2.5 | 0.0 | 1003 | 77.5 | 0.6 | 140 | 0.0 |
| 170 | 1/15/2013 | | -1.5 | -0.1 | 999 | 87.5 | 0.1 | 139 | 0.0 |
| 171 | 1/16/2013 | | -2.1 | -1.3 | 1006 | 84.8 | 0.0 | 87 | 0.0 |
| 172 | 1/17/2013 | | -2.0 | -1.2 | 1009 | 84.7 | 0.2 | 118 | 0.0 |
| 173 | 1/18/2013 | | -1.2 | 0.4 | 997 | 75.2 | 0.9 | 147 | 0.0 |
| 174 | 1/19/2013 | | -3.3 | -1.4 | 990 | 73.9 | 0.7 | 147 | 0.0 |
| 175 | 1/20/2013 | | -0.9 | -0.1 | 988 | 84.1 | 0.0 | 148 | 0.0 |
| 176 | 1/21/2013 | | -0.1 | 0.9 | 993 | 84.0 | 0.0 | 152 | 0.0 |
| 177 | 1/22/2013 | | 0.2 | 1.3 | 999 | 80.4 | 0.0 | 149 | 0.0 |
| 178 | 1/23/2013 | | -0.5 | 1.8 | 1002 | 78.9 | 0.2 | 128 | 0.6 |
| 179 | 1/24/2013 | | -1.1 | -0.3 | 1010 | 74.4 | 0.6 | 126 | 0.0 |
| 180 | 1/25/2013 | | -1.9 | -0.7 | 1008 | 77.1 | 1.0 | 155 | 0.0 |

**Annex 6** **Ambient conditions from field test sites** **Page 7 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 181 | 1/26/2013 | Cologne, winter | -0.1 | 2.7 | 1004 | 81.5 | 0.9 | 148 | 0.6 |
| 182 | 1/27/2013 | | 3.1 | 5.2 | 999 | 85.4 | 0.9 | 160 | 10.2 |
| 183 | 1/28/2013 | | 6.9 | 10.2 | 1004 | 78.3 | 1.9 | 172 | 9.8 |
| 184 | 1/29/2013 | | 11.9 | 15.0 | 1001 | 82.4 | 2.0 | 177 | 4.2 |
| 185 | 1/30/2013 | | 10.9 | 15.8 | 1005 | 71.5 | 2.9 | 149 | 4.4 |
| 186 | 1/31/2013 | | 8.6 | 10.1 | 1004 | 72.4 | 2.4 | 155 | 5.9 |
| 187 | 2/1/2013 | | 5.0 | 7.5 | 990 | 88.1 | 0.9 | 127 | 11.7 |
| 188 | 2/2/2013 | | 3.7 | 4.9 | 1006 | 78.8 | 1.8 | 94 | 0.9 |
| 189 | 2/3/2013 | | 5.8 | 9.2 | 1006 | 82.0 | 2.0 | 144 | 3.0 |
| 190 | 2/4/2013 | | 7.5 | 10.9 | 1000 | 76.2 | 1.9 | 149 | 3.3 |
| 191 | 2/5/2013 | | 2.5 | 7.0 | 990 | 79.2 | 1.0 | 142 | 0.9 |
| 192 | 2/6/2013 | | 2.4 | 3.6 | 997 | 84.5 | 0.9 | 112 | 5.4 |
| 193 | 2/27/2013 | Bonn, winter | 2.5 | 3.6 | 1021 | 78.9 | 0.9 | 185 | 0.0 |
| 194 | 2/28/2013 | | 4.1 | 6.8 | 1017 | 71.8 | 1.2 | 250 | 0.0 |
| 195 | 3/1/2013 | | 3.5 | 4.8 | 1016 | 72.0 | 1.7 | 249 | 0.0 |
| 196 | 3/2/2013 | | 3.0 | 5.8 | 1015 | 67.4 | 1.2 | 238 | 0.0 |
| 197 | 3/3/2013 | | 3.1 | 6.0 | 1014 | 72.8 | 0.5 | 196 | 0.0 |
| 198 | 3/4/2013 | | 6.6 | 12.4 | 1007 | 57.8 | 1.4 | 140 | 0.0 |
| 199 | 3/5/2013 | | 8.5 | 14.0 | 999 | 56.5 | 1.2 | 136 | 0.0 |
| 200 | 3/6/2013 | | 11.5 | 18.7 | 993 | 48.5 | 0.4 | 143 | 0.0 |
| 201 | 3/7/2013 | | 12.3 | 16.4 | 990 | 67.5 | 0.5 | 144 | 2.1 |
| 202 | 3/8/2013 | | 13.7 | 18.3 | 990 | 72.1 | 1.4 | 138 | 1.5 |
| 203 | 3/9/2013 | | 10.6 | 13.7 | 991 | 72.2 | 1.2 | 178 | 3.6 |
| 204 | 3/10/2013 | | 1.6 | 5.7 | 993 | 81.8 | 3.6 | 273 | 2.4 |
| 205 | 3/11/2013 | | -1.4 | 0.4 | 996 | 78.7 | 1.9 | 241 | 0.0 |
| 206 | 3/12/2013 | | -3.4 | -1.2 | 995 | 83.9 | 2.0 | 276 | 0.0 |
| 207 | 3/13/2013 | | -1.2 | 0.8 | 999 | 72.8 | 1.1 | 224 | 0.3 |
| 208 | 3/14/2013 | | -1.3 | 2.0 | 1004 | 75.3 | 1.1 | 209 | 2.1 |
| 209 | 3/15/2013 | | 2.3 | 5.7 | 1006 | 58.8 | 1.0 | 132 | 2.1 |
| 210 | 3/16/2013 | | 5.3 | 7.8 | 998 | 49.0 | 3.4 | 131 | 0.0 |

**Annex 6** **Ambient conditions from field test sites** **Page 8 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 211 | 3/17/2013 | Bonn, winter | 4.7 | 6.1 | 988 | 78.3 | 2.2 | 131 | 0.9 |
| 212 | 3/18/2013 | | 6.6 | 11.1 | 985 | 60.3 | 0.7 | 131 | 0.0 |
| 213 | 3/19/2013 | | 5.8 | 10.0 | 991 | 74.5 | 0.6 | 157 | 1.2 |
| 214 | 3/20/2013 | | 2.6 | 4.9 | 999 | 85.8 | 1.9 | 240 | 13.2 |
| 215 | 3/21/2013 | | 0.6 | 3.3 | 1010 | 78.8 | 1.0 | 229 | 0.3 |
| 216 | 3/22/2013 | | 2.9 | 7.3 | 1006 | 63.4 | 3.2 | 146 | 0.0 |
| 217 | 3/23/2013 | | 1.1 | 3.4 | 1005 | 56.8 | 4.2 | 146 | 0.0 |
| 218 | 3/24/2013 | | 1.0 | 4.7 | 1005 | 42.8 | 3.3 | 153 | 0.0 |
| 219 | 3/25/2013 | | 0.9 | 4.6 | 1004 | 49.0 | 2.6 | 153 | 0.0 |
| 220 | 3/26/2013 | | 1.6 | 6.1 | 1003 | 44.1 | 2.3 | 168 | 0.0 |
| 221 | 3/27/2013 | | 2.6 | 6.4 | 1001 | 49.5 | 2.0 | 148 | 0.0 |
| 222 | 3/28/2013 | | 3.0 | 6.7 | 999 | 58.9 | 1.2 | 243 | 0.0 |
| 223 | 3/29/2013 | | 0.4 | 3.1 | 999 | 77.8 | 1.1 | 271 | 1.5 |
| 224 | 3/30/2013 | | 1.8 | 4.4 | 1000 | 68.9 | 1.3 | 271 | 0.0 |
| 225 | 3/31/2013 | | 1.7 | 4.0 | 1003 | 68.2 | 1.1 | 269 | 0.0 |
| 226 | 4/1/2013 | | 3.2 | 7.3 | 1001 | 52.9 | 1.5 | 190 | 0.0 |
| 227 | 4/2/2013 | | 3.6 | 8.5 | 1003 | 52.2 | 1.8 | 201 | 0.0 |
| 228 | 4/3/2013 | | 3.0 | 6.6 | 1005 | 58.0 | 1.8 | 158 | 0.0 |
| 229 | 4/4/2013 | | 4.4 | 8.7 | 1001 | 60.5 | 1.8 | 166 | 0.0 |
| 230 | 4/5/2013 | | 3.8 | 4.7 | 1003 | 67.8 | 1.6 | 267 | 0.0 |
| 231 | 4/6/2013 | | 3.6 | 6.2 | 1012 | 73.9 | 1.7 | 221 | 0.3 |
| 232 | 4/7/2013 | | 6.4 | 11.4 | 1008 | 51.4 | 0.7 | 174 | 0.0 |
| 234 | 4/8/2013 | | 7.0 | 11.5 | 996 | 63.9 | 1.4 | 130 | 0.9 |
| 234 | 4/9/2013 | | 8.3 | 10.6 | 992 | 78.0 | 1.2 | 133 | 1.8 |
| 235 | 4/10/2013 | | 9.7 | 13.2 | 996 | 77.3 | 1.4 | 154 | 6.0 |
| 236 | 4/11/2013 | | 13.0 | 17.3 | 991 | 69.6 | 1.3 | 169 | 6.0 |
| 237 | 4/12/2013 | | 12.2 | 16.8 | 997 | 69.0 | 1.1 | 154 | 4.4 |
| 238 | 4/13/2013 | | 13.9 | 17.2 | 1011 | 56.8 | 1.4 | 152 | 0.6 |
| 239 | 4/14/2013 | | 18.3 | 24.1 | 1011 | 57.0 | 1.5 | 136 | 0.0 |
| 240 | 4/15/2013 | | 17.5 | 23.1 | 1011 | 67.0 | 1.5 | 214 | 2.7 |

**Annex 6** **Ambient conditions from field test sites** **Page 9 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 241 | 4/16/2013 | Bonn, winter | 18.4 | 22.8 | 1011 | 54.4 | 0.9 | 149 | 0.0 |
| 242 | 4/17/2013 | | 18.7 | 25.0 | 1009 | 54.3 | 0.6 | 141 | 0.0 |
| 243 | 4/18/2013 | | 15.6 | 19.8 | 1009 | 46.2 | 3.1 | 210 | 0.0 |
| 244 | 4/19/2013 | | 11.4 | 14.7 | 1017 | 57.7 | 3.5 | 260 | 0.0 |
| 245 | 4/20/2013 | | 10.3 | 13.9 | 1018 | 51.5 | 3.3 | 274 | 0.0 |
| 246 | 4/21/2013 | | 11.1 | 13.1 | 1009 | 57.4 | 1.1 | 253 | 0.0 |
| 247 | 4/22/2013 | | 13.2 | 17.4 | 1009 | 46.5 | 1.4 | 217 | 0.0 |
| 248 | 4/23/2013 | | 13.7 | 18.9 | 1014 | 63.6 | 1.7 | 187 | 0.0 |
| 249 | 4/24/2013 | | 17.9 | 24.6 | 1016 | 56.5 | 1.0 | 167 | 0.0 |
| 250 | 4/25/2013 | | 20.0 | 26.6 | 1010 | 51.5 | 0.4 | 146 | 0.0 |
| 251 | 4/26/2013 | | 11.9 | 20.3 | 1000 | 77.3 | 2.2 | 230 | 9.9 |
| 252 | 4/27/2013 | | 7.8 | 9.8 | 1003 | 70.3 | 3.2 | 293 | 0.0 |
| 253 | 4/28/2013 | | 9.2 | 12.2 | 1007 | 68.3 | 0.7 | 169 | 0.0 |
| 254 | 4/29/2013 | | 12.0 | 16.9 | 1010 | 56.1 | 1.9 | 209 | 0.0 |
| 255 | 4/30/2013 | | 11.8 | 15.1 | 1014 | 57.9 | 1.0 | 214 | 0.0 |
| 256 | 5/1/2013 | | 14.6 | 18.3 | 1011 | 62.8 | 0.9 | 173 | 0.3 |
| 257 | 5/2/2013 | | 16.5 | 21.6 | 1009 | 60.4 | 1.1 | 200 | 0.0 |
| 258 | 5/3/2013 | | 16.0 | 20.6 | 1007 | 60.0 | 1.5 | 253 | 0.0 |
| 259 | 5/4/2013 | | 15.7 | 21.0 | 1011 | 54.5 | 2.4 | 238 | 0.0 |
| 260 | 5/5/2013 | | 16.4 | 22.1 | 1013 | 55.9 | 1.3 | 190 | 0.0 |
| 261 | 5/14/2013 | Bornheim, summer | No weather data available | | | | | | |
| 262 | 5/15/2013 | | | | | | | | |
| 263 | 5/16/2013 | | 12.6 | 16.7 | 989 | 85.5 | 0.7 | 263 | 8.6 |
| 264 | 5/17/2013 | | 10.0 | 10.6 | 995 | 89.1 | 0.8 | 265 | 2.4 |
| 265 | 5/18/2013 | | 12.0 | 17.8 | 1000 | 77.7 | 0.4 | 216 | 0.0 |
| 266 | 5/19/2013 | | 16.7 | 22.4 | 998 | 66.5 | 2.7 | 273 | 7.4 |
| 267 | 5/20/2013 | | 11.9 | 15.0 | 1000 | 83,,1 | 0.3 | 175 | 6.2 |
| 268 | 5/21/2013 | | 12.9 | 18.2 | 1001 | 78.8 | 1.8 | 239 | 13.1 |
| 269 | 5/22/2013 | | 8.8 | 11.1 | 1004 | 82.4 | 2.4 | 258 | 7.4 |
| 270 | 5/23/2013 | | 6.4 | 10.6 | 1000 | 81.9 | 1.8 | 255 | 2.4 |

**Annex 6** **Ambient conditions from field test sites** **Page 10 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 271 | 5/24/2013 | Bornheim, summer | 8.3 | 14.6 | 1003 | 69.9 | 0.7 | 192 | 0.9 |
| 272 | 5/25/2013 | | 10.5 | 15.0 | 1005 | 70.9 | 2.8 | 270 | 3.0 |
| 273 | 5/26/2013 | | 9.8 | 11.8 | 1002 | 79.9 | 3.2 | 271 | 5.7 |
| 274 | 5/27/2013 | | 14.0 | 20.5 | 1000 | 61.4 | 1.6 | 244 | 0.0 |
| 275 | 5/28/2013 | | 17.2 | 23.9 | 993 | 60.4 | 2.0 | 179 | 1.2 |
| 276 | 5/29/2013 | | 9.7 | 11.1 | 995 | 88.4 | 0.6 | 207 | 15.0 |
| 277 | 5/30/2013 | | 13.5 | 16.6 | 999 | 69.6 | 1.7 | 237 | 2.4 |
| 278 | 5/31/2013 | | 16.1 | 22.0 | 1001 | 73.0 | 4.7 | 299 | 0.9 |
| 279 | 6/1/2013 | | 11.9 | 14.7 | 1009 | 79.4 | 4.4 | 290 | 0.3 |
| 280 | 6/2/2013 | | 13.3 | 18.6 | 1016 | 57.6 | 4.0 | 288 | 0.0 |
| 281 | 6/3/2013 | | 12.9 | 17.9 | 1017 | 61.6 | 3.6 | 269 | 0.0 |
| 282 | 6/4/2013 | | 15.6 | 21.6 | 1012 | 64.5 | 1.7 | 237 | 0.0 |
| 283 | 6/5/2013 | | 19.9 | 26.6 | 1009 | 54.2 | 0.6 | 197 | 0.0 |
| 284 | 6/6/2013 | | 20.9 | 28.3 | 1010 | 52.6 | 0.8 | 168 | 0.0 |
| 285 | 6/7/2013 | | 21.7 | 29.1 | 1010 | 55.5 | 1.0 | 211 | 0.0 |
| 286 | 6/8/2013 | | 21.1 | 26.8 | 1005 | 62.3 | 2.1 | 243 | 0.0 |
| 287 | 6/9/2013 | | 15.6 | 19.2 | 1001 | 78.7 | 1.8 | 273 | 4.5 |
| 288 | 6/10/2013 | | 14.4 | 18.1 | 1005 | 75.9 | 1.2 | 253 | 0.6 |
| 289 | 6/11/2013 | | 18.8 | 23.8 | 1008 | 61.5 | 0.6 | 198 | 0.0 |
| 290 | 6/12/2013 | | 21.1 | 23.7 | 1008 | 67.1 | 1.0 | 181 | 0.0 |
| 291 | 6/13/2013 | | 17.0 | 27.6 | 1007 | 77.9 | 1.3 | 209 | 22.5 |
| 292 | 6/14/2013 | | 16.1 | 21.2 | 1009 | 65.4 | 0.6 | 181 | 0.0 |
| 293 | 6/15/2013 | | 17.2 | 22.6 | 1005 | 63.1 | 1.4 | 209 | 0.0 |
| 294 | 6/16/2013 | | 17.7 | 23.7 | 1007 | 63.9 | 0.7 | 226 | 0.0 |
| 295 | 6/17/2013 | | 23.3 | 29.7 | 1004 | 64.7 | 0.9 | 185 | 0.0 |
| 296 | 6/18/2013 | | 27.2 | 34.8 | 1005 | 61.3 | 0.4 | 178 | 0.0 |
| 297 | 6/19/2013 | | 26.9 | 35.0 | 1003 | 67.8 | 1.9 | 244 | 0.0 |
| 298 | 6/20/2013 | | 20.5 | 25.1 | 1003 | 78.5 | 1.0 | 187 | 34.6 |
| 299 | 6/21/2013 | | 19.0 | 23.4 | 1005 | 69.8 | 1.6 | 196 | 0.3 |
| 300 | 6/22/2013 | | 19.0 | 23.7 | 1004 | 67.8 | 1.8 | 198 | 1.5 |

**Annex 6** **Ambient conditions from field test sites** **Page 11 of 11**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 301 | 6/23/2013 | Bornheim, summer | 16.2 | 19.2 | 1005 | 69.9 | 1.6 | 216 | 0.9 |
| 302 | 6/24/2013 | | 14.2 | 17.4 | 1013 | 76.9 | 1.8 | 255 | 1.5 |
| 303 | 6/25/2013 | | 13.4 | 16.8 | 1018 | 71.1 | 1.8 | 259 | 0.3 |
| 304 | 6/26/2013 | | 13.9 | 16.7 | 1018 | 70.9 | 1.1 | 250 | 9.8 |
| 305 | 6/27/2013 | | 13.2 | 17.1 | 1014 | 78.5 | 0.7 | 230 | 3.9 |
| 306 | 6/28/2013 | | 14.1 | 16.7 | 1010 | 86.1 | 0.3 | 174 | 16.4 |
| 307 | 6/29/2013 | | 14.8 | 18.8 | 1012 | 73.9 | 2.6 | 269 | 1.8 |
| 308 | 6/30/2013 | | 17.7 | 22.4 | 1012 | 66.4 | 0.6 | 198 | 0.0 |
| 309 | 7/1/2013 | | 18.8 | 25.4 | 1008 | 74.9 | 0.7 | 215 | 21.0 |
| 310 | 7/2/2013 | | 21.6 | 27.1 | 1003 | 62.7 | 0.6 | 183 | 0.3 |
| 311 | 7/3/2013 | | 17.5 | 20.1 | 1004 | 85.6 | 0.2 | 213 | 16.0 |
| 312 | 7/4/2013 | | 20.0 | 24.7 | 1014 | 71.1 | 0.9 | 232 | 0.0 |
| 313 | 7/5/2013 | | 19.8 | 24.8 | 1020 | 74.4 | 0.3 | 222 | 0.0 |
| 314 | 7/6/2013 | | 22.4 | 29.3 | 1020 | 65.4 | 1.0 | 191 | 0.0 |
| 315 | 7/7/2013 | | 23.1 | 29.7 | 1020 | 58.8 | 1.2 | 218 | 0.0 |
| 316 | 7/8/2013 | | 23.0 | 29.8 | 1019 | 59.6 | 1.4 | 214 | 0.0 |
| 317 | 7/9/2013 | | 23.4 | 29.9 | 1014 | 59.4 | 1.4 | 237 | 0.0 |
| 318 | 7/10/2013 | | 19.5 | 24.2 | 1012 | 62.6 | 3.5 | 261 | 0.0 |
| 319 | 7/11/2013 | | 15.7 | 19.7 | 1013 | 70.1 | 1.7 | 215 | 0.0 |
| 320 | 7/12/2013 | | 16.5 | 21.9 | 1013 | 70.8 | 1.2 | 250 | 0.0 |
| 321 | 7/13/2013 | | 17.7 | 22.9 | 1014 | 68.3 | 1.1 | 241 | 0.0 |
| 322 | 7/14/2013 | | 18.9 | 24.2 | 1014 | 69.1 | 1.7 | 249 | 0.0 |

**Annex 7** **Measured values from UK field test sites, related to actual conditions** **Page 1 of 4**

Manufacturer: PALAS
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 | | | | | | | | | | | |

**Annex 7** **Measured values from UK field test sites, related to actual conditions** **Page 2 of 4**

| | |
|---|---|
| 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 PM2,5 [µg/m³] | SN 0112 PM2,5 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 29.03.2014 | | | | | | | | | | | Teddington, Winter |
| 32 | 30.03.2014 | | | | | | | | | | | |
| 33 | 31.03.2014 | | | | | | | | | | | |
| 34 | 01.04.2014 | 33,9 | 32,7 | 44,5 | 42,9 | 76,2 | 32,2 | 32,7 | 41,1 | 41,3 | | |
| 35 | 02.04.2014 | 58,6 | 57,7 | | | | 58,0 | 59,9 | 80,6 | 81,8 | Outlier Ref. PM10 | |
| 36 | 03.04.2014 | 35,6 | 35,6 | 51,6 | 49,9 | 70,1 | 37,7 | 39,0 | 49,8 | 50,4 | | |
| 37 | 04.04.2014 | 6,8 | 6,6 | 10,6 | 10,6 | 63,3 | 6,5 | 6,6 | 9,2 | 9,1 | | |
| 38 | 05.04.2014 | 4,2 | 4,1 | 6,1 | 6,0 | 68,9 | 4,2 | 4,4 | 5,6 | 5,8 | | |
| 39 | 06.04.2014 | 3,1 | 2,8 | 5,6 | 5,3 | 53,6 | 2,9 | 2,9 | 4,6 | 4,5 | | |
| 40 | 07.04.2014 | 3,4 | 3,2 | 7,2 | 6,7 | 47,8 | 3,9 | 3,9 | 6,7 | 6,8 | | |
| 41 | 08.04.2014 | 5,8 | 5,8 | 13,5 | 12,8 | 44,1 | 7,3 | 7,4 | 11,4 | 11,4 | | |
| 42 | 09.04.2014 | 8,4 | 8,5 | 15,5 | 14,8 | 56,0 | 8,9 | 8,8 | 13,4 | 12,9 | | |
| 43 | 10.04.2014 | 9,1 | 8,9 | 14,8 | 14,5 | 61,4 | 8,2 | 8,0 | 13,2 | 12,8 | | |
| 44 | 11.04.2014 | 14,3 | 14,3 | 19,9 | 19,3 | 73,1 | 13,2 | 13,3 | 17,6 | 17,5 | | |
| 45 | 12.04.2014 | 8,3 | 8,2 | 13,9 | 13,0 | 61,4 | 9,2 | 9,0 | 13,1 | 12,7 | | |
| 46 | 13.04.2014 | 8,0 | 7,5 | 14,5 | 13,8 | 54,8 | 7,9 | 7,7 | 12,8 | 12,1 | | |
| 47 | 14.04.2014 | 7,5 | 7,4 | 15,6 | 15,0 | 49,0 | 6,9 | 6,7 | 13,1 | 12,4 | | |
| 48 | 15.04.2014 | 9,0 | 8,4 | 21,4 | 20,5 | 41,4 | 9,4 | 9,3 | 17,8 | 17,2 | | |
| 49 | 16.04.2014 | 16,1 | 15,6 | 28,4 | 28,0 | 56,2 | 15,3 | 14,8 | 23,2 | 22,0 | | |
| 50 | 17.04.2014 | 9,6 | 9,1 | 18,1 | 17,5 | 52,5 | 10,6 | 10,1 | 17,7 | 16,5 | | |
| 51 | 18.04.2014 | 5,3 | 5,0 | 12,5 | 11,8 | 42,1 | 5,7 | 5,5 | 10,6 | 10,2 | | |
| 52 | 19.04.2014 | 18,5 | 18,5 | 26,6 | 26,2 | 70,0 | 18,9 | 18,8 | 23,3 | 22,8 | | Teddington, Summer |
| 53 | 20.04.2014 | 39,0 | 39,1 | 45,7 | 44,7 | 86,3 | 39,4 | 38,5 | 43,1 | 41,9 | | |
| 54 | 21.04.2014 | 20,7 | 20,8 | 28,0 | 26,9 | 75,5 | 22,3 | 21,0 | 26,2 | 24,3 | | |
| 55 | 22.04.2014 | 8,9 | 9,8 | 14,6 | 14,0 | 65,5 | 9,7 | 9,1 | 12,6 | 11,6 | | |
| 56 | 23.04.2014 | 7,2 | 7,4 | 10,9 | 10,4 | 68,1 | 7,6 | 7,1 | 9,7 | 8,7 | | |
| 57 | 24.04.2014 | 13,2 | 12,8 | 16,8 | 16,0 | 79,3 | 11,3 | 10,6 | 13,5 | 12,5 | | |
| 58 | 25.04.2014 | 9,0 | 9,0 | 13,5 | 12,8 | 68,8 | 9,3 | 9,1 | 11,5 | 11,4 | | |
| 59 | 26.04.2014 | 4,1 | 4,2 | 9,2 | 8,9 | 46,1 | 4,4 | 4,2 | 7,9 | 7,2 | | |
| 60 | 27.04.2014 | 17,9 | 17,6 | 25,1 | 24,4 | 71,5 | 16,4 | 15,7 | 19,6 | 18,4 | | |

**Annex 7** **Measured values from UK field test sites, related to actual conditions** **Page 3 of 4**

| | | |
|---|---|---|
| Manufacturer | PALAS | PM10 and PM2.5<br>Measured values in µg/m³ (ACT) |
| Type of instrument | FIDAS 200 S | |
| Serial-No. | SN 0111 / SN 0112 | |

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 28.04.2014 | 18,7 | 18,9 | 24,3 | 23,3 | 78,8 | 18,2 | 19,2 | 22,0 | 22,8 | | Teddington, Summer |
| 62 | 29.04.2014 | 17,5 | 16,8 | 23,5 | 22,8 | 74,1 | 18,5 | 19,2 | 21,5 | 22,1 | | |
| 63 | 30.04.2014 | 12,5 | 12,1 | 15,6 | 15,3 | 79,6 | 12,0 | 12,3 | 13,8 | 14,1 | | |
| 64 | 01.05.2014 | 13,0 | 12,8 | 17,8 | 17,8 | 72,5 | 12,4 | 12,8 | 14,9 | 15,1 | | |
| 65 | 02.05.2014 | 5,4 | 5,8 | 12,3 | 12,2 | 45,4 | 6,3 | 6,5 | 11,3 | 11,5 | | |
| 66 | 03.05.2014 | 8,9 | 9,0 | 14,3 | 14,3 | 62,5 | 9,1 | 9,0 | 12,4 | 12,0 | | |
| 67 | 04.05.2014 | 13,1 | 13,4 | 20,3 | 19,7 | 66,3 | 13,1 | 12,9 | 16,4 | 15,8 | | |
| 68 | 05.05.2014 | 10,7 | 11,2 | 15,4 | 15,2 | 71,8 | 13,1 | 12,5 | 17,2 | 16,1 | | |
| 69 | 06.05.2014 | 4,2 | 4,4 | 10,8 | 10,5 | 40,6 | 5,0 | 4,8 | 9,4 | 9,0 | | |
| 70 | 07.05.2014 | 3,1 | 3,0 | 7,7 | 7,4 | 40,6 | 3,5 | 3,4 | 7,3 | 7,0 | | |
| 71 | 08.05.2014 | 3,4 | 3,1 | 7,3 | 7,1 | 45,4 | 4,4 | 4,2 | 7,9 | 7,4 | | |
| 72 | 09.05.2014 | 5,1 | 4,6 | 12,3 | 11,7 | 40,2 | 6,2 | 5,8 | 12,1 | 10,6 | | |
| 73 | 10.05.2014 | 3,8 | 3,3 | 10,6 | 10,1 | 34,3 | 5,8 | 5,5 | 11,5 | 10,4 | | |
| 74 | 11.05.2014 | 4,1 | 3,7 | 11,0 | 10,1 | 37,1 | 5,8 | 5,4 | 11,4 | 10,2 | | |
| 75 | 12.05.2014 | 4,4 | 4,6 | 8,4 | 8,0 | 54,8 | 4,5 | 4,3 | 7,7 | 7,0 | | |
| 76 | 13.05.2014 | 6,3 | 6,2 | 9,7 | 9,1 | 66,7 | 6,9 | 6,7 | 9,5 | 9,1 | | |
| 77 | 14.05.2014 | 8,7 | 9,1 | 13,5 | 12,9 | 67,8 | 8,8 | 9,4 | 12,7 | 13,3 | | |
| 78 | 15.05.2014 | 9,7 | 9,8 | 14,8 | 14,4 | 66,9 | 9,8 | 10,3 | 13,6 | 14,0 | | |
| 79 | 16.05.2014 | 15,3 | 14,8 | 22,4 | 21,7 | 68,1 | 15,6 | 16,3 | 21,6 | 22,2 | | |
| 80 | 17.05.2014 | 13,9 | 13,6 | 18,6 | 18,3 | 74,4 | 14,6 | 15,0 | 19,5 | 19,7 | | |
| 81 | 18.05.2014 | | | 25,4 | 25,4 | | 20,6 | 21,3 | 26,7 | 27,2 | Outlier Ref. PM2,5 | |
| 82 | 19.05.2014 | 11,8 | 11,3 | 17,7 | 17,1 | 66,5 | 11,0 | 11,1 | 16,4 | 16,4 | | |
| 83 | 20.05.2014 | 7,2 | 6,6 | 10,7 | 10,0 | 66,4 | 7,5 | 7,7 | 10,6 | 10,6 | | |
| 84 | 21.05.2014 | 6,7 | 6,4 | 10,6 | 10,3 | 62,3 | 6,9 | 6,8 | 10,8 | 10,7 | | |
| 85 | 22.05.2014 | 4,4 | 3,8 | 9,8 | 8,9 | 43,7 | 4,3 | 4,3 | 8,6 | 8,4 | | |
| 86 | 23.05.2014 | 5,6 | 5,3 | 9,9 | 9,1 | 57,1 | 5,0 | 5,1 | 7,5 | 7,5 | | |
| 87 | 24.05.2014 | 3,9 | 3,7 | 9,0 | 8,3 | 43,9 | 4,5 | 4,5 | 7,9 | 7,6 | | |
| 88 | 25.05.2014 | 8,1 | 7,9 | 13,1 | 12,6 | 62,1 | 7,7 | 7,6 | 10,7 | 10,3 | | |
| 89 | 26.05.2014 | 9,2 | 9,1 | 14,2 | 13,0 | 67,2 | 8,4 | 8,4 | 11,5 | 11,4 | | |
| 90 | 27.05.2014 | 6,0 | 6,2 | 8,4 | 8,0 | 74,7 | 4,9 | 4,9 | 6,8 | 6,5 | | |

**Annex 7** **Measured values from UK field test sites, related to actual conditions** **Page 4 of 4**

| | |
|---|---|
| Manufacturer | PALAS |
| Type of instrument | FIDAS 200 S |
| 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 | 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 | | |
| 97 | | | | | | | | | | | | |
| 98 | | | | | | | | | | | | |
| 99 | | | | | | | | | | | | |
| 100 | | | | | | | | | | | | |
| 101 | | | | | | | | | | | | |
| 102 | | | | | | | | | | | | |
| 103 | | | | | | | | | | | | |
| 104 | | | | | | | | | | | | |
| 105 | | | | | | | | | | | | |
| 106 | | | | | | | | | | | | |
| 107 | | | | | | | | | | | | |
| 108 | | | | | | | | | | | | |
| 109 | | | | | | | | | | | | |
| 110 | | | | | | | | | | | | |
| 111 | | | | | | | | | | | | |
| 112 | | | | | | | | | | | | |
| 113 | | | | | | | | | | | | |
| 114 | | | | | | | | | | | | |
| 115 | | | | | | | | | | | | |
| 116 | | | | | | | | | | | | |
| 117 | | | | | | | | | | | | |
| 118 | | | | | | | | | | | | |
| 119 | | | | | | | | | | | | |
| 120 | | | | | | | | | | | | |

**Annex 8** **Ambient conditions from field test sites, UK** **Page 1 of 4**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 27.02.2014 | Teddington, Winter | 6,4 | 12,6 | 984 | 80,6 | 0,2 | 109 | 2,5 |
| 2 | 28.02.2014 | | 4,8 | 9,6 | 984 | 89,3 | 0,8 | 8 | 5,1 |
| 3 | 01.03.2014 | | 4,9 | 10,6 | 983 | 83,7 | 0,1 | 189 | 0,0 |
| 4 | 02.03.2014 | | 6,9 | 11,4 | 969 | 88,1 | 1,1 | 162 | 10,2 |
| 5 | 03.03.2014 | | 4,4 | 8,9 | 976 | 92,1 | 0,1 | 116 | 10,2 |
| 6 | 04.03.2014 | | 4,8 | 12,2 | 992 | 85,6 | 0,0 | 188 | 0,0 |
| 7 | 05.03.2014 | | 8,5 | 15,1 | 1005 | 76,0 | 0,1 | 199 | 0,0 |
| 8 | 06.03.2014 | | 9,2 | 14,4 | 1004 | 80,5 | 0,4 | 177 | 0,0 |
| 9 | 07.03.2014 | | 11,0 | 17,1 | 1007 | 77,5 | 0,4 | 131 | 0,0 |
| 10 | 08.03.2014 | | 11,5 | 16,7 | 1004 | 64,2 | 0,5 | 156 | 0,0 |
| 11 | 09.03.2014 | | 10,7 | 19,5 | 1005 | 68,2 | 0,4 | 155 | 0,0 |
| 12 | 10.03.2014 | | 9,1 | 14,4 | 1013 | 75,6 | 2,3 | 14 | 0,0 |
| 13 | 11.03.2014 | | 7,4 | 12,4 | 1015 | 84,2 | 1,0 | 27 | 0,0 |
| 14 | 12.03.2014 | | 9,4 | 17,5 | 1012 | 76,7 | 0,3 | 40 | 0,0 |
| 15 | 13.03.2014 | | 9,8 | 19,6 | 1011 | 74,5 | 0,2 | 21 | 0,0 |
| 16 | 14.03.2014 | | 11,4 | 18,9 | 1007 | 71,5 | 0,0 | 266 | 0,0 |
| 17 | 15.03.2014 | | 11,4 | 18,9 | 1006 | 69,7 | 0,2 | 307 | 0,0 |
| 18 | 16.03.2014 | | 12,2 | 20,6 | 1004 | 69,2 | 0,2 | 294 | 0,0 |
| 19 | 17.03.2014 | | 10,4 | 15,9 | 1000 | 73,7 | 0,1 | 250 | 0,0 |
| 20 | 18.03.2014 | | 10,3 | 14,4 | 1000 | 74,6 | 0,2 | 239 | 0,0 |
| 21 | 19.03.2014 | | 10,9 | 18,5 | 1000 | 75,7 | 0,3 | 188 | 0,0 |
| 22 | 20.03.2014 | | 10,1 | 14,4 | 987 | 79,5 | 0,5 | 200 | 2,5 |
| 23 | 21.03.2014 | | 8,3 | 13,8 | 984 | 73,2 | 0,6 | 187 | 7,6 |
| 24 | 22.03.2014 | | 6,2 | 12,8 | 984 | 76,6 | 0,2 | 224 | 0,0 |
| 25 | 23.03.2014 | | 5,5 | 11,1 | 994 | 72,3 | 0,7 | 309 | 0,0 |
| 26 | 24.03.2014 | | 7,9 | 12,0 | 991 | 70,6 | 1,3 | 139 | 5,1 |
| 27 | 25.03.2014 | | 6,2 | 9,4 | 996 | 81,3 | 0,6 | 40 | 0,0 |
| 28 | 26.03.2014 | | 8,8 | 10,2 | 999 | 59,6 | 1,7 | 359 | 0,0 |
| 29 | 27.03.2014 | | | | | | | | |
| 30 | 28.03.2014 | | | | | | | | |

**Annex 8** **Ambient conditions from field test sites, UK** **Page 2 of 4**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 31 | 29.03.2014 | Teddington, Winter | | | | | | | |
| 32 | 30.03.2014 | | 14,1 | 15,0 | 994 | 67,3 | 0,8 | 119 | 0,0 |
| 33 | 31.03.2014 | | 15,5 | 17,3 | 993 | 60,3 | 0,7 | 127 | 0,0 |
| 34 | 01.04.2014 | | 14,5 | 21,1 | 988 | 71,7 | 0,3 | 26 | 0,0 |
| 35 | 02.04.2014 | | 14,7 | 19,6 | 982 | 73,4 | 0,9 | 49 | 0,0 |
| 36 | 03.04.2014 | | 13,8 | 18,9 | 983 | 77,1 | 0,5 | 112 | 0,0 |
| 37 | 04.04.2014 | | 10,8 | 17,2 | 993 | 77,6 | 0,1 | 157 | 0,0 |
| 38 | 05.04.2014 | | 13,7 | 16,1 | 994 | 86,5 | 0,6 | 173 | 2,5 |
| 39 | 06.04.2014 | | 13,7 | 15,6 | 993 | 88,0 | 0,6 | 178 | 0,0 |
| 40 | 07.04.2014 | | 10,3 | 15,0 | 991 | 86,5 | 0,2 | 194 | 2,5 |
| 41 | 08.04.2014 | | 9,2 | 16,2 | 1005 | 70,7 | 0,3 | 299 | 0,0 |
| 42 | 09.04.2014 | | 12,0 | 20,0 | 1005 | 69,0 | 0,0 | 222 | 0,0 |
| 43 | 10.04.2014 | | 13,5 | 18,2 | 1002 | 56,2 | 0,3 | 329 | 0,0 |
| 44 | 11.04.2014 | | 11,1 | 17,6 | 1002 | 63,8 | 0,3 | 351 | 0,0 |
| 45 | 12.04.2014 | | 11,3 | 16,1 | 1001 | 70,3 | 0,2 | 275 | 0,0 |
| 46 | 13.04.2014 | | 11,6 | 18,0 | 1003 | 64,8 | 0,5 | 312 | 0,0 |
| 47 | 14.04.2014 | | 10,9 | 17,7 | 1009 | 59,0 | 0,8 | 354 | 0,0 |
| 48 | 15.04.2014 | | 9,8 | 16,6 | 1011 | 60,2 | 0,5 | 75 | 0,0 |
| 49 | 16.04.2014 | | 10,9 | 19,4 | 1005 | 59,7 | 0,3 | 123 | 0,0 |
| 50 | 17.04.2014 | | 12,3 | 19,4 | 1000 | 60,1 | 1,0 | 332 | 0,0 |
| 51 | 18.04.2014 | | 9,3 | 13,8 | 1002 | 57,5 | 1,4 | 13 | 0,0 |
| 52 | 19.04.2014 | Teddington, Summer | 10,7 | 15,1 | 995 | 68,0 | 1,5 | 34 | 0,0 |
| 53 | 20.04.2014 | | 9,9 | 17,8 | 986 | 90,0 | 0,4 | 38 | 7,6 |
| 54 | 21.04.2014 | | 13,8 | 20,8 | 986 | 80,0 | 0,2 | 348 | 22,9 |
| 55 | 22.04.2014 | | 11,7 | 16,7 | 994 | 81,9 | 0,3 | 165 | 0,0 |
| 56 | 23.04.2014 | | 12,8 | 17,4 | 1000 | 81,2 | 0,3 | 164 | 2,5 |
| 57 | 24.04.2014 | | 13,4 | 19,4 | 996 | 71,8 | 0,4 | 16 | 0,0 |
| 58 | 25.04.2014 | | 10,2 | 14,3 | 989 | 93,3 | 0,5 | 138 | 5,1 |
| 59 | 26.04.2014 | | 12,2 | 16,7 | 984 | 70,4 | 1,4 | 138 | 0,0 |
| 60 | 27.04.2014 | | 12,3 | 15,4 | 987 | 77,1 | 0,8 | 58 | 0,0 |

**Annex 8** **Ambient conditions from field test sites, UK** **Page 3 of 4**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 61 | 28.04.2014 | Teddington, Summer | 13,0 | 18,4 | 993 | 75,8 | 0,6 | 49 | 0,0 |
| 62 | 29.04.2014 | | 11,6 | 17,7 | 994 | 79,4 | 0,4 | 59 | 0,0 |
| 63 | 30.04.2014 | | 13,6 | 21,6 | 992 | 74,4 | 0,3 | 180 | 5,1 |
| 64 | 01.05.2014 | | 11,5 | 13,9 | 995 | 90,2 | 0,7 | 358 | 12,7 |
| 65 | 02.05.2014 | | 8,5 | 13,1 | 1009 | 69,6 | 1,0 | 16 | 0,0 |
| 66 | 03.05.2014 | | 10,6 | 17,0 | 1008 | 58,7 | 0,3 | 16 | 0,0 |
| 67 | 04.05.2014 | | 11,9 | 19,4 | 1000 | 66,3 | 0,3 | 161 | 0,0 |
| 68 | 05.05.2014 | | 15,3 | 19,1 | 988 | 61,6 | 0,6 | 158 | 0,0 |
| 69 | 06.05.2014 | | 15,0 | 21,7 | 987 | 63,2 | 0,2 | 201 | 0,0 |
| 70 | 07.05.2014 | | 13,4 | 17,2 | 991 | 69,4 | 0,2 | 208 | 2,5 |
| 71 | 08.05.2014 | | 13,5 | 16,4 | 988 | 83,9 | 0,2 | 211 | 2,5 |
| 72 | 09.05.2014 | | 14,2 | 18,9 | 991 | 68,0 | 0,3 | 209 | 2,5 |
| 73 | 10.05.2014 | | 12,1 | 18,5 | 983 | 71,6 | 0,5 | 198 | 2,5 |
| 74 | 11.05.2014 | | 11,9 | 16,1 | 988 | 66,8 | 0,2 | 242 | 0,0 |
| 75 | 12.05.2014 | | 12,0 | 19,4 | 994 | 74,9 | 0,2 | 309 | 5,1 |
| 76 | 13.05.2014 | | 11,6 | 17,2 | 1006 | 76,2 | 0,4 | 331 | 0,0 |
| 77 | 14.05.2014 | | 14,2 | 20,4 | 1014 | 62,1 | 0,6 | 346 | 0,0 |
| 78 | 15.05.2014 | | 15,3 | 22,6 | 1015 | 65,2 | 0,1 | 59 | 0,0 |
| 79 | 16.05.2014 | | 17,1 | 24,4 | 1008 | 64,4 | 0,1 | 55 | 0,0 |
| 80 | 17.05.2014 | | 18,5 | 26,5 | 999 | 67,4 | 0,2 | 150 | 0,0 |
| 81 | 18.05.2014 | | 18,7 | 24,5 | 987 | 57,2 | 0,7 | 142 | 0,0 |
| 82 | 19.05.2014 | | 20,0 | 25,3 | 983 | 56,9 | 1,3 | 124 | 0,0 |
| 83 | 20.05.2014 | | 14,9 | 20,3 | 990 | 75,0 | 0,3 | 158 | 0,0 |
| 84 | 21.05.2014 | | 16,0 | 20,1 | 984 | 71,4 | 0,7 | 49 | 7,6 |
| 85 | 22.05.2014 | | 14,6 | 18,3 | 983 | 70,7 | 1,4 | 138 | 5,1 |
| 86 | 23.05.2014 | | 13,7 | 17,6 | 988 | 74,1 | 0,7 | 145 | 10,2 |
| 87 | 24.05.2014 | | 12,7 | 17,1 | 994 | 75,1 | 0,6 | 163 | 0,0 |
| 88 | 25.05.2014 | | 13,1 | 19,6 | 1000 | 69,9 | 0,3 | 161 | 5,1 |
| 89 | 26.05.2014 | | 11,9 | 13,3 | 997 | 93,2 | 0,5 | 324 | 2,5 |
| 90 | 27.05.2014 | | 11,2 | 13,4 | 994 | 94,4 | 0,8 | 318 | 15,2 |

**Annex 8** **Ambient conditions from field test sites, UK** **Page 4 of 4**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 91 | 28.05.2014 | Teddington, Summer | 13,9 | 16,8 | 993 | 89,4 | 0,1 | 46 | 0,0 |
| 92 | 29.05.2014 | | 15,6 | 19,3 | 999 | 76,3 | 0,8 | 54 | 0,0 |
| 93 | 30.05.2014 | | 13,2 | 19,3 | 1006 | 71,0 | 0,5 | 40 | 0,0 |
| 94 | 31.05.2014 | | 16,1 | 20,7 | 1004 | 65,3 | 0,3 | 333 | 0,0 |
| 95 | 01.06.2014 | | 18,1 | 24,9 | 1000 | 60,5 | 0,1 | 351 | 0,0 |
| 96 | 02.06.2014 | | 16,4 | 23,2 | 996 | 74,3 | 0,1 | 174 | 0,0 |

# Appendix 2

# Filter weighing procedure

## A.1 Carrying out the weighing

All weighings are done in an air-conditioned weighing room. Ambient conditions are 20 °C ±1 °C and 50 % ±5 % relative humidity, which conforms to the requirements of Standard EN 14907.

The filters used in the field test are weighed manually. In order to condition the filters (including control filters), they are placed on sieves to avoid overlap.
The specifications for pre- and post-weighing are specified beforehand and conform to the Standard.

| Before sampling = pre-weighing | After sampling = post-weighing |
|---|---|
| Conditioning 48 h + 2 h | Conditioning 48 h + 2 h |
| Filter weighing | Filter weighing |
| Re-conditioning 24 h +2 h | Re-conditioning 24 h + 2 h |
| Filter weighing and immediate packaging | Filter weighing |

The balance is always ready for use. An internal calibration process is started prior to each weighing series. The standard weight of 200 mg is weighed as reference and the boundary conditions are noted down if nothing out of the ordinary results from the calibration process. Deviations of prior weighings conform to the Standard and do not exceed 20 µg (refer to Figure 134). All six control filters are weighed afterwards and a warning is displayed for control filters with deviations > 40 µg during evaluation. These control filters are not used for post-weighing. Instead, the first three acceptable control filters are used while the others remain in the protective jar in order to replace a defective or deviating filter, if necessary. Figure 135 shows an exemplary process over a period of more than four months.

All filters which display a difference of more than 40 µg between the first and second weighing are excluded from the pre-weighing process. Filters exhibiting deviations of more than 60 µg are not considered for evaluation after post-weighing, as conforming to standards.

Weighed filters are packed in separate polystyrene jars for transport and storage. These jars remain closed until the filter is inserted. Virgin filters can be stored in the weighing room for up to 28 days before sampling. Another pre-weighing is carried out if this period is exceeded.

Sampled filters can be stored for up to 15 days at a temperature of 23 °C or less. The filters are stored at 7 °C in a refrigerator.

**A2 Filter evaluation**

The filters are evaluated with the help of a corrective term in order to minimise relative mass changes caused by the weighing room conditions.

Equation:

$$Dust = MF_{post} - ( M_{Tara} \times ( MKon_{post} / MKon_{pre} ) ) \qquad (F1)$$

$MKon_{pre}$ = mean mass of the 3 control filters after 48 h and 72 h pre-weighing

$MKon_{post}$ = mean mass of the 3 control filters after 48 h and 72 h post-weighing

$M_{Tara}$ = mean mass of the filter after 48 h and 72 h pre-weighing

$MF_{post}$ = mean mass of the loaded filter after 48 h and 72 h post-weighing

Dust = corrected dust mass of the filter

This shows that the method becomes independent from weighing room conditions due to the corrective calculation. Influence due to the water content of the filter mass between virgin and loaded filter can be controlled and do not change the dust content of sampled filters. Hence, point 9.3.2.5 of EN 14907 is fulfilled.

The example of the standard weight between November 2008 and February 2009 shows that the permissible difference of max. 20 µg from the previous measurement is not exceeded.

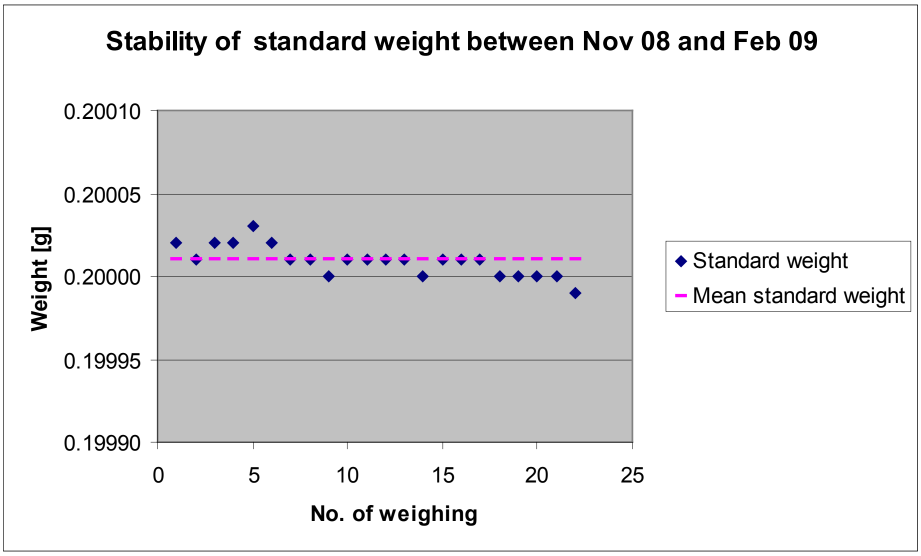



*Figure 134: Stability of standard weight*

*Table 64: Stability of standard weight*

| Date | Weighing No. | Standard weight | Difference to the previous weighing |
|---|---|---|---|
| | | g | µg |
| 12.11.2008 | 1 | 0.20002 | |
| 13.11.2008 | 2 | 0.20001 | -10 |
| 10.12.2008 | 3 | 0.20002 | 10 |
| 11.12.2008 | 4 | 0.20002 | 0 |
| 17.12.2008 | 5 | 0.20003 | 10 |
| 18.12.2008 | 6 | 0.20002 | -10 |
| 07.01.2009 | 7 | 0.20001 | -10 |
| 08.01.2009 | 8 | 0.20001 | 0 |
| 14.01.2009 | 9 | 0.20000 | -10 |
| 15.01.2009 | 10 | 0.20001 | 10 |
| 21.01.2009 | 11 | 0.20001 | 0 |
| 22.01.2009 | 12 | 0.20001 | 0 |
| 29.01.2009 | 13 | 0.20001 | 0 |
| 30.01.2009 | 14 | 0.20000 | -10 |
| 04.02.2008 | 15 | 0.20001 | 10 |
| 05.02.2009 | 16 | 0.20001 | 0 |
| 11.02.2009 | 17 | 0.20001 | 0 |
| 12.02.2009 | 18 | 0.20000 | -10 |
| 18.02.2009 | 19 | 0.20000 | 0 |
| 19.02.2009 | 20 | 0.20000 | 0 |
| 26.02.2009 | 21 | 0.20000 | 0 |
| 27.02.2009 | 22 | 0.19999 | -10 |

Marked in yellow = average value

Marked in green = lowest value

Marked in blue = highest value

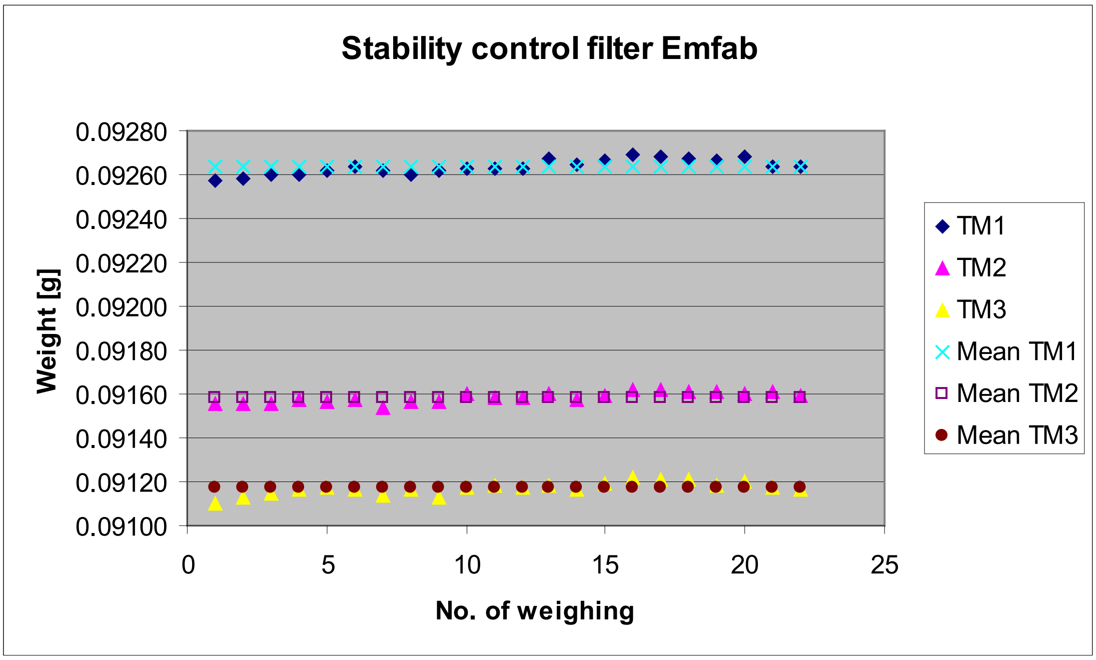



*Figure 135: Stability of the control filters*

*Table 65: Stability of the control filters*

| | Control filter no. | | |
|---|---|---|---|
| Weighing no. | TM1 | TM2 | TM3 |
| 1 | 0.09257 | 0.09155 | 0.09110 |
| 2 | 0.09258 | 0.09155 | 0.09113 |
| 3 | 0.09260 | 0.09155 | 0.09115 |
| 4 | 0.09260 | 0.09157 | 0.09116 |
| 5 | 0.09262 | 0.09156 | 0.09117 |
| 6 | 0.09264 | 0.09157 | 0.09116 |
| 7 | 0.09262 | 0.09154 | 0.09114 |
| 8 | 0.09260 | 0.09156 | 0.09116 |
| 9 | 0.09262 | 0.09156 | 0.09113 |
| 10 | 0.09263 | 0.09160 | 0.09117 |
| 11 | 0.09263 | 0.09158 | 0.09118 |
| 12 | 0.09263 | 0.09158 | 0.09117 |
| 13 | 0.09267 | 0.09160 | 0.09118 |
| 14 | 0.09265 | 0.09157 | 0.09116 |
| 15 | 0.09266 | 0.09159 | 0.09119 |
| 16 | 0.09269 | 0.09162 | 0.09122 |
| 17 | 0.09268 | 0.09162 | 0.09121 |
| 18 | 0.09267 | 0.09161 | 0.09121 |
| 19 | 0.09266 | 0.09161 | 0.09118 |
| 20 | 0.09268 | 0.09160 | 0.09120 |
| 21 | 0.09264 | 0.09161 | 0.09117 |
| 22 | 0.09264 | 0.09159 | 0.09116 |
| | | | |
| | | | |
| Mean value | 0.09264 | 0.09158 | 0.09117 |
| Standard deviation. | 3.2911E-05 | 2.4937E-05 | 2.8558E-05 |
| Rel. standard deviation. | 0.036 | 0.027 | 0.031 |
| | | | |
| Median | 0.09264 | 0.09158 | 0.09117 |
| Lowest value | 0.09257 | 0.09154 | 0.09110 |
| Highest value | 0.09269 | 0.09162 | 0.09122 |

Marked in yellow = average value

Marked in green = lowest value

Marked in blue = highest value

# Appendix 3

## Manuals

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# Operating Manual

# Fine Dust Monitor System

# Fidas®

## Fidas® 100
## Fidas® 200/200 S/200 E

Valid from Firmware-Version 100417


Model 100/200


Model 200 S

PALASCOUNTS

**CONTENTS**

**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 conductive 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 gravimetrical, 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 gravimetrical $PM_{10}$ reference procedure according to DIN EN 12341.
- The measurement system has to be regularly calibrated onsite with the gravimetrical $PM_{2.5}$ 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:

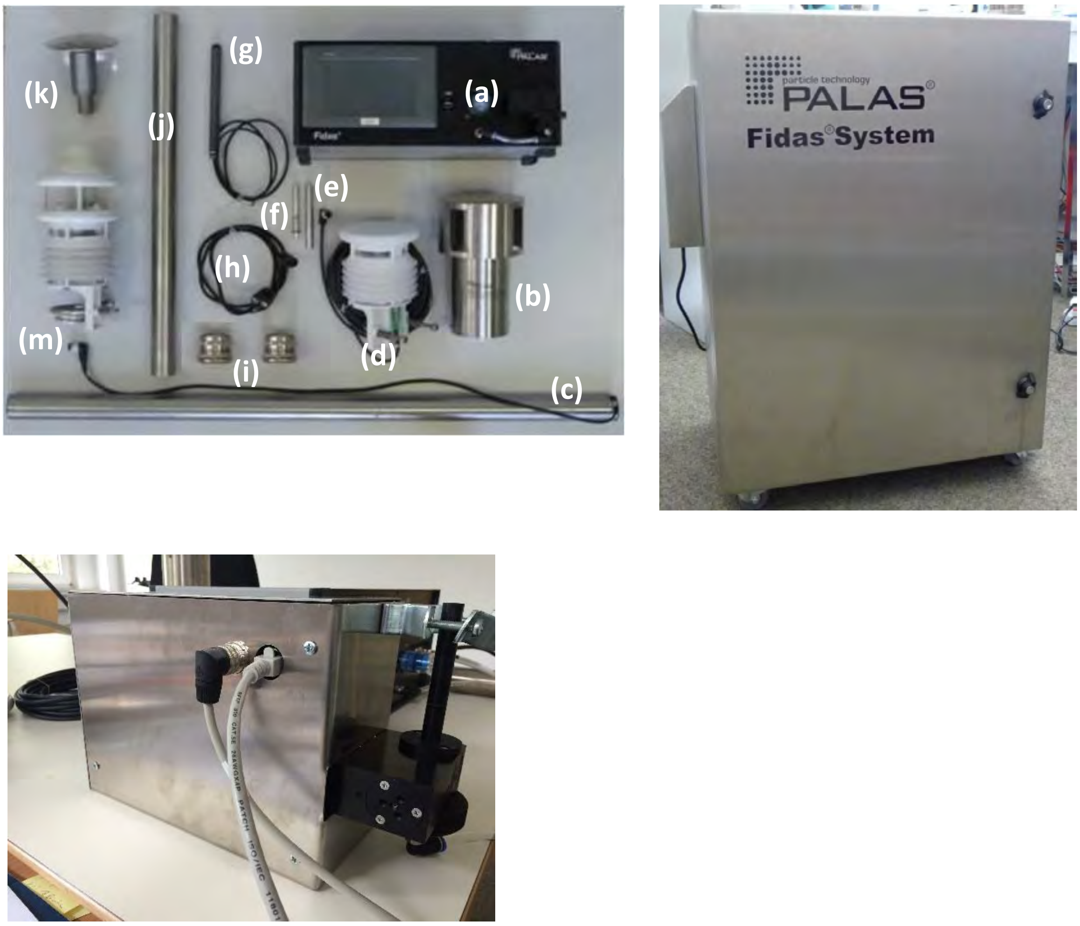



Fig. 1 A+B+C: on the top left components of a Fidas® system, on the top right IP-65 weather protective housing, on the bottom left external aerosol sensor unit for Fidas® 200 E

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:

<u>Only Fidas® 100:</u>

- Sensor for temperature, relative humidity and pressure

<u>Only Fidas® 200:</u>

- Weather station WS300-UMB (d) – optional instead also WS600-UMB (m)
- Sampling tube with IADS (c)
- Connection sampling inlet to sampling tube (e)
- Sampling inlet Sigma-2 (b) – optional additional also PM-10 or PM-2.5 sampling inlet (not certified) (k)

<u>Only Fidas® 200 E:</u>

- Weather station WS300-UMB (d) – optional instead also WS600-UMB (m)
- Sampling tube with IADS (c)
- Connection sampling inlet to sampling tube (e)
- Sampling inlet Sigma-2 (b) – optional additional also PM-10 or PM-2.5 sampling inlet (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 inlet to sampling tube (e)
- Sampling inlet Sigma-2 (b) – optional additional also PM-10 or PM-2.5 sampling inlet (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

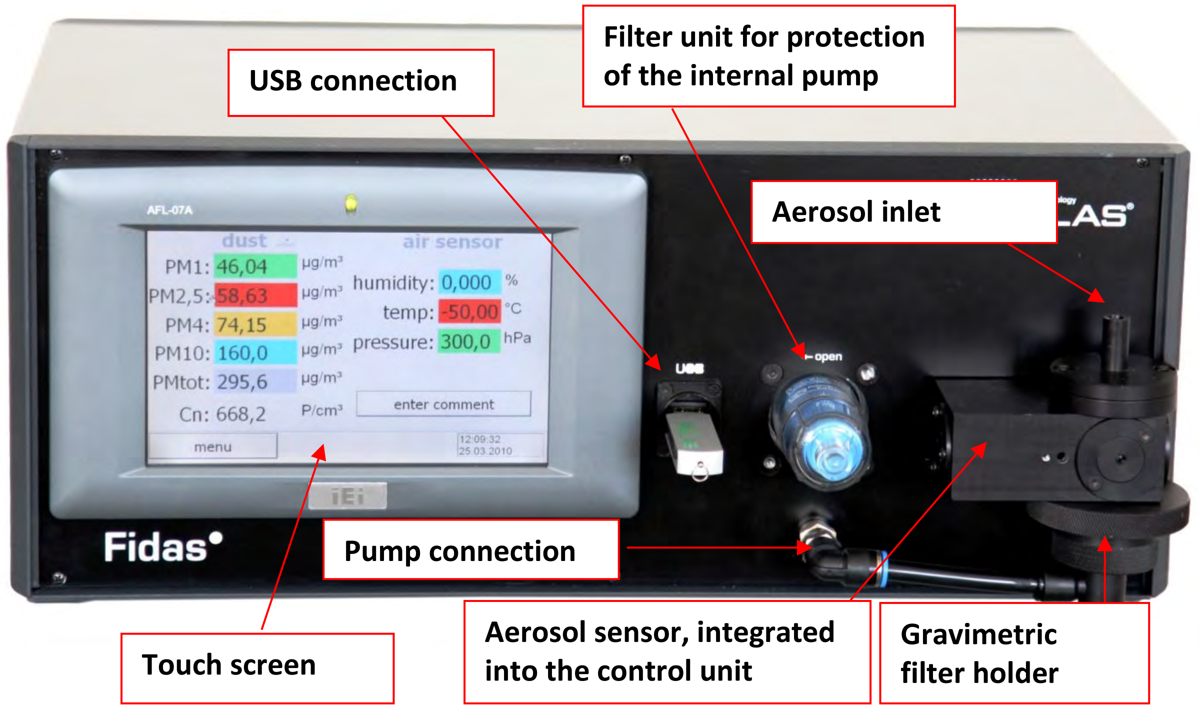



Fig. 2: Front panel of the Fidas® control unit

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.

**<u>Note:</u> 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

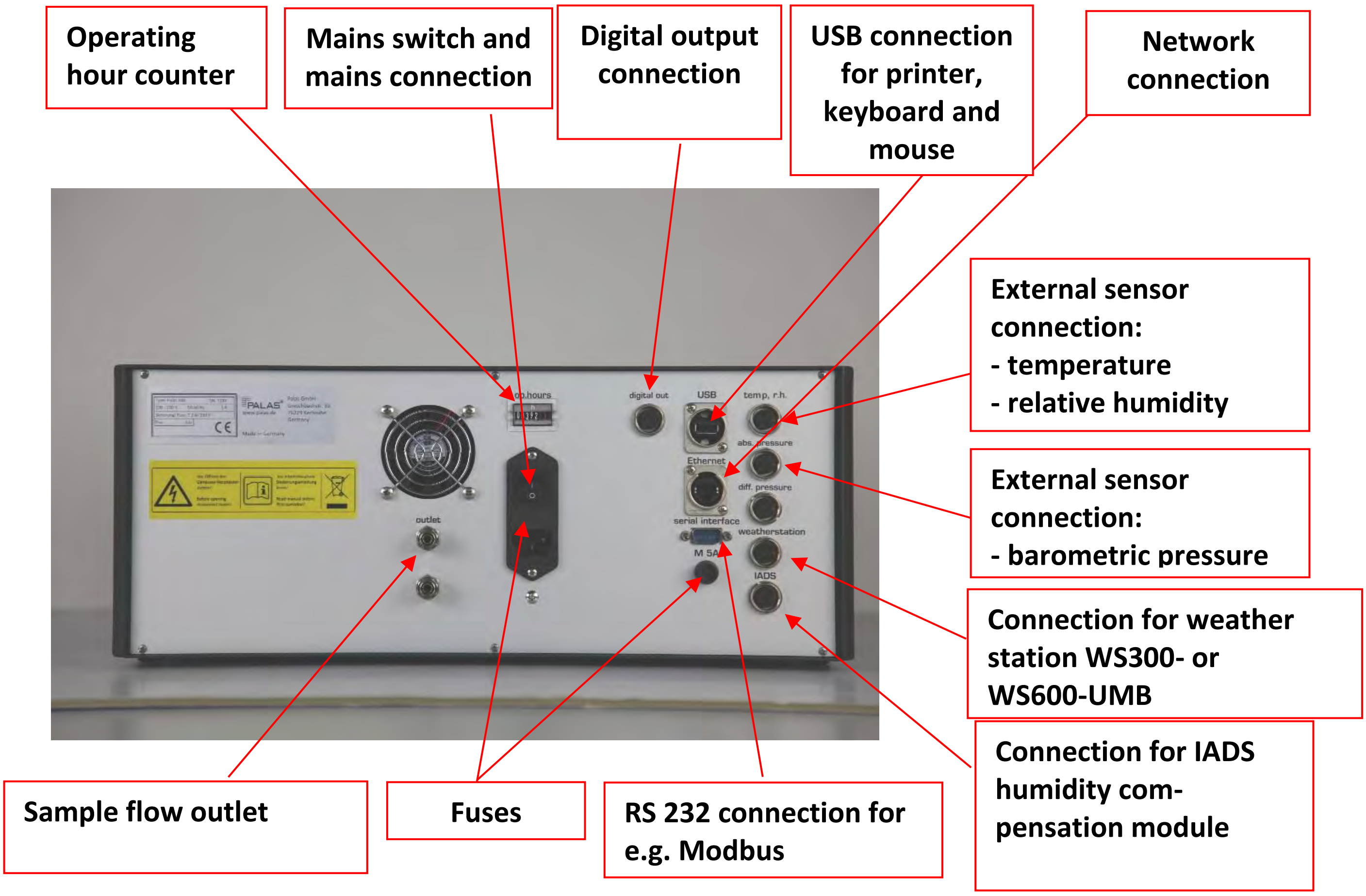



Fig. 3: Rear side of the Fidas® control unit

The control unit is switched on and off with the mains switch.
There are two fuses at the rear 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 rear 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)

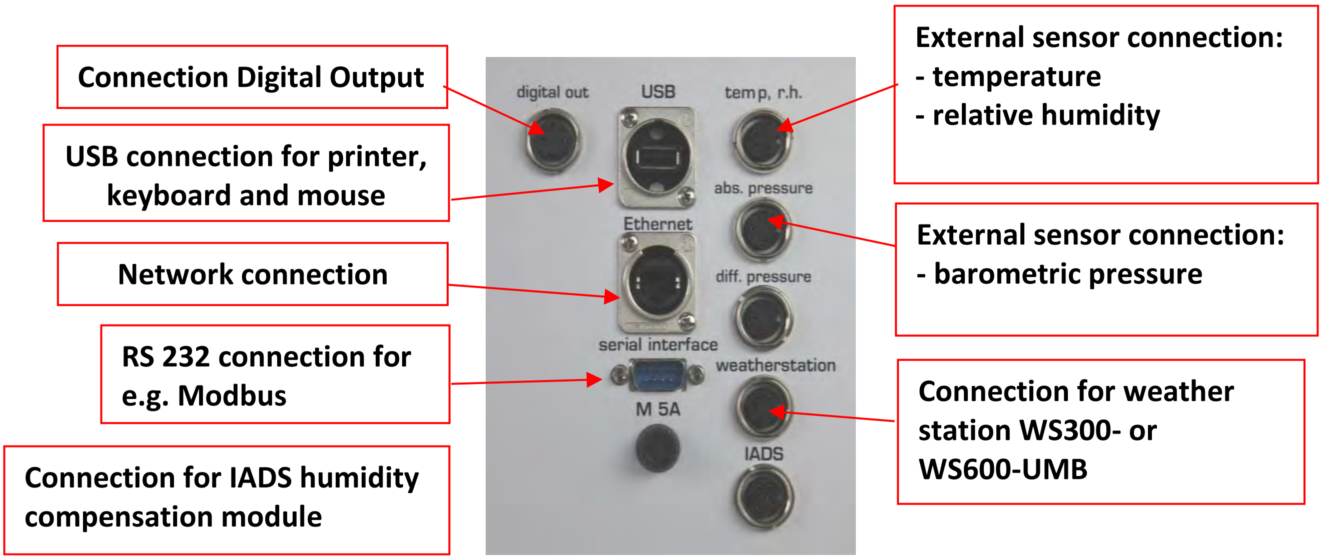



Fig. 4: Connection possibilities on the rear side of the Fidas® control unit

### 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

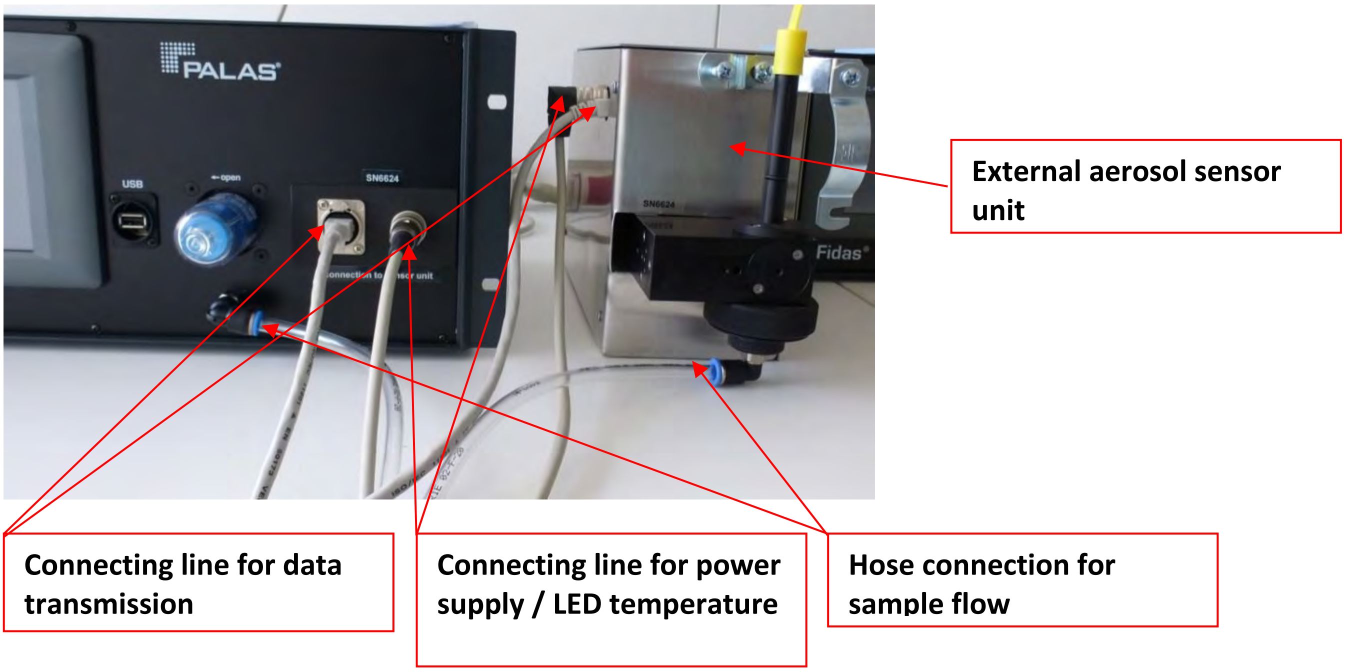



Fig. 5: Connection of the external aerosol sensor unit

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/0 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).

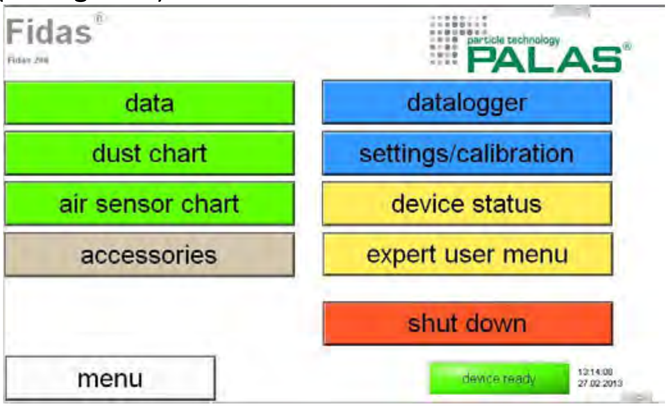



Fig 6: Start screen

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

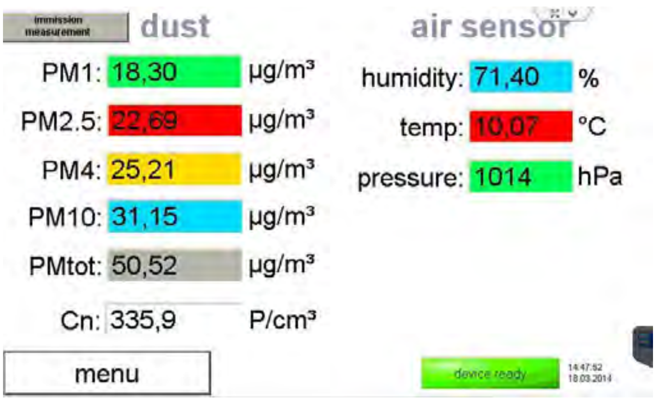



Fig. 7: Data overview, e.g. PM values

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.
**<u>Attention:</u> 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.

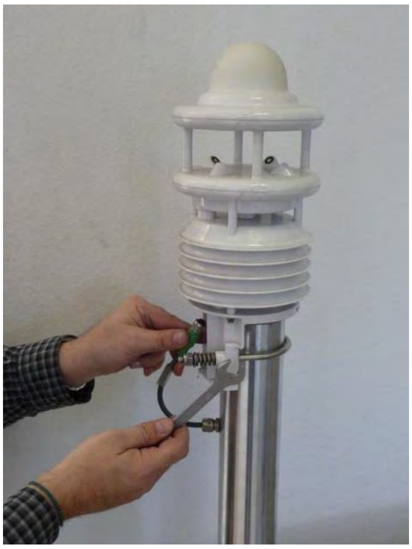


Fig. 11: Connection of the cable with the weather station

## 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).

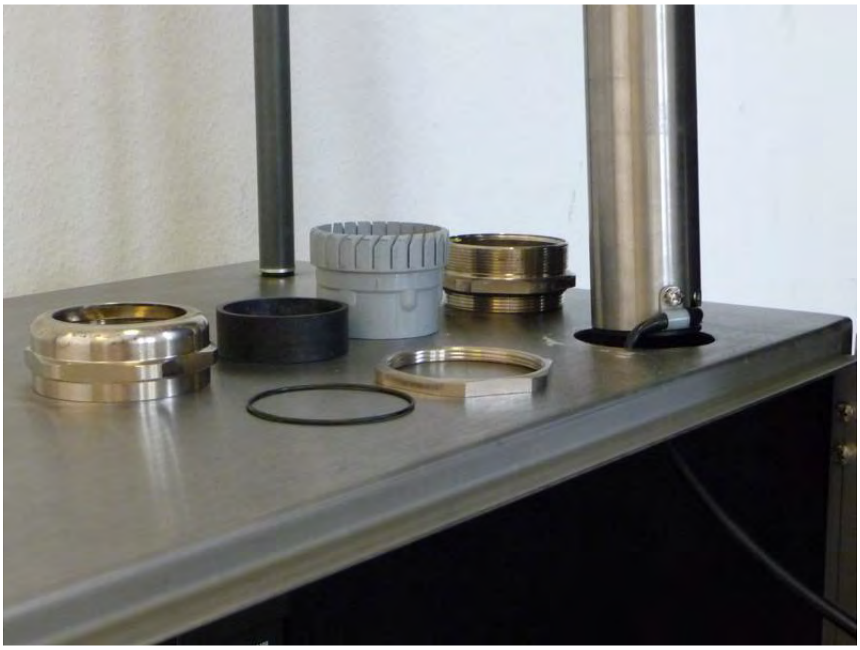


Fig. 13: Insert the sampling tube

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.

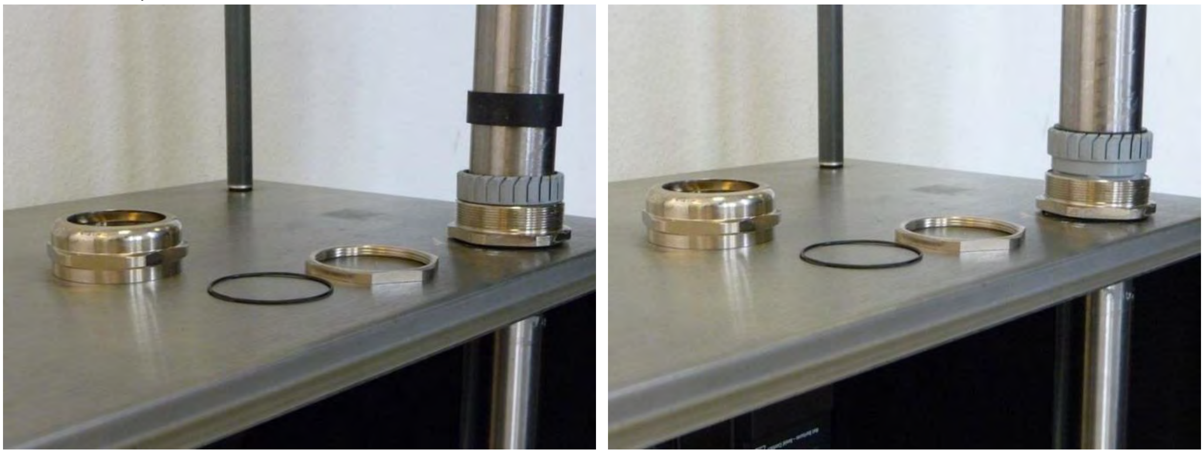


Fig. 14 A+B: Outer fixing of the sampling tube

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!

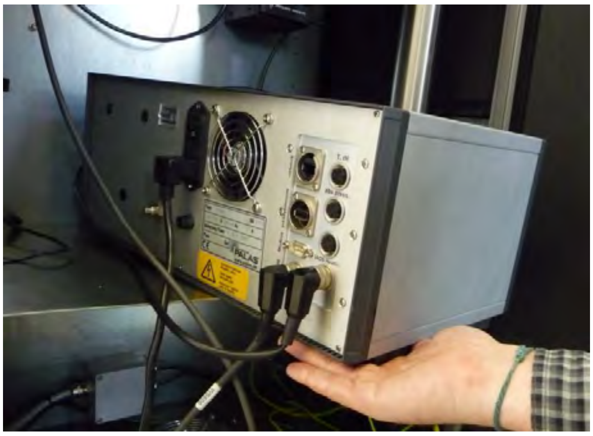


Fig. 16: Connection of the weather station, IADS with the ports on the back side

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.

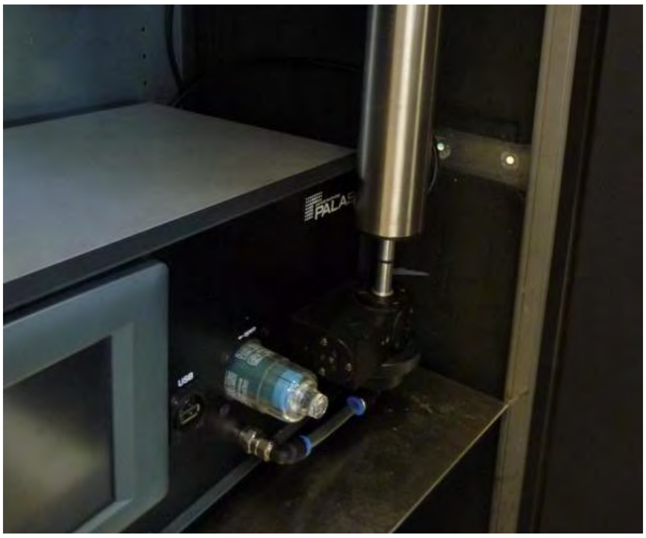


Fig. 17: Connection of the sampling tube with the sampling inlet tube and the control unit

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.

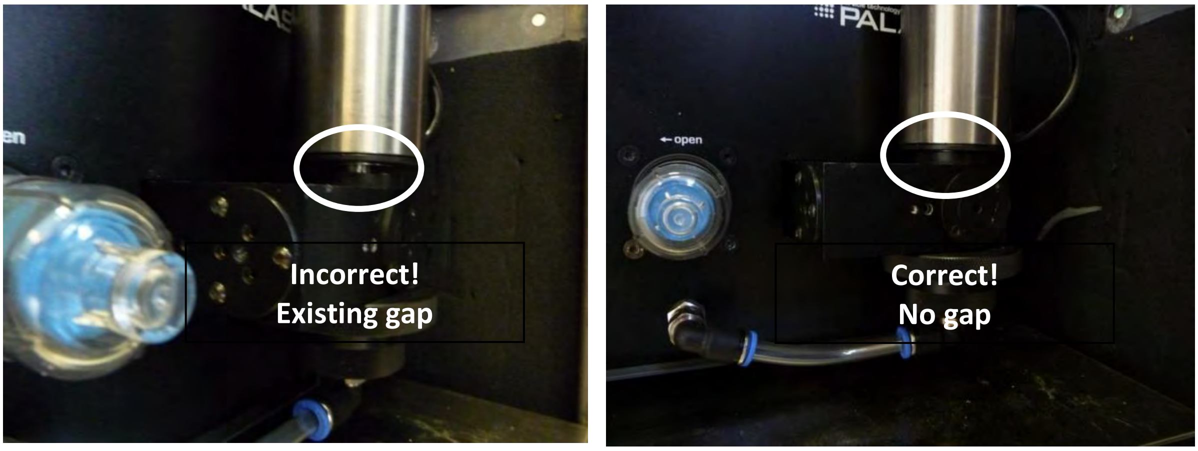



Fig. 18 A+B: on the left wrong position of the sampling tube, on the right correct position

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.

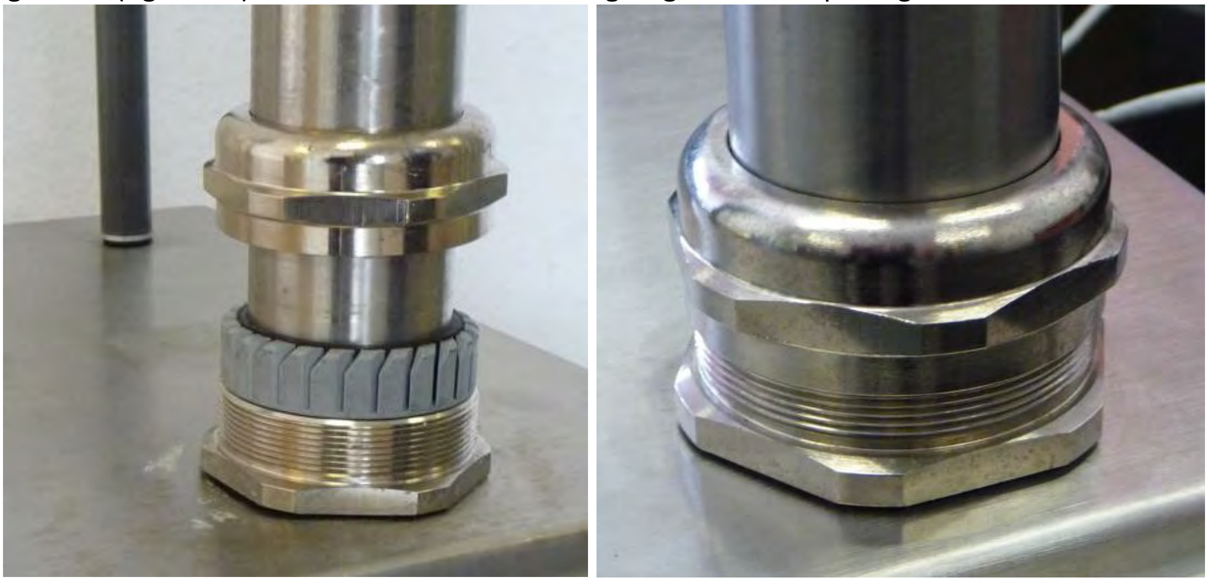


Fig. 19 A+B: Final fixing of the sampling tube

## 2.5 Mounting of the Sigma-2 sampling inlet (Fidas® 200 / 200 S / 200 E)

First, please place the connection piece sampling inlet to sampling tube as shown in figure 20:

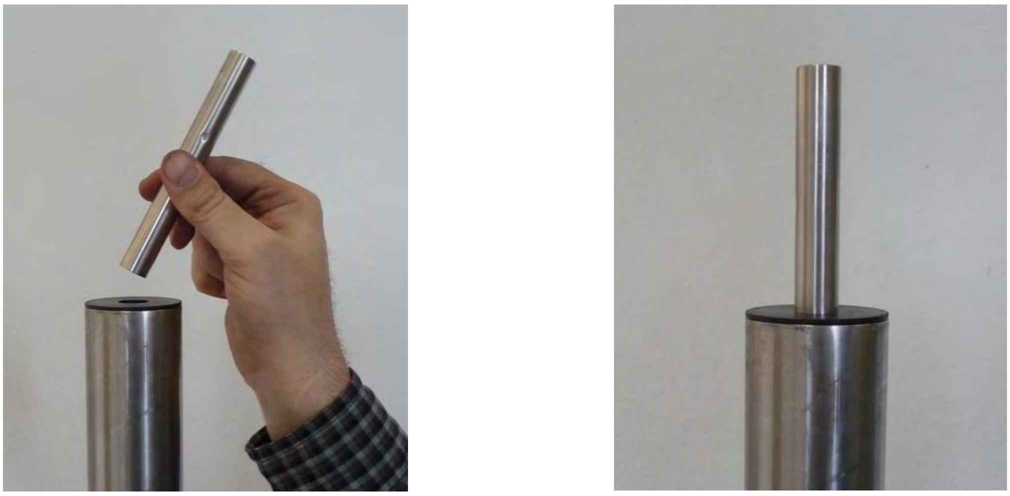


Fig. 20 A+B: Placing of the connection piece

Then slide the sigma-2 sampling inlet on this connection piece (it should be rest on the sampling tube) and then fix the sampling inlet with the size 2 Allen key (see figure 21).

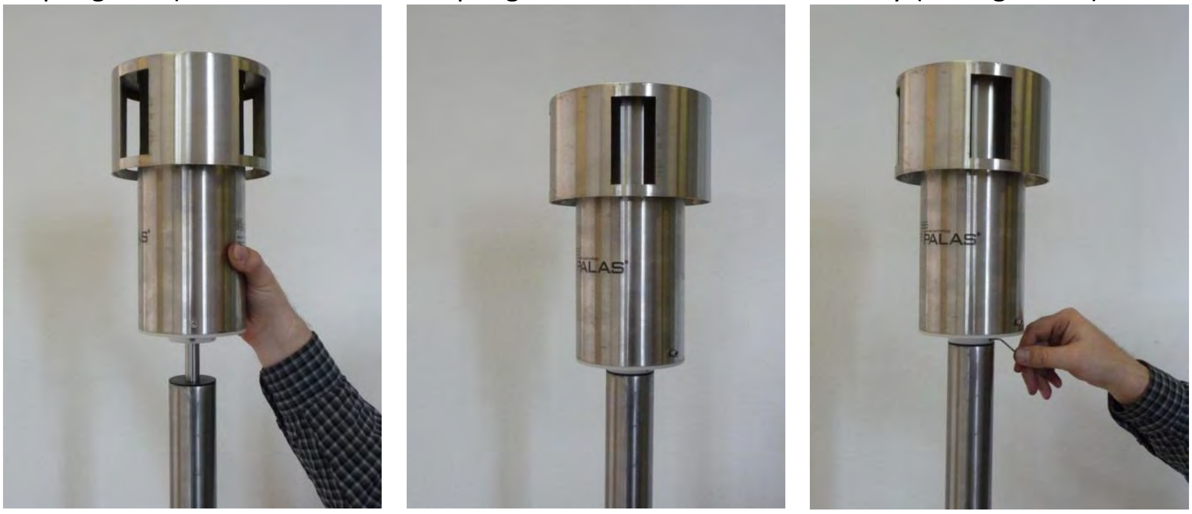


Fig. 21 A-C: Mounting of the Sigma-2 sampling inlet

If you use a PM-10 or PM-2.5 sampling inlet instead of the Sigma-2 sampling inlet, 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.

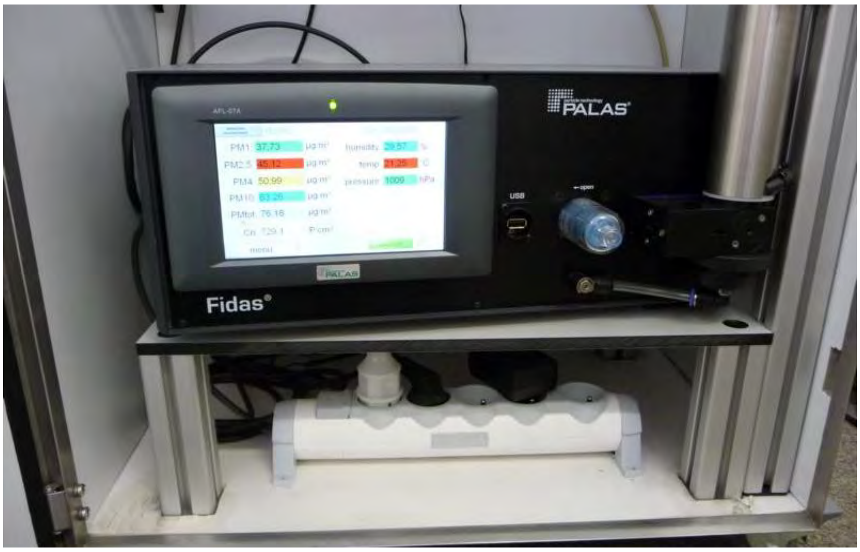


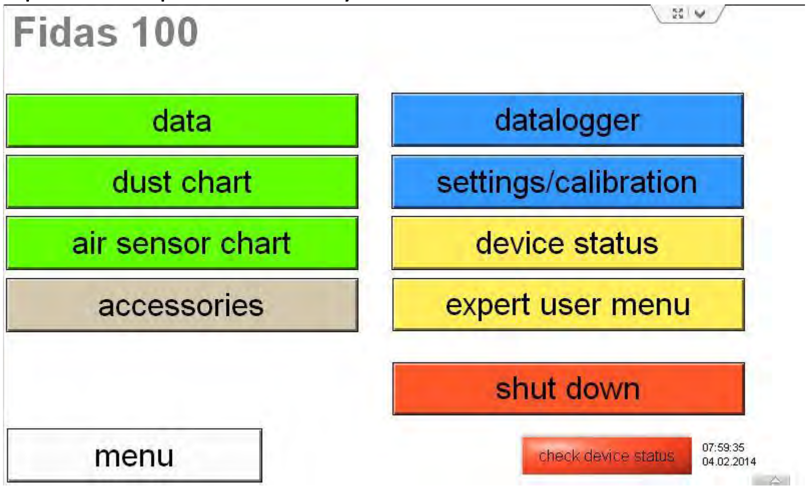

Fig. 23: Fidas® during operation

# 3 System annotations

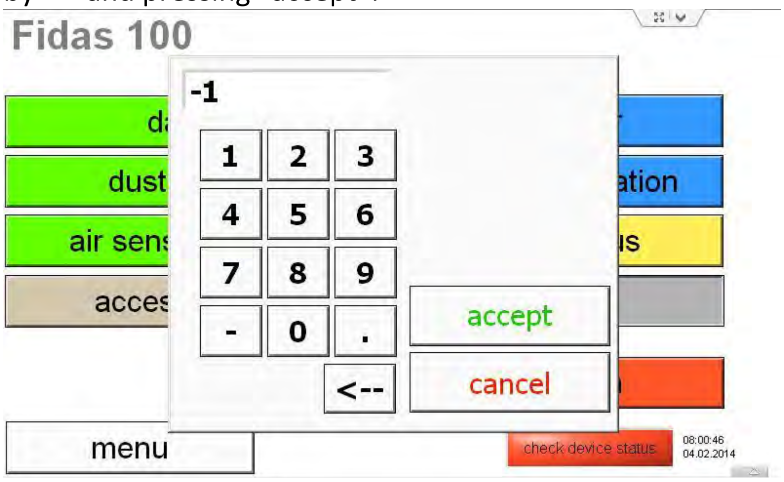
## 3.1 Activation of coincidence correction

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:

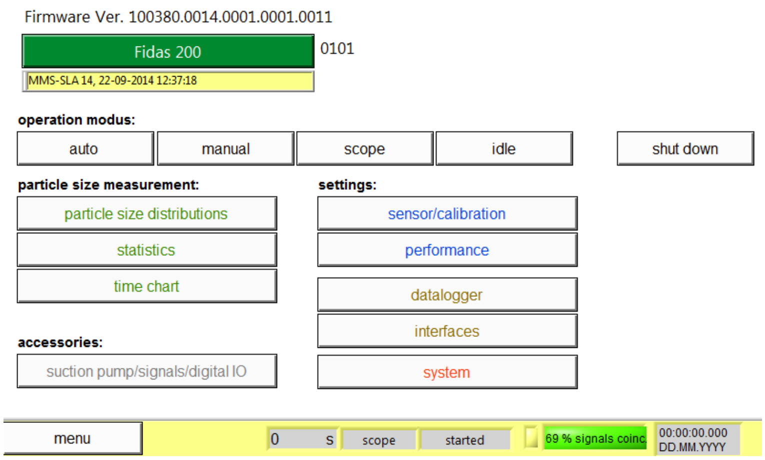
Upon startup of the Fidas you are in the main menu:




Switch to the expert user menu by pressing “expert user menu, then entering “1” followed by “-“ and pressing “accept”:

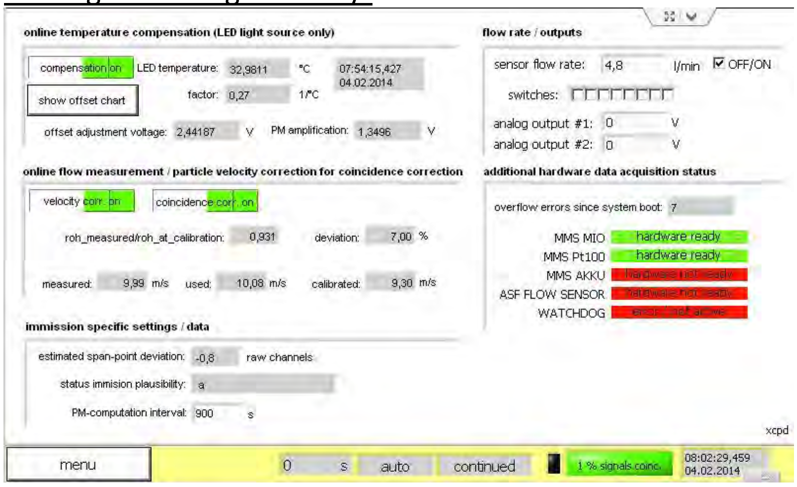



You are now in the expert user menu from which you return to the Fidas main menu by pressing on the green Fidas 100 bar on the upper left corner. Please continue by pressing “system”:

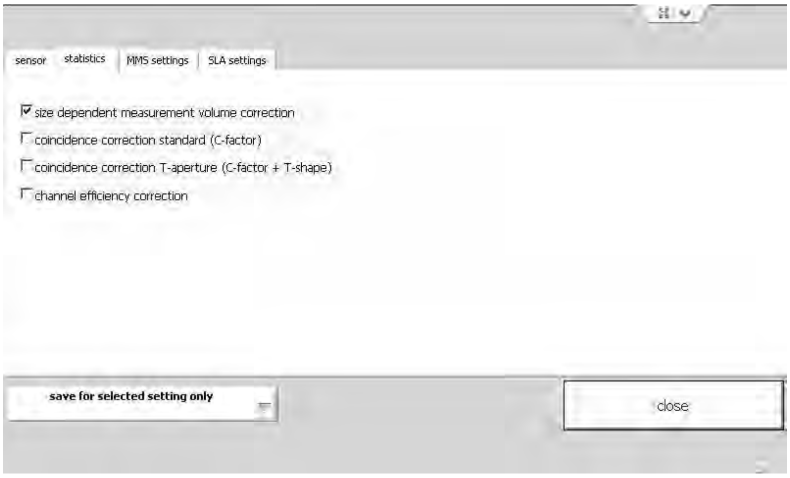



You are now in the "system" screen. Continue by pressing "advanced system settings":


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. <u>Please do not change anything else but only what is described below, else you risk that your instrument is no longer working correctly!</u>



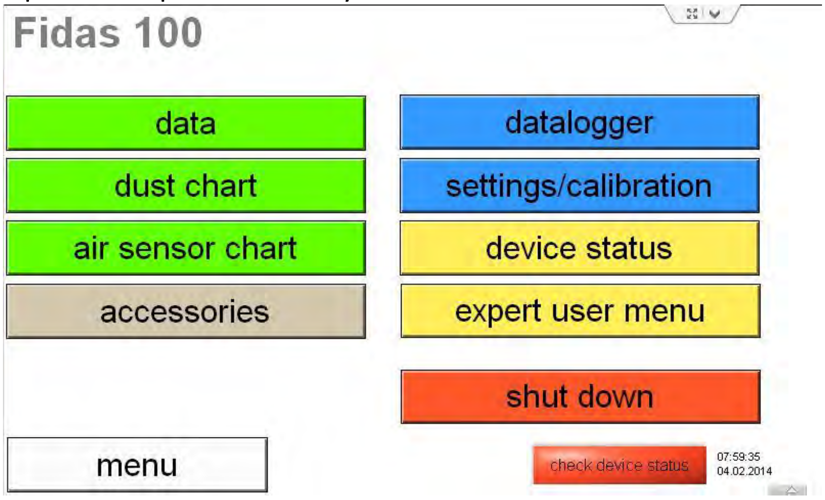

You are now in the hidden calibration screen, switch to the tab "statistics" and activate "coincidence correction T-aperture (C-factor + T-shape). Then press "save for selected settings only" followed by "close"


sensor
statistics
MMS settings
SLA settings
size dependent measurement volume correction
coincidence correction standard (C-factor)
coincidence correction T-aperture (C-factor + T-shape)
channel efficiency correction
save for selected setting only
close

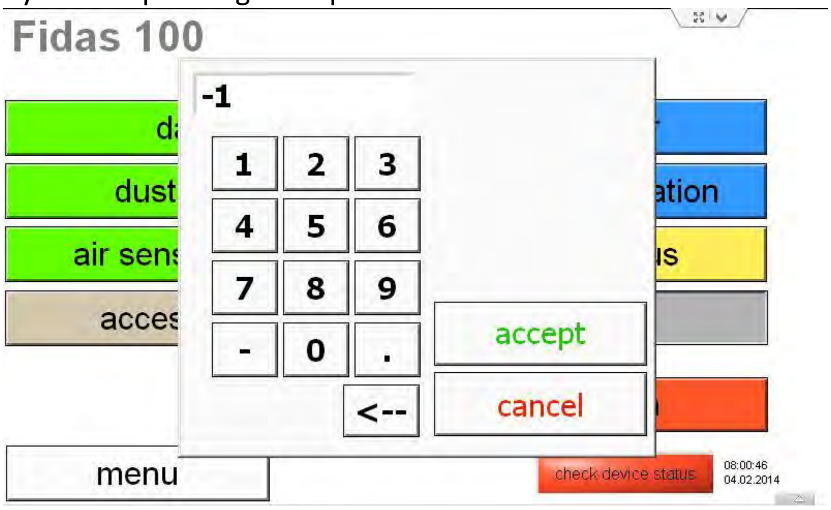
## 3.2 Switching the time base of the sliding average for Fidas® measurements

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:

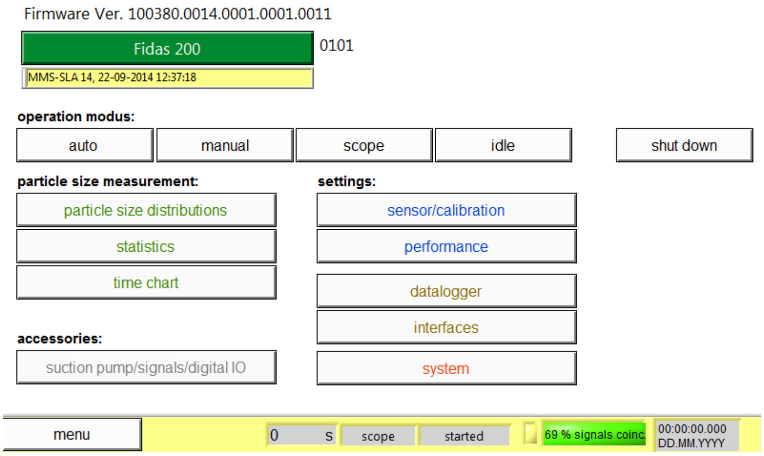
Upon startup of the Fidas you are in the main menu:



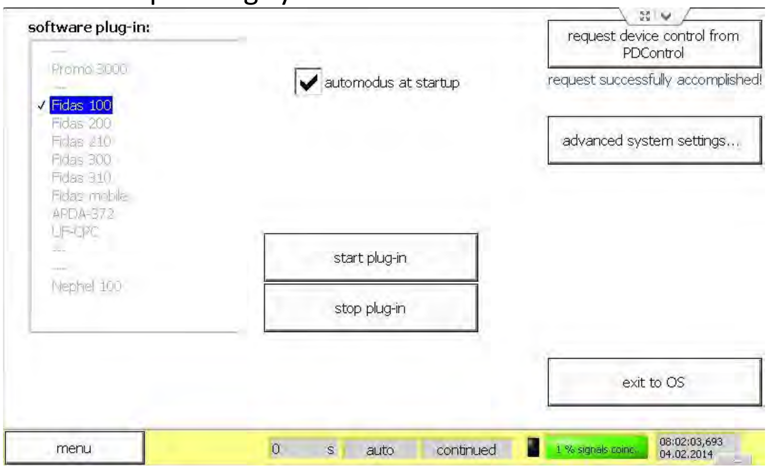

Switch to the expert user menu by pressing "expert user menu, then entering "1" followed by "-" and pressing "accept":



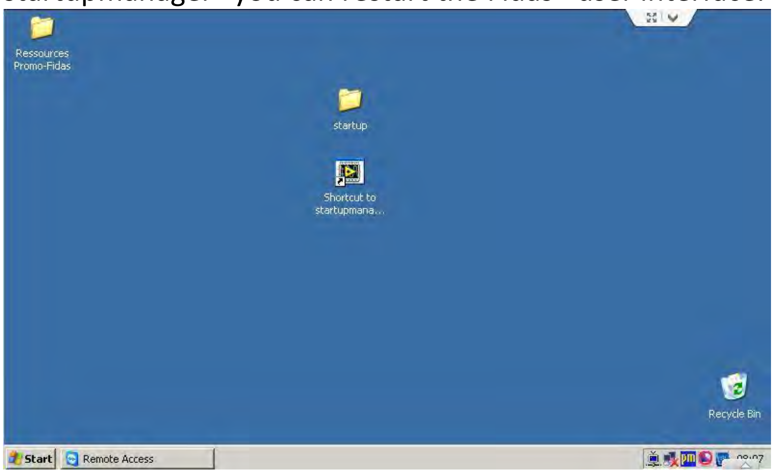

You are now in the expert user menu from which you return to the Fidas main menu by pressing on the green Fidas 100 bar on the upper left corner. Please continue by pressing "system":



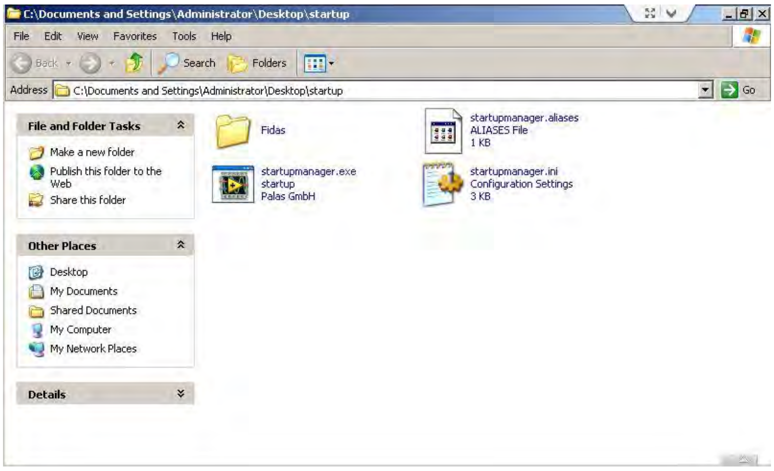

You are now in the "system" screen. Continue by pressing "exit to OS" to access the Windows operating system:




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:

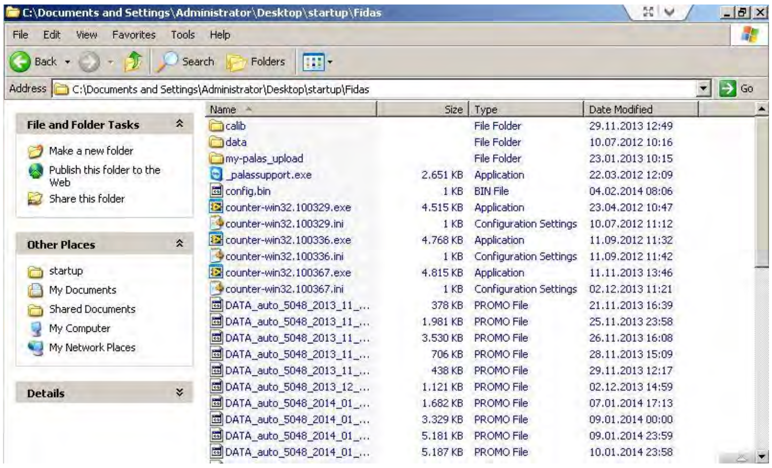


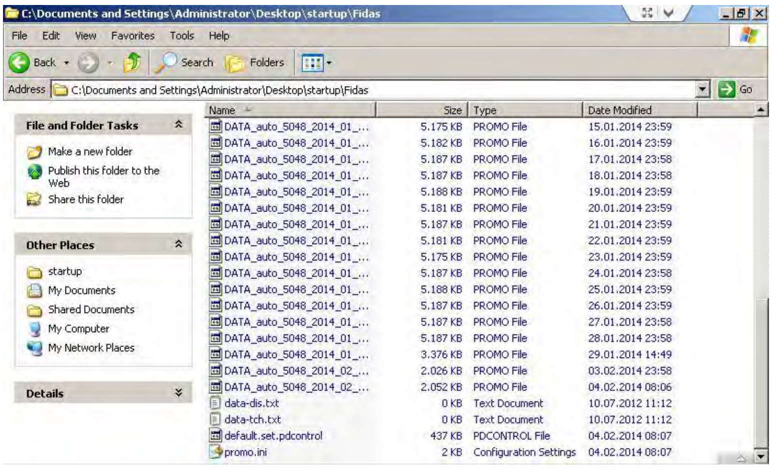

You are in the "startup" folder, next go to the "Fidas" folder:




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:

```
[system]
type=Fidas 200
ser#=XXXX
password=yxcvbXXXX
user_device#=

[plugin]
Promo 3000_enabled=no
Fidas 100_enabled=yes
Fidas 200/210_enabled=yes
Fidas 300/310_enabled=yes
Fidas mobile_enabled=no
Nanoco 100_enabled=no
Nephel 100_enabled=no
stop_enabled=yes
start_enabled=yes

[my-palas.com]
my-palas.com_autostart=no

[Fidas]
velocity_calibrated=9.3 m/s
PM10_slope=1.000
PM10_intercept=0
PM4_slope=1.000
PM4_intercept=0
PM2.5_slope=1.000
PM2.5_intercept=0
PM1_slope=1.000
PM1_intercept=0
PMtotal_slope=1.000
PMtotal_intercept=0
PM_alternative=yes
PM_volatile=no
textfile=yes
textfile_interval=60s
PM_autoadjust=no
gravimetric_correction_factor=1.00
IADS_modus=1
dust_type=2
sensor_selection=2
automated_cleaning=no
alarm_threshold=99999 µg/m³
alarm_value=PM10
alarm_email_address=""
password_service=-1
calibration_IADS_restrict=yes
calibration_temperature=50
```

```
[Promo3000]
interval=300
sensor1=15.000000
sensor2=33.000000

[hardware]
weatherstation_connected=yes
weatherstation_comport=4
weatherstation_scale_T=1
weatherstation_scale_p=1
weatherstation_scale_h=1
weatherstation_offset_T=0
weatherstation_offset_p=0
weatherstation_offset_h=0
weatherstation_equation=  x_corr=scale*x+offset
GPS_connected=no
GPS_comport=8
discmini_connected=no
discmini_comport=81
discmini_interval=300s

[UF-CPC]
liquid_pump_impulsinterval=45 s
liquid_pump_impulsamplitude=0.5 V

[settings]
sensor_selection=2
PM_interval=900s                     Time basis for moving average of PM fractions
IP_UDP_broadcast=127.0.0.1           Recommended and TUV-approved setting: 900 s
PLC_interface=1
temperature_compensation=yes
temperature_slope=0.17
velocity_correction=yes
velocity_calibration_enabled=no
flow_calibration_enabled=yes
server_IP-accesslist=+*
RSBaudRate=9600
BayerHessen_DA_commmand=60>60,61>61,62>62,63>63,64>64,65>65
```

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 $PM_{10}$

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 $PM_{10}$ and $PM_{2.5}$ (report number: 936/21218896/A of 20th September 2014 respectively 936/21227195/A of 9th March 2015), it was determined that the correlation of $PM_{10}$ and $PM_{2.5}$ to gravimetry is better if the slope and offset of the data conversion is adjusted.
It was found (section 6.1 5.4.10 resp. 5.4.11 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.

| | |
|---|---|
| | **Explanation** |
| | **Please note: Settings, that are not necessary for designated operation of Fidas®, are crossed out** |
| [system] | |
| type=Fidas 200 | Instrument model, note that Fidas® 200 S / Fidas® 200 E are also displayed as Fidas® 200 |
| ser#=XXXX | Serial number of instrument [DO NOT CHANGE!] |
| password=yxcvbXXXX | Password for internal use [DO NOT CHANGE!] |
| user_device#= | Customized user identifier (3 characters) |
| | |
| [plugin] | |
| ~~Promo 3000_enabled=no~~ | |
| Fidas 100_enabled=yes | Plugins (top level user interface), that are enabled resp. disabled |
| Fidas 200/210_enabled=yes | [DO NOT CHANGE!] |
| Fidas 300/310_enabled=yes | |
| ~~Fidas mobile_enabled=no~~ | |
| ~~Nanoco 100_enabled=no~~ | |
| ~~Nephel 100_enabled=no~~ | |
| stop_enabled=yes | |
| start_enabled=yes | |
| | |
| [my-palas.com] | Automatically connect after every start-up to the Palas® website for data upload and remote |
| my-palas.com_autostart=no | control - Requirement: Instrument is registered on Palas® website |
| | |
| [Fidas] | |
| velocity_calibrated=9.3 m/s | Nominal value for particle velocity, determined during factory calibration |
| PM10_slope=1.000 | Entry of slope and offset factors for PM fractions possible |
| PM10_intercept=0 | (e.g. from TÜV-report 936/21227195) |
| PM4_slope=1.000 | |
| PM4_intercept=0 | |
| PM2.5_slope=1.000 | |
| PM2.5_intercept=0 | |
| PM1_slope=1.000 | |
| PM1_intercept=0 | |
| PMtotal_slope=1.000 | |
| PMtotal_intercept=0 | |
| PM_alternative=yes | Display of alternative PM-values under "accessories" is active |
| ~~PM_volatile=no~~ | |
| textfile=yes | Data logging as text file is active |
| textfile_interval=60s | Interval for data logging as text file |
| PM_autoadjust=no | [DO NOT CHANGE!] |
| ~~gravimetric_correction_factor=1.00~~ | |
| IADS_modus=1 | Operating mode of IADS |
| dust_type=2 | [DO NOT CHANGE!] |
| sensor_selection=2 | [DO NOT CHANGE!] |
| automated_cleaning=no | Automatic cleaning not active |
| alarm_threshold=99999 µg/m³ | Limit value for PM fraction, that triggers the digital alarm (digital out) |
| alarm_value=PM10 | Setting of PM fraction, that triggers the alarm |
| alarm_email_address="" | E-mail adress, to which a notification is sent in case of error message |
| password_service=-1 | Password for "Expert User Mode" |
| calibration_IADS_restrict=yes | Enabling of calibration only, if nominal temperature is reached |
| calibration_temperature=50 | Nominal temperature IADS for calibration (35°C or 50°C) |

~~[Promo3000]~~
~~interval=300~~
~~sensor1=15.000000~~
~~sensor2=33.000000~~

| | |
|---|---|
| [hardware] | |
| weatherstation_connected=yes | Weather station is connected |
| weatherstation_comport=4 | COM-port of connected weather station |
| weatherstation_scale_T=1 | Entry of slope and offset factors possible for adjustment of weather station |
| weatherstation_scale_p=1 | from comparison with transfer standard |
| weatherstation_scale_h=1 | |
| weatherstation_offset_T=0 | |
| weatherstation_offset_p=0 | |
| weatherstation_offset_h=0 | |
| weatherstation_equation= x_corr=scale*x+offset | Applied equation for calibration of weather station |
| ~~GPS_connected=no~~ | GPS is currently not supported |
| ~~GPS_comport=8~~ | GPS is currently not supported |
| discmini_connected=no | DISCmini is not connected |
| discmini_comport=81 | COM-port of DISCmini |
| discmini_interval=300s | Time basis for reported data from DISCmini |

~~[UF-CPC]~~
~~liquid_pump_impulsinterval=45 s~~
~~liquid_pump_impulsamplitude=0.5 V~~

| | |
|---|---|
| [settings] | |
| sensor_selection=2 | [DO NOT CHANGE!] |
| PM_interval=900s | Time basis for moving average of PM fractions (according to TUV test 900s) |
| IP_UDP_broadcast=127.0.0.1 | UDP adress for data transmission |
| PLC_interface=1 | Selected communication protocol upon start-up (see below legend) |
| temperature_compensation=yes | LED temperature control [DO NOT CHANGE!] |
| temperature_slope=0.18 | Setting 0.15 for Fidas® 200, 0.15 for Fidas® 200 S and 0.19 for Fidas® 200 E [DO NOT CHANGE!] |
| velocity_correction=yes | [DO NOT CHANGE!] |
| velocity_calibration_enabled=no | [DO NOT CHANGE!] |
| flow_calibration_enabled=yes | Calibration of flow rate is possible (button under "sensor calibration") |
| ~~server_IP-accesslist=+*~~ | |
| RSBaudRate=9600 | Baud rate for data transmission |
| BayerHessen_DA_commmand=60>60,61>61,62>62,63>63,64>64,65>65 | Mapping of addresses for Bayern-Hessen protocol |

Selected communication protocol upon start-up

| | |
|---|---|
| 0 | Modbus |
| 1 | Bayern/Hessen |
| 2 | UDP ASCII |
| 3 | UDP single particle data stream |
| 4 | Modbus with UDP |
| 5 | Serial ASCII |

# 4 Maintentance

We recommend to check regularly the correct function of the Fidas® according to the following table 1.

| Procedure | Check interval | Chapter in manual |
|---|---|---|
| Calibration/verification | 1 month resp. 3 months | 4.2 |
| Cleaning of the optical sensor | 1 year<br>resp. if photomultiplier voltage during calibration of optical sensor is >15 % above the value of the calibration after the last cleaning respectively the delivery states | 4.4 |
| Cleaning/changing of the suction filter of the internal pump (Art.-No. 1993) | 1 year<br>resp. if performance of pump is >50 % | 4.5 |
| Check/cleaning of Sigma-2 inlet | 3 months | 4.6 |
| Replacement of O-ring seals (Art.-No. 1380) | 1 year<br>resp. in case of a determined leak | 4.7 |
| Replacement of pump module (Art.-No. 987) | In case of failure or if pump performance > 80% | 4.8 |

Table 1: Overview on maintenance activities

Otherwise the device has to be maintained only, if one of the status bits starts up (please see figure 24).

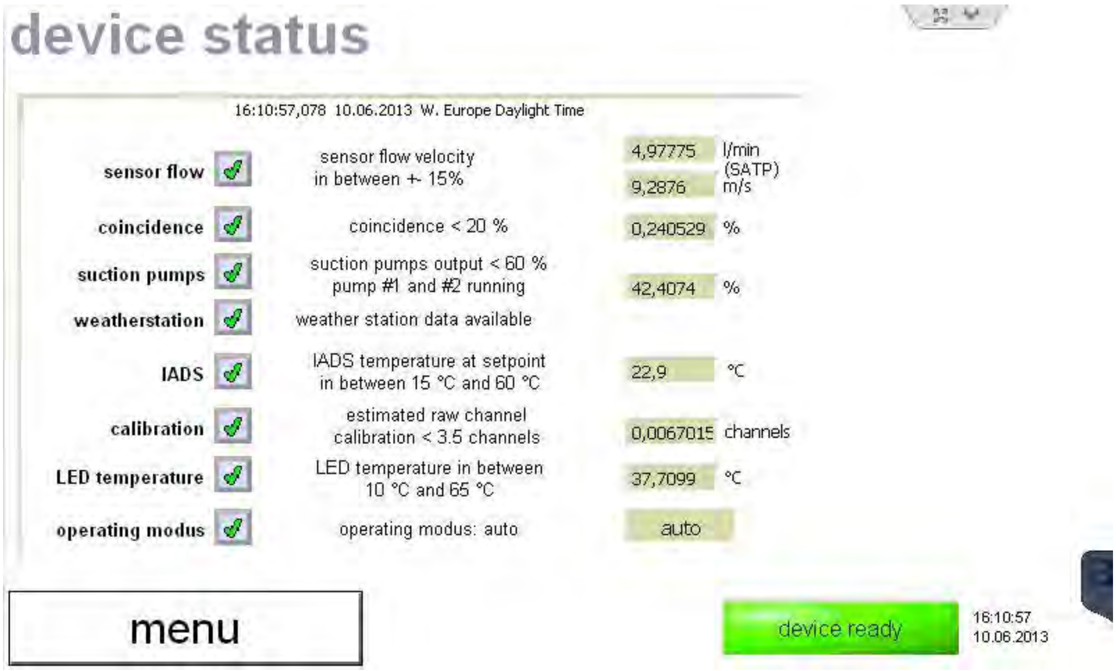



Fig. 24: The status overview shows the different sensor information, which is necessary for the correct operation of the Fidas®. This information is saved in form of an status/error byte with every data record.

In detail:

Sensor flow

a feedback circuit with a mass flow meter and with respect to 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, standardized to „standard atmospheric temperature and pressure (SATP)“, which means related to 25°C & 1013 hPa.

An error is set, if the flow deviates more than 5 % from the set value.

The second value shows the particle velocity through the optical detection volume.
An error is set, if the particle velocity differs more than 15 % from the nominal value. This nominal value corresponds to the velocity determined during the factory calibration taking into account the current IADS temperature and the ambient pressure.

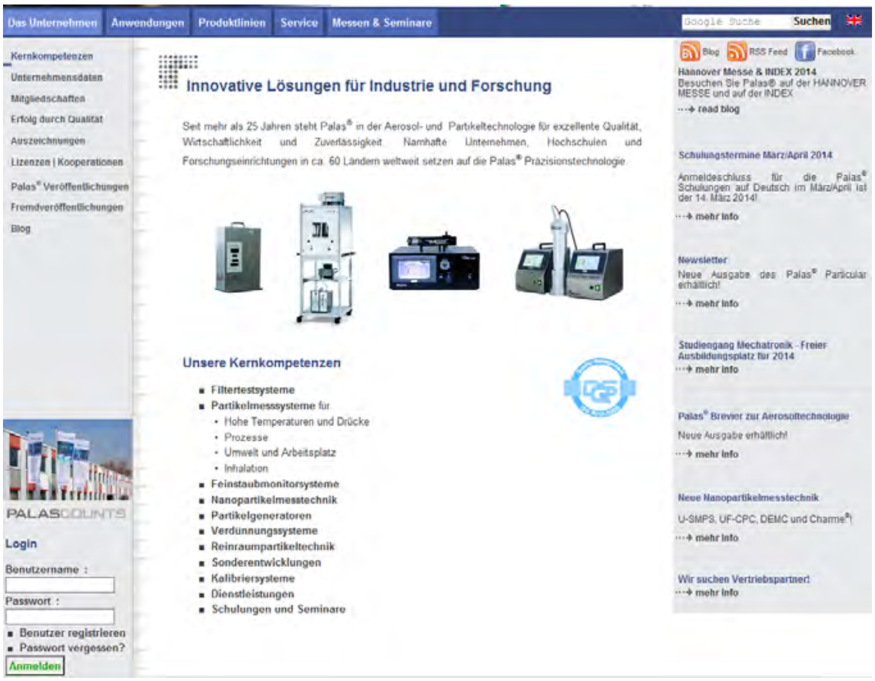
| | |
|---|---|
| Coincidence | Detection of more than one particle in the optical detection volume. Error output if it occurs with a frequency of more than 20 %. |
| Suction pumps | In Fidas® 100 und 200 two pumps (connected in parallel) provide the volume flow. If one pump fails, the other one can take it over, but then the input is higher which leads to an error. If both pumps consistently age, an error occurs if they exceed 80 %. 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 | monitors the calibration online, if it differs for more than 3.5 raw data channels (as an 40h average), an error occurs. |

**<u>Please note:</u> 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 2).
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°C and +40°C.

**Note:**
**When calibrating the instrument with MonoDust, this calibration is only valid if performed at a temperature within the range +5 °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 respectivey conditioned to a fixed nominal temperature (default setting 35 °C, as an alternate 50°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 the calibration can be carried out with an IADS temperature of 35°C. However in case of IADS-temperatures >35°C during operation under certain meteorological conditions (e.g. very hot temperatures during Summer), the conditioning of the IADS to a nominal temperature of 35°C can be a lengthy process, as the IADS does not have active cooling. Therefore the calibration can also be carried out at a nominal temperature of 50°C.

In order to set the nominal temperature of the IADS to 50°C for calibration, the following setting in the promo.ini file in the section [Fidas] needs to be applied:

calibration_temperature=50

During the conditioning procedure the current IADS temperature as well as the nominal temperature are displayed and the calibration procedure is cleared if the temperature is stable at 35°C respectively 50°C (+- 1.0°C). Usually, you have to wait at least ten minutes.

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 25). 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.

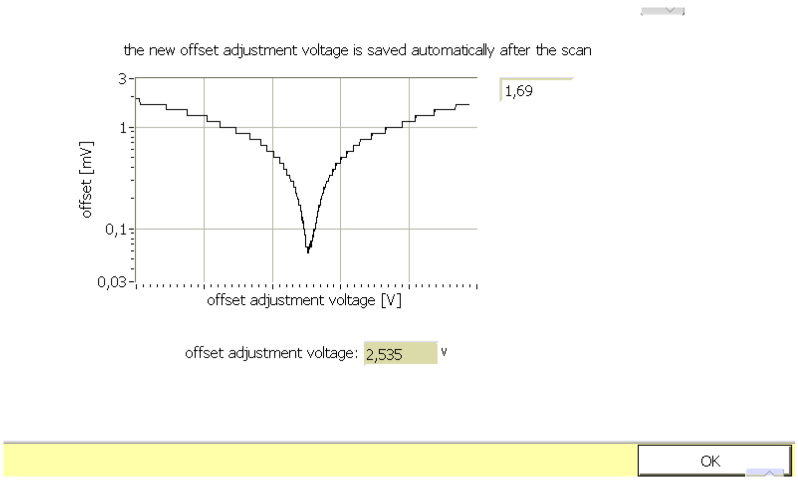



Fig. 25: Screen display during automatic offset adjustment

### 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 upstream of the pump (see figure 26). In order to check the tightness of the total system it is sufficient to seal the inlet with e.g. a thumb. The indicated volume flow has to decrease below 0.1 l/min (deducted the flow-offset). This flow-offset can be fund among “Settings/calibration” as “calibrate flow sensor offset”.

### 4.2.3 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.

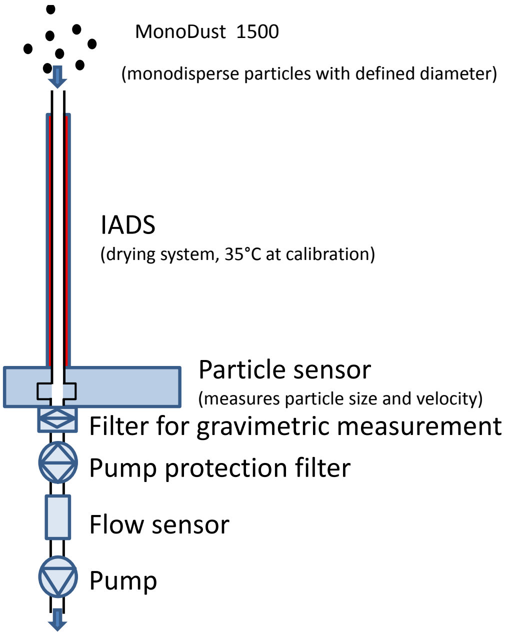



Fig. 26: Schematic set-up of the flow of the sampling volume flow

The particle size distribution of this dust is monodisperse. The instrument shows the raw data distribution of the measurement (see figure 27).

In this case, the peak of the raw data distribution has to be in channel 141.3 (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 < 139.8, the voltage of the photomultiplier must be increased. If the peak is > 142.8 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 141.3 (± 0.5).

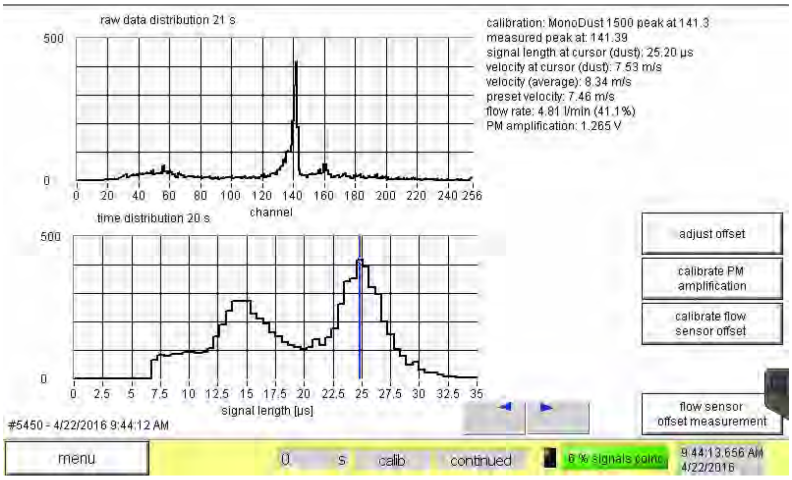



Fig. 27: Screen display during calibration (on the top: raw data distribution of channel 60 to 256 with maximum at 141.39)

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 itselfs 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*

| | PM2,5 | | PM10 | |
|---|---|---|---|---|
| channel shift | slope | offset | slope | offset |
| -3 | 1,086 | 0,03889 | 1,0877 | 0,0331 |
| -2 | 1,056 | 0,025 | 1,057 | 0,012 |
| -1 | 1,029 | 0,0122 | 1,028 | 0,048 |
| 0 | 1 | 0 | 1 | 0 |
| 1 | 0,973 | -0,00785 | 0,976 | -0,0047 |
| 2 | 0,945 | -0,0197 | 0,947 | 0,038 |
| 3 | 0,918 | -0,031 | 0,9224 | 0,083 |

For instance, if there is a shift by -3 channels, the actual PM values bear relation to the hypothetically determined PM values in the following way:

$PM_{2.5}$_actual=1.086*$PM_{2,5}$_hypothetical+0.03889
$PM_{10}$_actual=1.0877*$PM_{10}$_hypothetical+0.0331.

A shift by -3 channels results in the particle size being determined too small. As a consequence, the $PM_{2.5}$ value is measured too low by the factor 1.086.

For evaluation, the ideal event (peak exactly in channel 130) was assumed and hypothetical values of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for $PM_{10}$ were defined. The concentration value to be expected depending on the peak shift was then calculated according to the following matrix

### 4.2.4 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.

To calibrate the velocity, MonoDust 1500 is also 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 28) 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 ("velocity at cursor (dust)"). This velocity must match the velocity set during factory calibration (= preset velocity according to entry in promo.ini, please refer also to fine dust calibration certificate; Attention: Please consider IADS temperature during calibration) with a tolerance of +/- 0.5 m/s. Due to manufacturing tolerances in the nozzle, the velocities in individual units are slightly different.

If deviations outside the permissible tolerances are detected and if the reason for the deviation is not due to a leakage, the service resp. manufacturer has to be contacted.

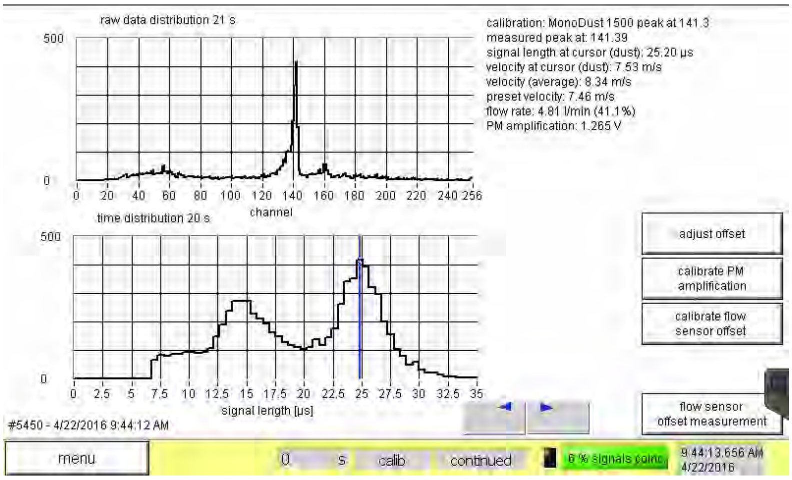


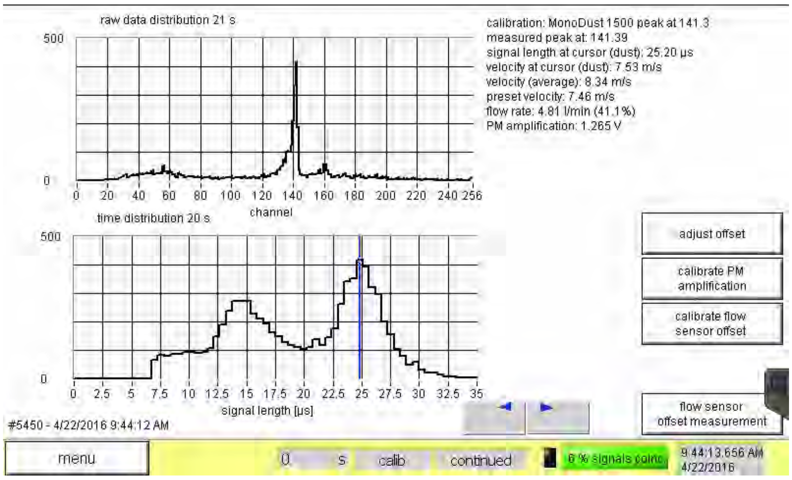

Fig. 28: Screen display during calibration (on the bottom: measured signal length distribution with determined velocity here at 7.53 m/s)

### 4.2.5 Check of the volume flow

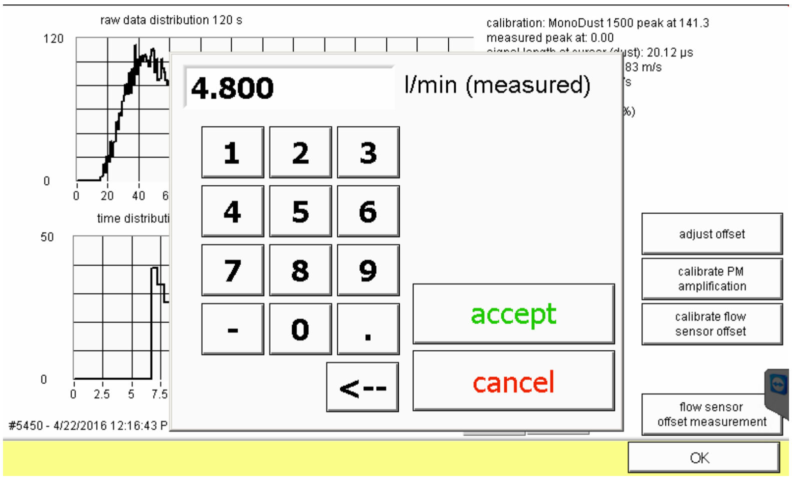
The volume flow of the Fidas® is regulated to mass flow with a mass flow meter, i.e. the volume flow changes with temperature and pressure. The flow is regulated to 4.8 l/min, standardized to „standard atmospheric temperature and pressure (SATP)“, which means related to 25°C & 1013 hPa.

This can be verified for example with a „Bubble-flow-meter“. If the device is tight (point 4.2.2) and if the velocity of the particle flow in the sensor is correct (point 4.2.4), then a check of the volume flow is not necessary.

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.




**<u>Important note:</u> 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!**

<u>Note:</u> 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

| **Procedure (incl. test intervall)** | **Parameter to be checked** | **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 | < 0.1 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* ± 0,5<br>*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) | +- 0.5 m/s of the factory setting*<br>*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) | flow rate | 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 2: 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.

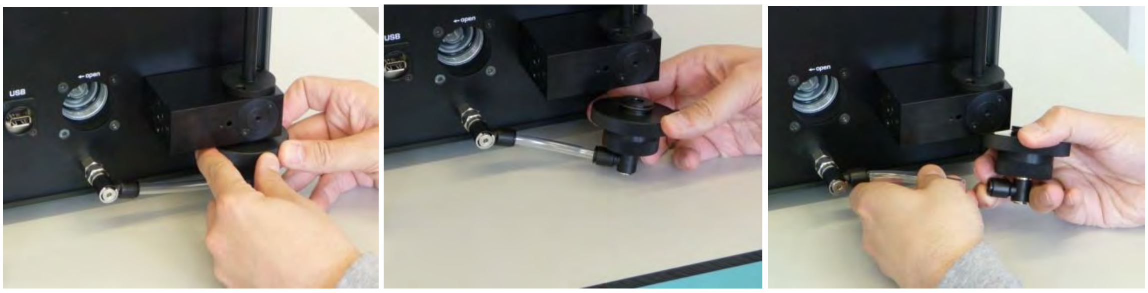


Fig. 29 A-C: Removing the filter holder

The filter holder (Fig. 29 A) can easily be detached by a downward movement (Fig. 29 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. 29 C).

Now, the filter holder can easily be opened by a counter-clockwise rotation.

Fig. 30 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. 30 A and B).
Additionally, on the bottom side, a little fence serves as support for the gravimetric filter.

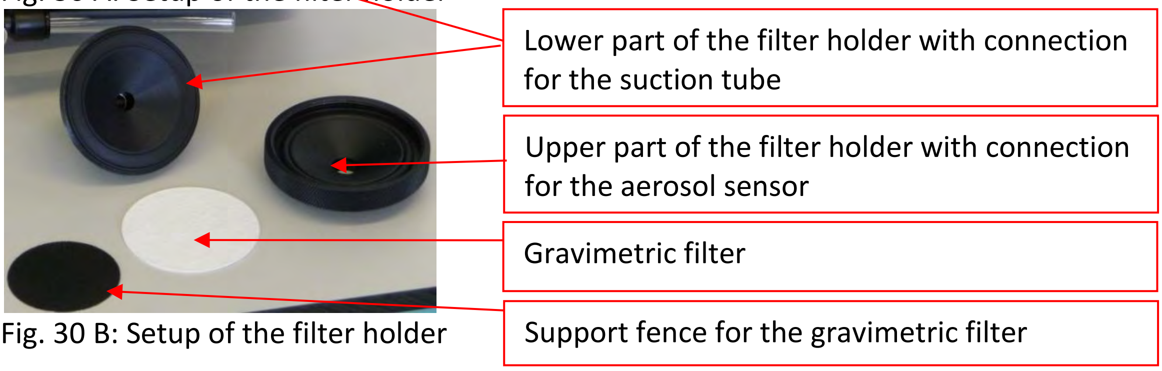



Fig. 30 B: Setup of the filter holder

## 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 4.2) 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. 31: 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.

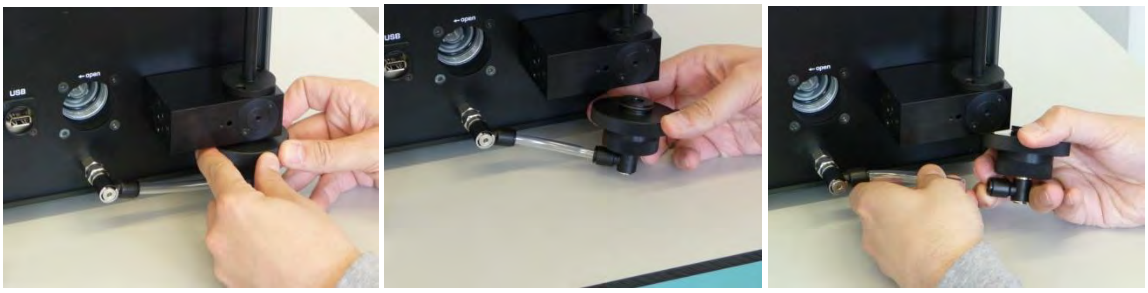


Fig. 32 A-C**:** Removing the filter holder

The filter holder (Fig. 32 A) can now easily be detached by a downward movement (Fig. 32 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. 32 C).

Then, loosen the two M3 cross-head screws with an adequate screwdriver.


**Loosening the two M3 cross-head screws**

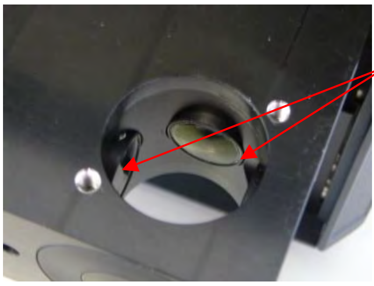
Then, the guiding tube can carefully be removed upwards from the aerosol sensor by simultaneously pushing at the bottom side and pulling at the upper side.


Fig. 33**:** Loosening the M3 cross-head screws

Fig. 34: Removing the aerosol guiding tube

**Attention:**
**When removing the aerosol guiding tube, take care that the optical glasses lying inside the aerosol sensor are not scratched or damaged with the cuvette!**

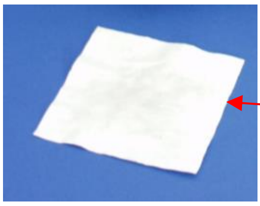
Now, the two optical glasses inside the aerosol inlet can be cleaned. This must only be done with an optical wipe (included in the delivery)!



**The two optical glasses inside the aerosol inlet**

**Attention:**
Do not touch the glasses with your fingers!
Cleaning only with optical wipes!

Fig. 35: Optical glasses inside the aerosol sensor



**Optical wipe to clean the optical glasses**

Fig. 36: Optical wipe

The aerosol guiding tube itself 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 %.


Fig. 37: Removing the protection cap

Loosen the protection cap of the suction filter (Fig. 38) by a counter clockwise rotation and remove it.

**To be loosen by a left rotation**

The filter itself can be removed the same way (Fig. 40)

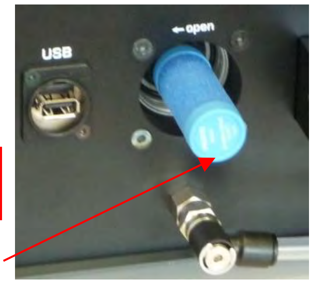



Fig. 38: Filter without protection cap


Fig. 39: Removing the filter

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. 40: Removed filter and protection cap

For installation of filter and protection cap, please proceed vice versa.

## 4.6 Cleaning of Sigma-2 inlet

The Sigma-2 inlet 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 41: Sealing ring set for Fidas® 200

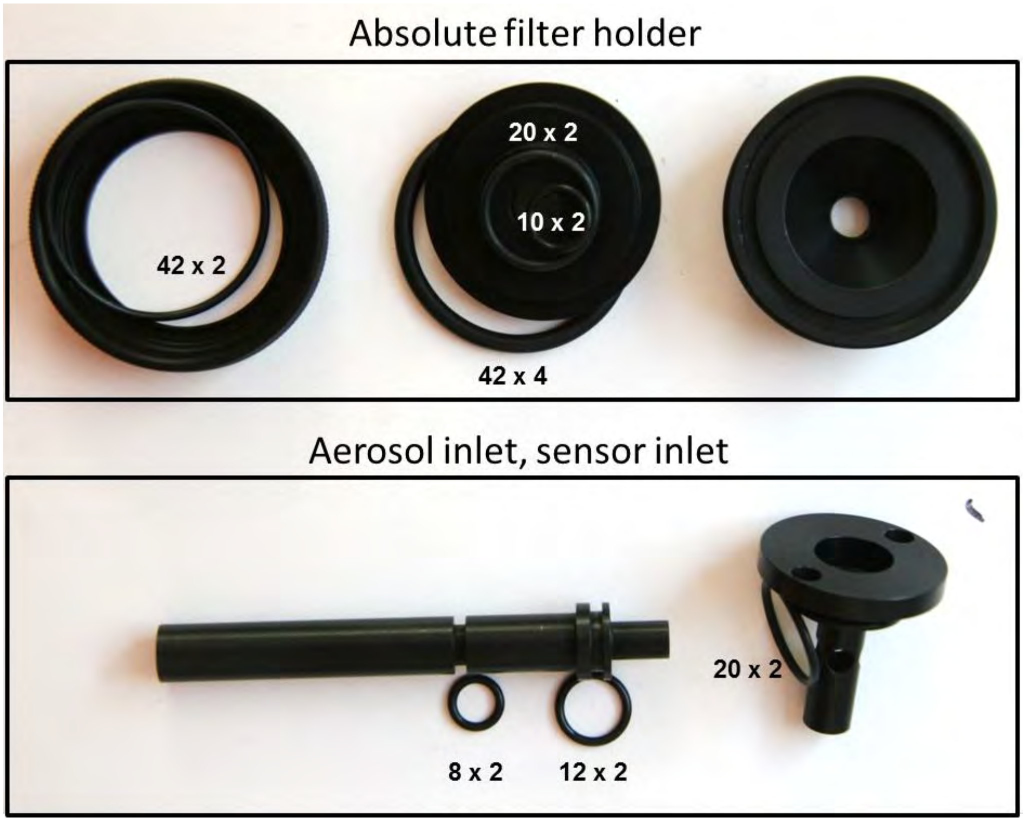



Figure 42: Application of the O-rings

## 4.8 Maintenance of the pump module

In the Fidas® 100 and 200 two pumps (=pump module), connected in parallel, provide the volume flow. The used pumps don´t need maintenance during operation. The pump performance is monitored continuously (refer also to chapter 4). A replacement of the pump module is only necessary, if the pump performance exceeds 80% (status warning). Usually the service life of the pump module is at least two years.

# 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.

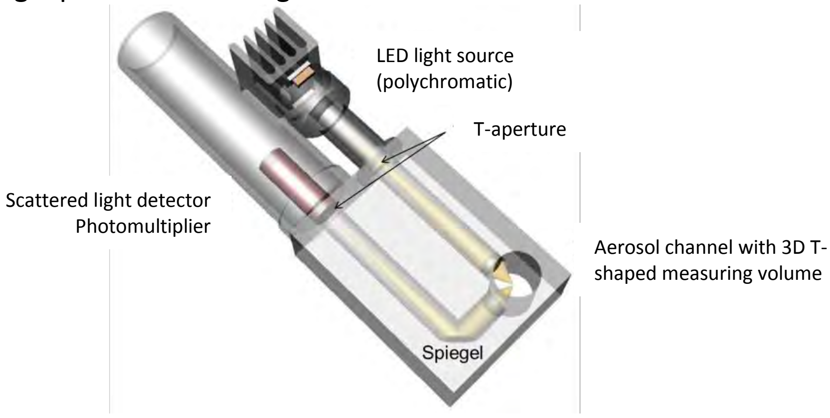



Fig. 43: Set-up of the sensor of the Fidas® measurement system

The particles move separately through an optically differentiated measurement volume, homogeneously illuminated with polychromatic light.

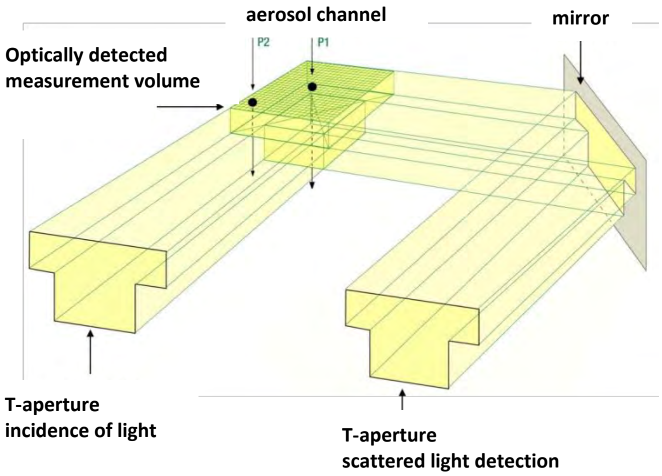



Fig. 44: Illustration of T-aperture

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.

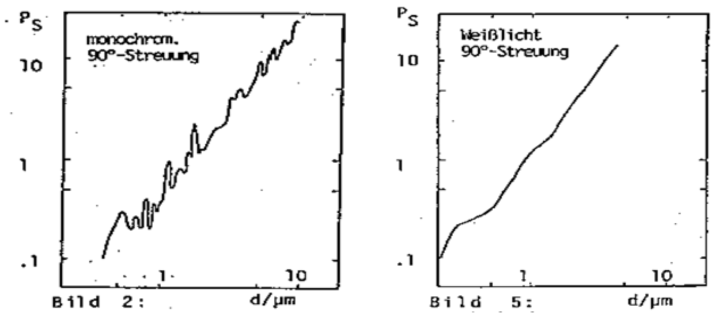



Fig. 45: Calibration curve for 90° scattered light detection with monochromatic light source (left) and polychromatic light source (right)

Each particle generates a scattered light impulse, detected at an angle of 85° to 95° degrees. The number concentration is deducted from the number of scattered light impulses. The amplitude (height) of the scattered light impulse is a measure for the particle size diameter.

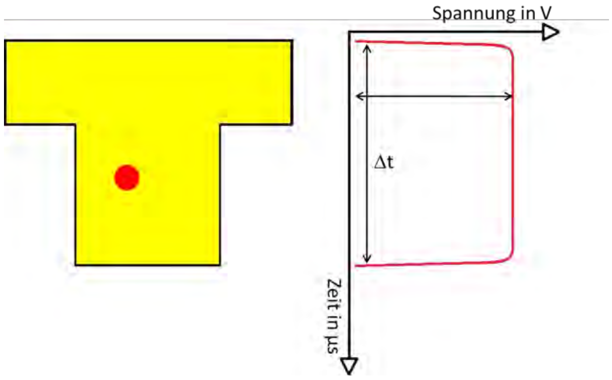



Fig. 46: Measurement of scattered light impulse at the single particle. Amplitude and signal length are measured

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 47, 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. 47, blue curve).

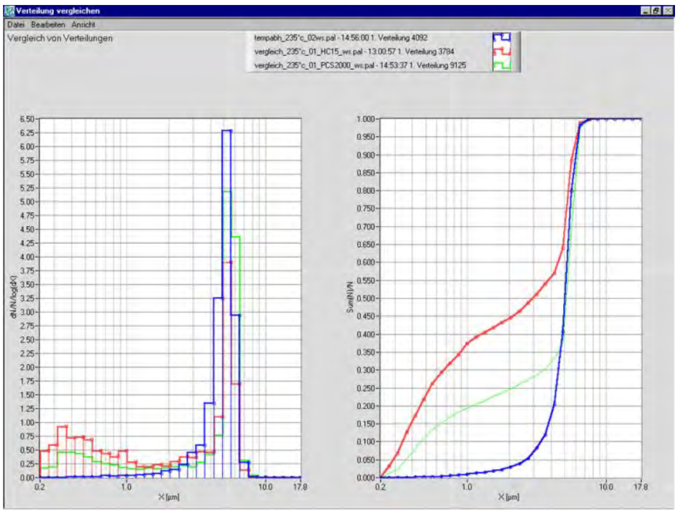



Fig. 47: Comparison of an optical scattered light spectrometer with simple rectangular aperture (HC15, red) with an optical scattered light spectrometer with T-aperture (welas®, blue) by using monodisperse particles in the size of 5 µm.

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 48).

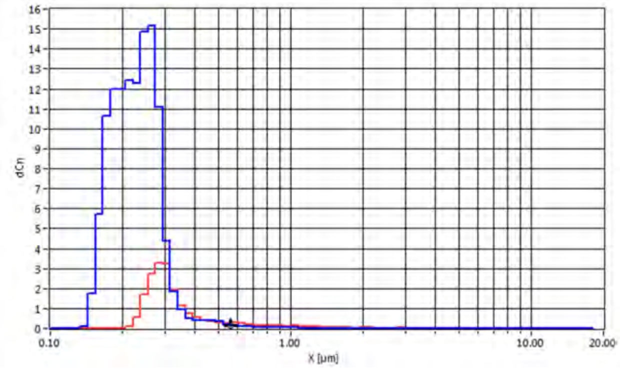



Fig. 48: Measurements with the Fidas® roadside (size range from 0.18 µm, blue curve) compared to a different optical measurement system (size range from 0.25 µm, red curve)

## 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

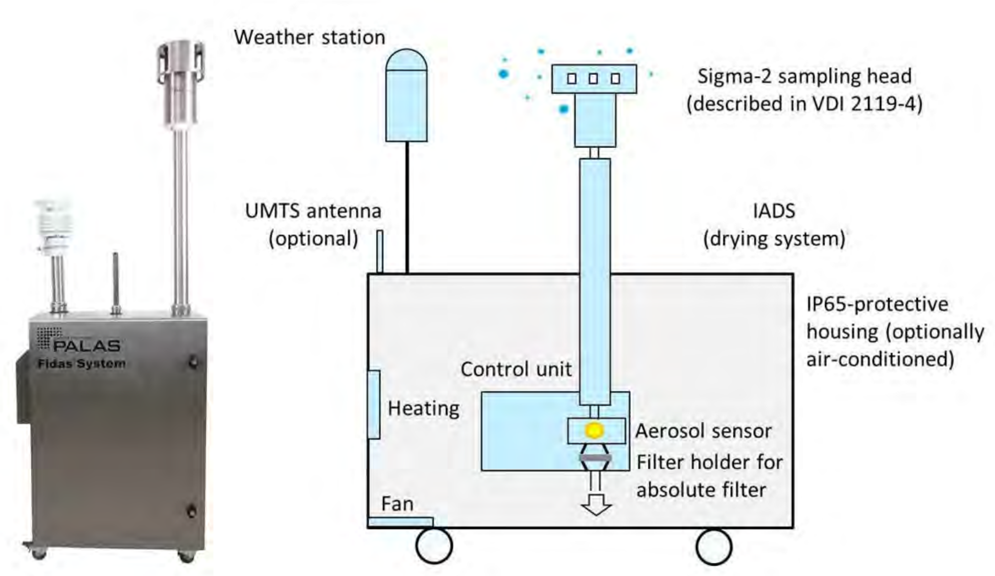
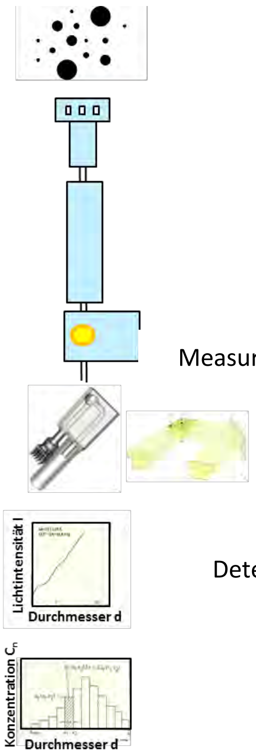



Fig. 49: Schematic setup of the Fidas® 200 S measurement system

## 5.3 Overview of the individual measurement steps




**Particles** of different sizes

**Representative „suction“** of particles in ambient air with Sigma-2

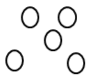
**Drying** of particles with IADS (Intelligent Aerosol Drying System)

Measurement of **scattered light intensity** with white light and 90° scattered light at the single particle

**Filtration of border zone and coincidence signals**

Determination of optical particle size by allocation of the scattered light signal to the **particle diameter** via an unambiguous calibration curve **based on Latex**

Classification of measured particles into size classes **in form of a histogram**



Detection of fog by analyzing the distribution form, **eliminating the mass of fog droplets**

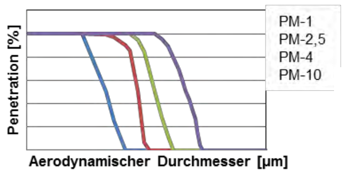
$n_{Umwelt}$

Conversion of particle size distribution based on the Latex diameter to a **distribution based on a representative refractive index for the environment**

**Brechungsindex für die Umwelt**

Conversion of particle size distribution based on the optical diameter to a **distribution based on the aerodynamic diameter**

Analysis of the distribution form, **determination of density parameters** depending on the distribution form




**Transfer of the separation behavior of the individual PM sampling inlets** to the size distribution depending on the density parameters

$$PM = \frac{\sum N(d) \cdot \frac{1}{6} \cdot \pi \cdot d^3 \cdot \rho(d)}{V}$$

**Calculation of the particle mass by using a size depended transformation function depending on the form of the distribution**

**PM value**

The 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 µm according to US-EPA

**P-2.5** [µg/m³]: dust content smaller than $d_{50,Aero}$ = 2.5 µm according to US-EPA

**PM-4** [µg/m³]: dust content smaller than $d_{50,Aero}$ = 4 µm

**PM-10** [µg/m³]: dust content smaller than $d_{50,Aero}$ = 10 µm 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 inlets 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).

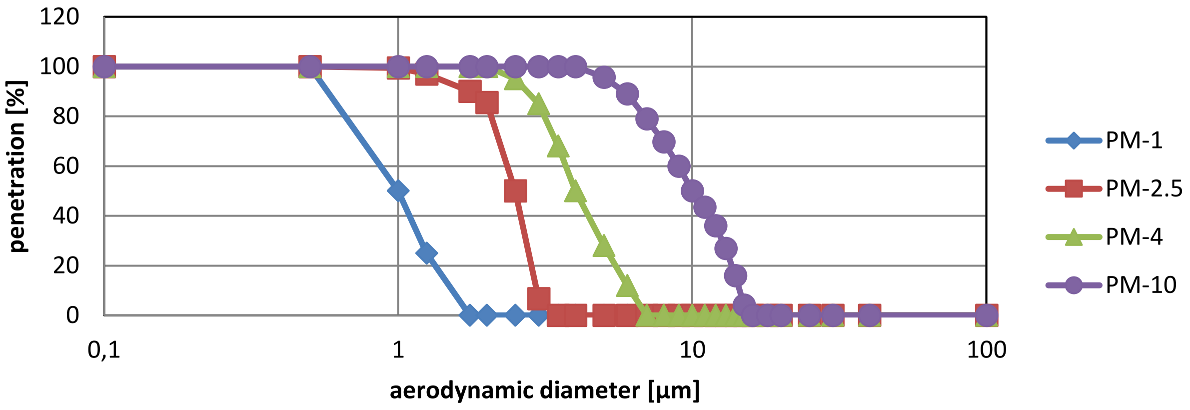



Figure 50: Used penetration curves for PM-1, PM-2.5, PM-4, PM-10 (US-EPA)

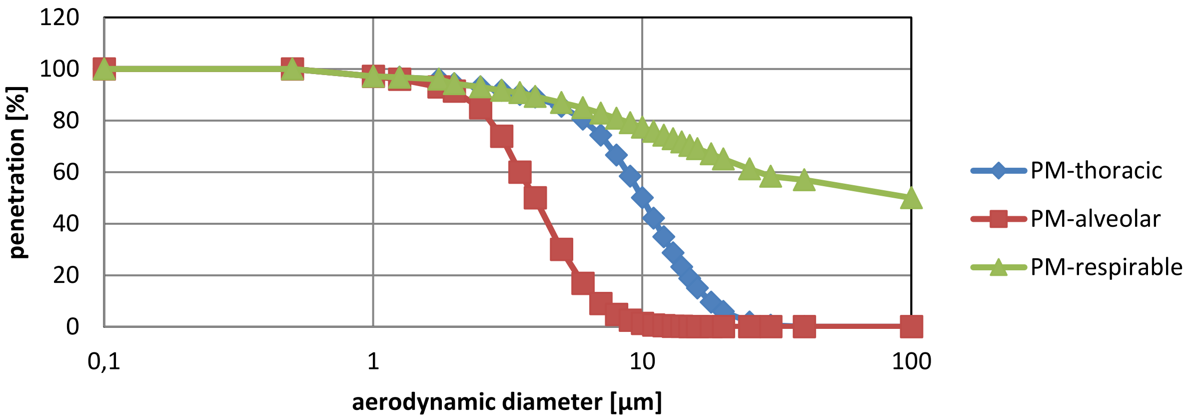



Figure 51: Used penetration curves for dust measurements at workplaces in the health related sector (EN 481)

Table 3: 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:

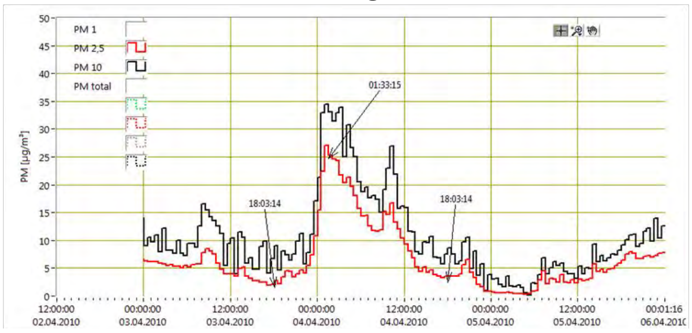
$$PM_{corrected} = C \cdot PM.$$

## 5.4 Further advantages

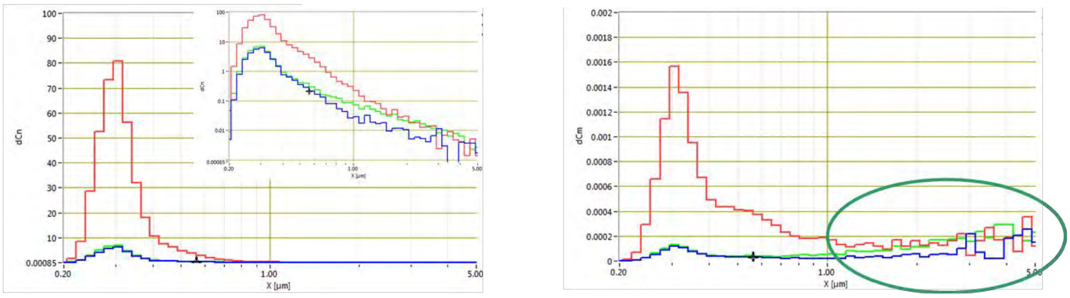
Beneath the PM-fractions, which are measured continuously and simultaneously, the measured particle number concentration and particle size distribution with a high time and size resolution (up to 128 size classes) are available.
These additional information can be used to conduct a „Source Apportionment“ or to evaluate the health-related relevance (larger particles go deeper into the human respiratory tract).
Figure 52 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. 52: 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 to 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<br>max. concentration up to 4,000 P/cm³ | |
| Maximum concentration and coincidence detection/correction | 20,000 P/cm³ | |
| Maximum concentration (mass) | 10,000 µg/m³ | |
| Communication between control unit and evaluation PC | RS-232 (Bayern-Hessen, ASCII or Modbus)<br>Ethernet (UDP ASCII, TeamViewer, etc.) | |
| Suction volume flow | 1.4 l/min SATP (Model Fidas® mobile)<br>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<br>(see identification plate!)<br>mains voltage:<br>mains fuse: | 230 V, +/-10 %<br>2 pieces T 2 A / 250 V | 115 V, +/-10 %<br>2 pieces T 4 A / 130 V |
| Power consumption<br>frequency | 200 W<br>47-63 Hz | |
| Environmental conditions | Temperature range from -20°C to 50 °C<br>(Fidas® 200 S)<br>Temperature range from 5°C to 40 °C<br>(Fidas® 200, Fidas® 200 E)<br>Sound emission << 85 dBA | |
| Dimensions (HxWxD) | Control unit incl. integrated sensor:<br>195 mm x 450 mm x 310 mm<br>Weather protective housing with IADS and weather station:<br>1810 mm x 600 mm x 400 mm | |
| **Weight** | Control unit incl. integrated sensor: 9,3 kg<br>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:

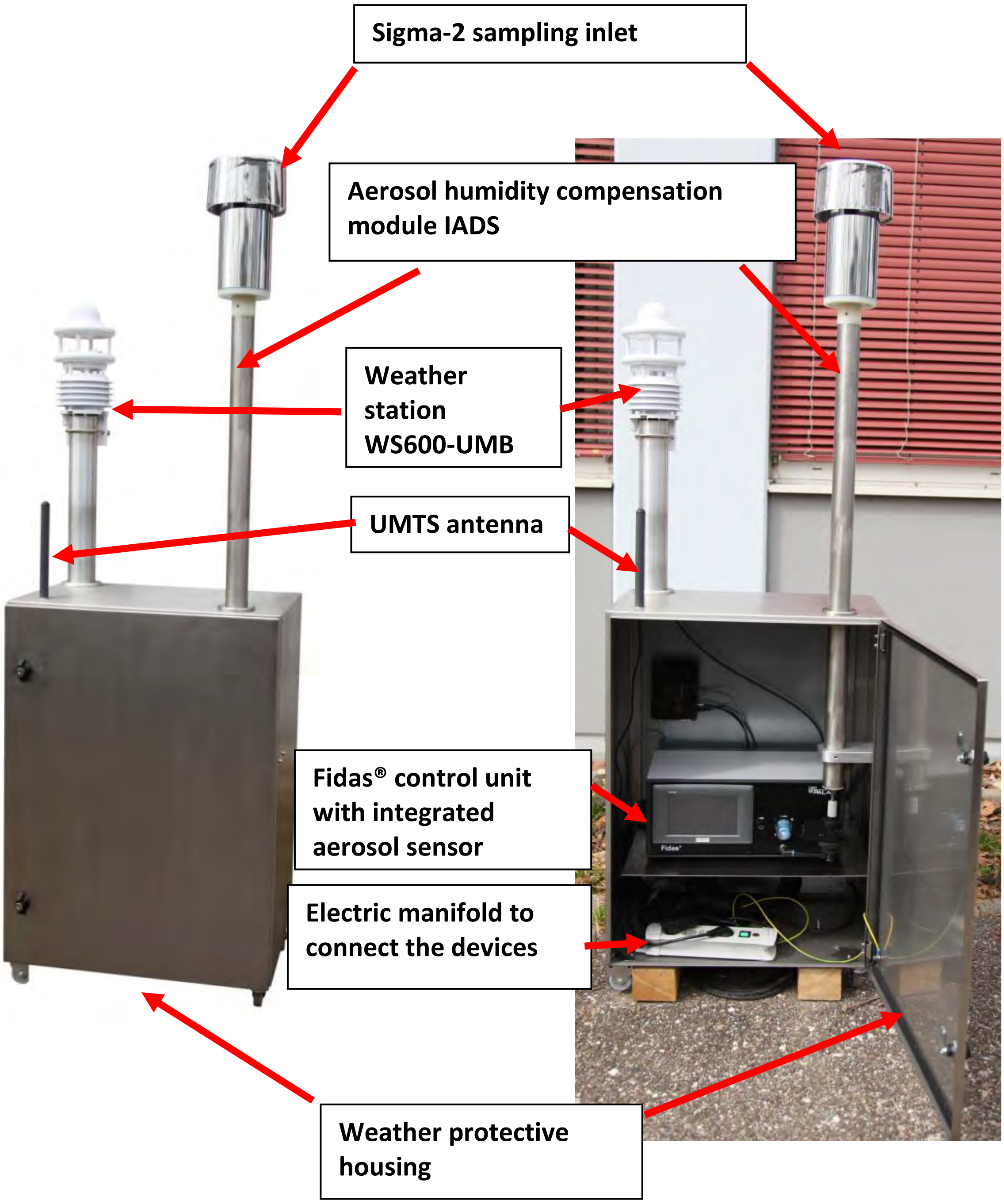



Fig. 53: Weather-protective housing closed

Fig. 54: 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).

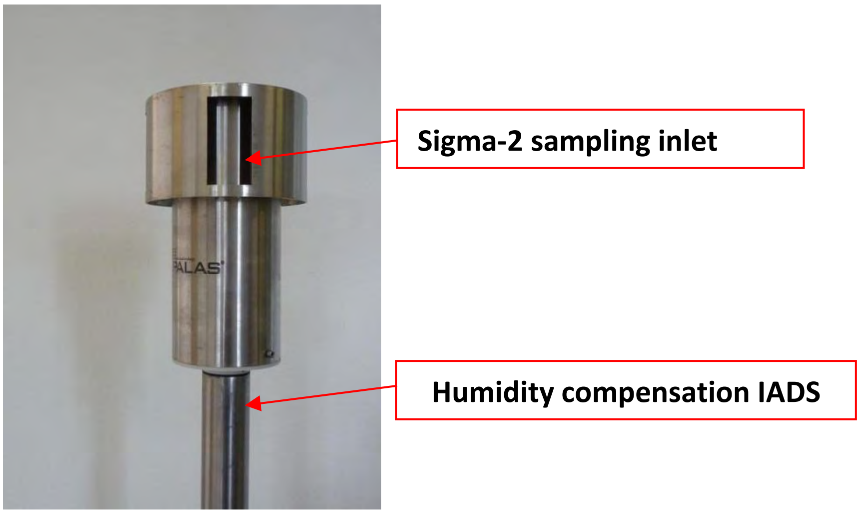



Fig. 55: Sigma-2 sampling inlet with IADS

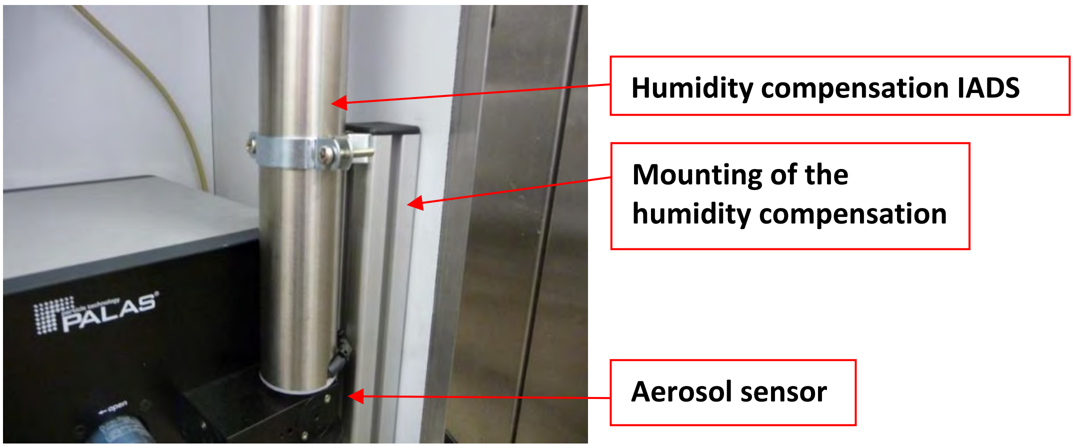



Fig. 56: Fidas® control unit, aerosol sensor with IADS

Important technical dimensions of the IADS are:

| | |
|---|---|
| Length: | 1150 mm plus 80 mm small tubing on which the Sigma-2 inlet 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:

| | |
|---|---|
|  |  |
| IADS extension inner tube | IADS extension with outer tube |

| | |
|---|---|
| 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 inlet.

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 inlet by sliding it over the 8 cm inner tubing until it rests on the outer tubing.

## 8.3 Sigma-2 sampling inlet

The Sigma-2 sampling inlet 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.

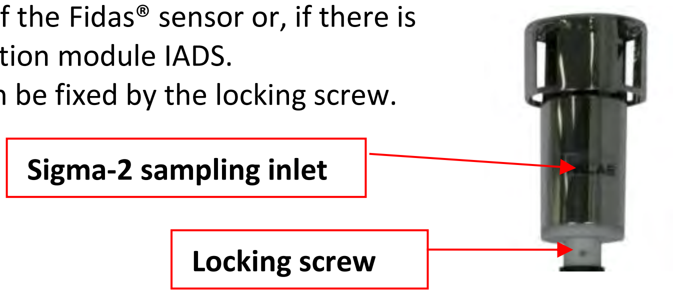



Fig. 57: Sigma-2 sampling inlet

The Sigma-2 inlet should be checked up on dirt every three month (in combination with the calibration).

## 8.4 Compact weather station WS600-UMB respectively WS300-UMB

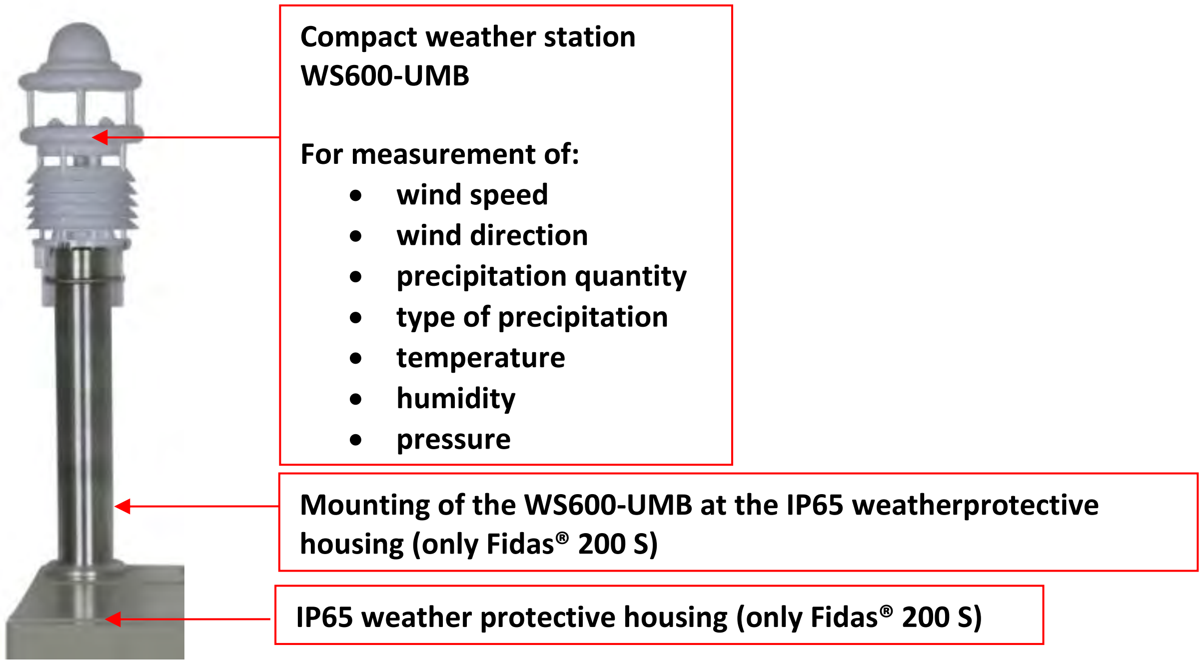



Fig. 58: Compact weather station (here: WS600-UMB)

**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 ±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 | ±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 |
| | |
| **Sensor for wind direction** | |
| Principle | Ultrasonic |
| Measuring range | 0...359.9° |
| Unit | ° |
| Accuracy | ±3° |
| | |
| **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

# Index:

# 1. Overview

The PDAnalyze-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 **PDAnalyze software** that Palas® provides with the optical aerosol spectrometers (e.g. Promo®) and nanoparticle instrumentation (e.g. UF-CPC, U-SMPS).

# 2. Installing the PDAnalyze-Fidas Software

## 2.1 Installing from CD or USB stick

Go to Software PC/Software PDAnalyze you then see three folders:

| Name | Änderungsdatum | Typ |
|---|---|---|
| PDAnalyze | 26.03.2013 09:11 | Dateiordner |
| PDAnalyze 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 PDAnalyze software (for more information on this evaluation software for general use with Palas® particle measurement systems please see "Manual PDAnalyze Software").
Then copy the files under "PDAnalyze Fidas" to a location of your choice on your computer.

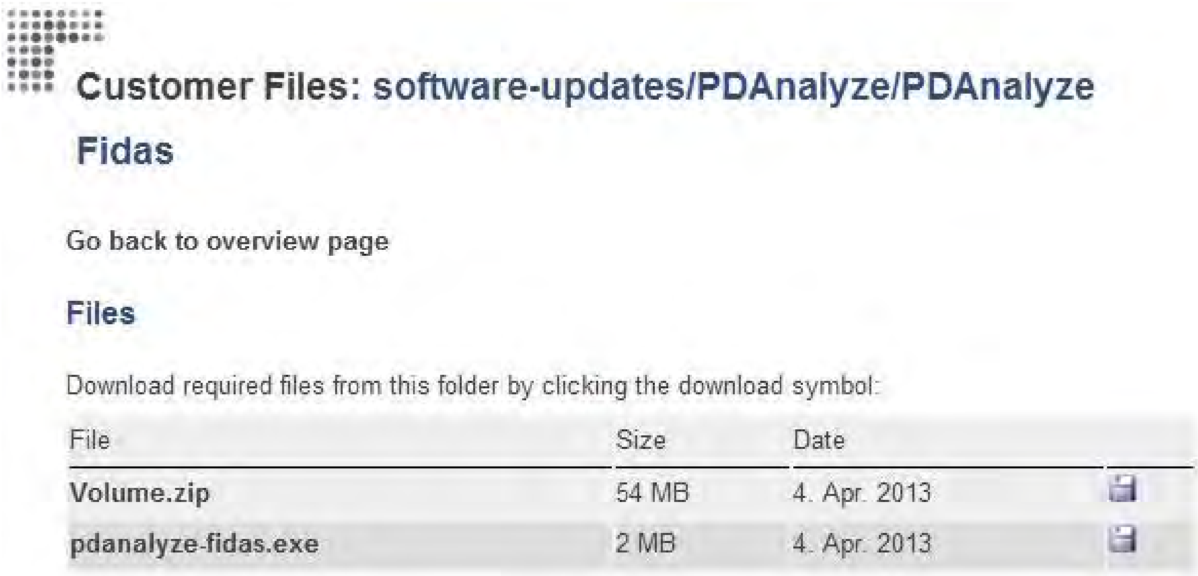
**Note:** Please make sure you have read/write/delete rights in the folder that you copy the files to, otherwise the PDAnalyze-Fidas will not run correctly.

## 2.2 Installing from the Palas® webpage

Sign on to the password protected user area on the Palas® webpage:


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:


Customer Files: software-updates/PDAnalyze/PDAnalyze Fidas

Go back to overview page

Files

Download required files from this folder by clicking the download symbol:

| File | Size | Date | |
|---|---|---|---|
| Volume.zip | 54 MB | 4. Apr. 2013 | |
| pdanalyze-fidas.exe | 2 MB | 4. Apr. 2013 | |

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

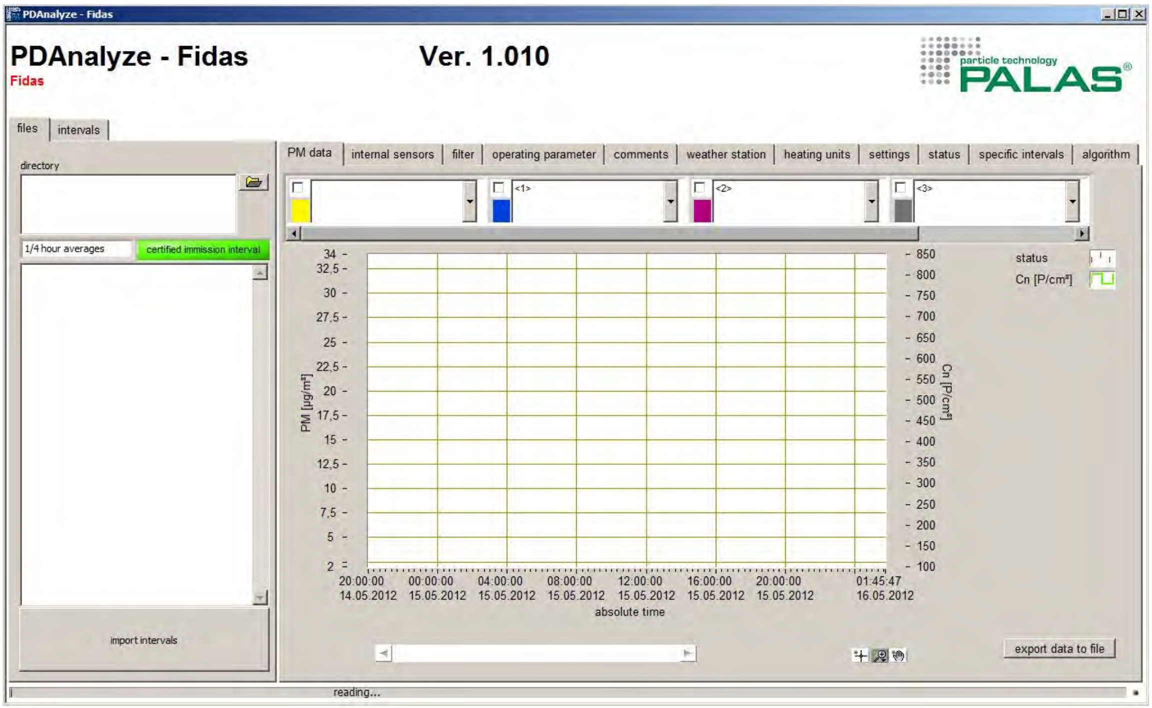



Figure 4: Main screen of the PDAnalyze-Fidas evaluation software

# 4. Left section of PDAnalyze-Fidas – “files”, “intervals”

## 4.1 Tab “files”

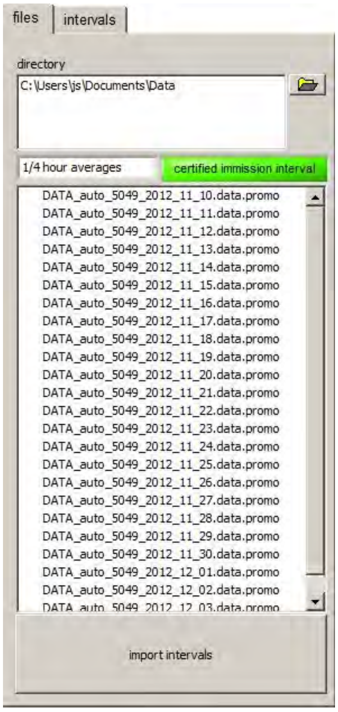


Figure 5: Tab “files”

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:

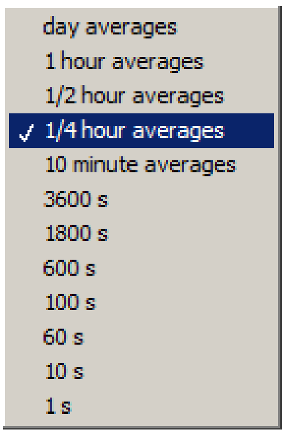


Figure 6: Possible choices for averaging interval

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.

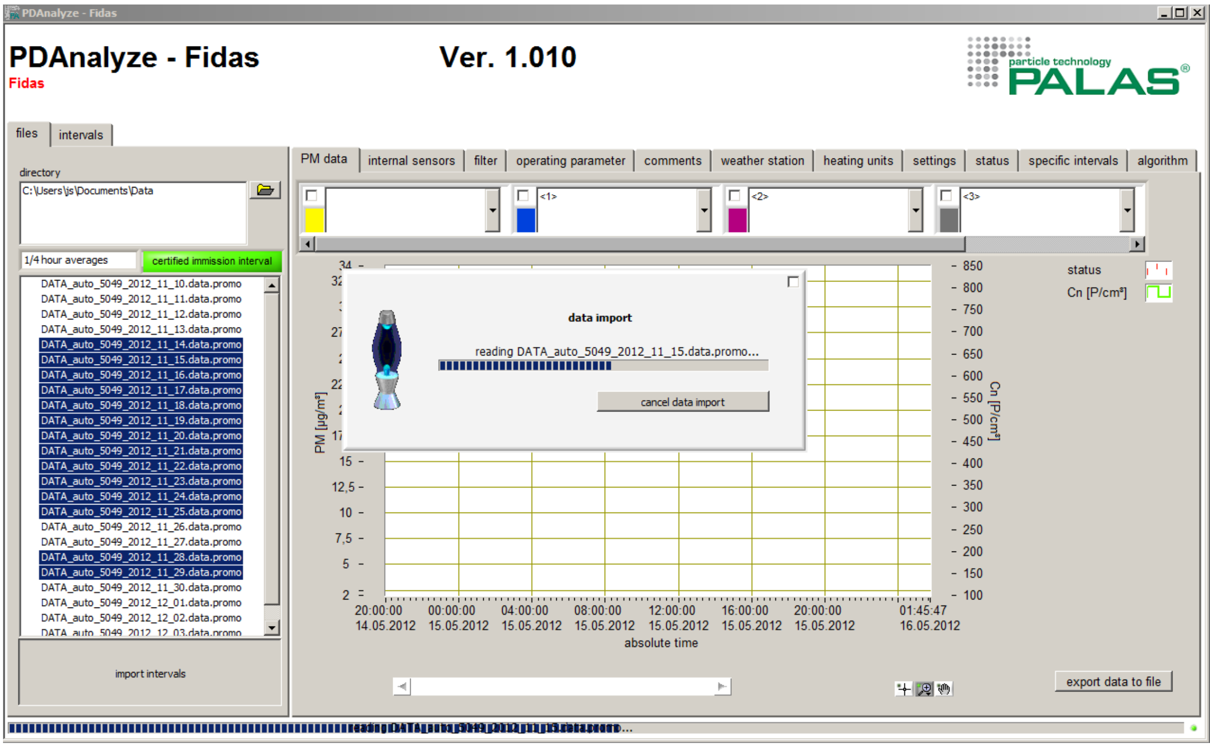


Figure 7: Importing the selected data files with the selected averaging intervals

When all selected data are imported the software will show the following result next to the version number of the software:

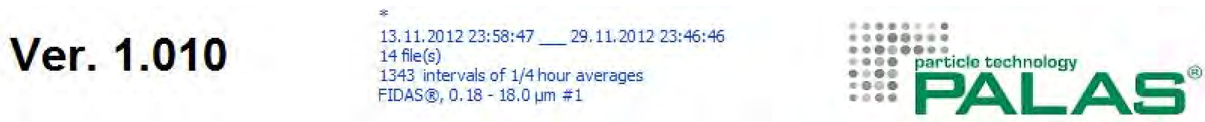


Figure 8: Result of importing the data

<u>Note:</u> 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 "**ø**" 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:

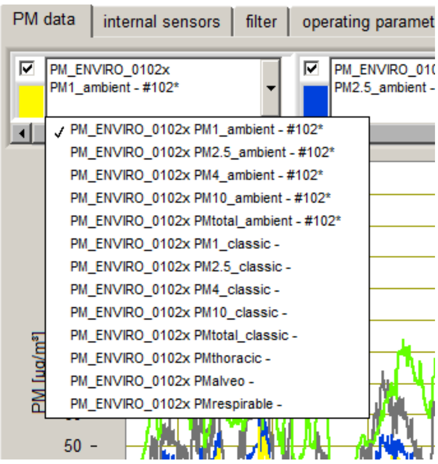



Figure 10: Select what data to display

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:

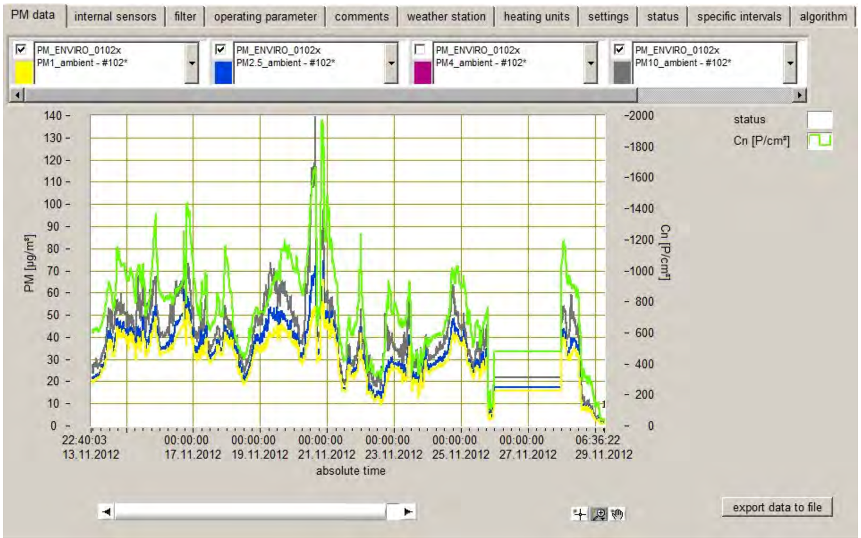


Figure 11: Tab "PM data"

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/cm$^3$], 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.

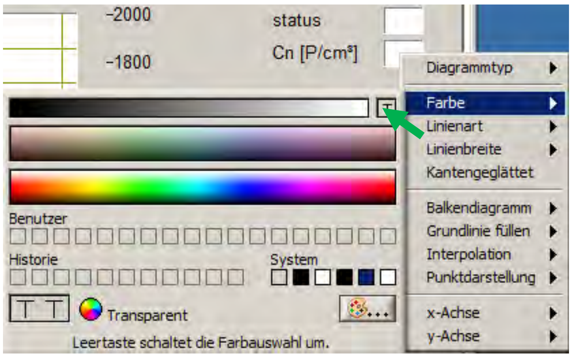


Figure 12: Removing the curve for number concentration "Cn" from the graph

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.

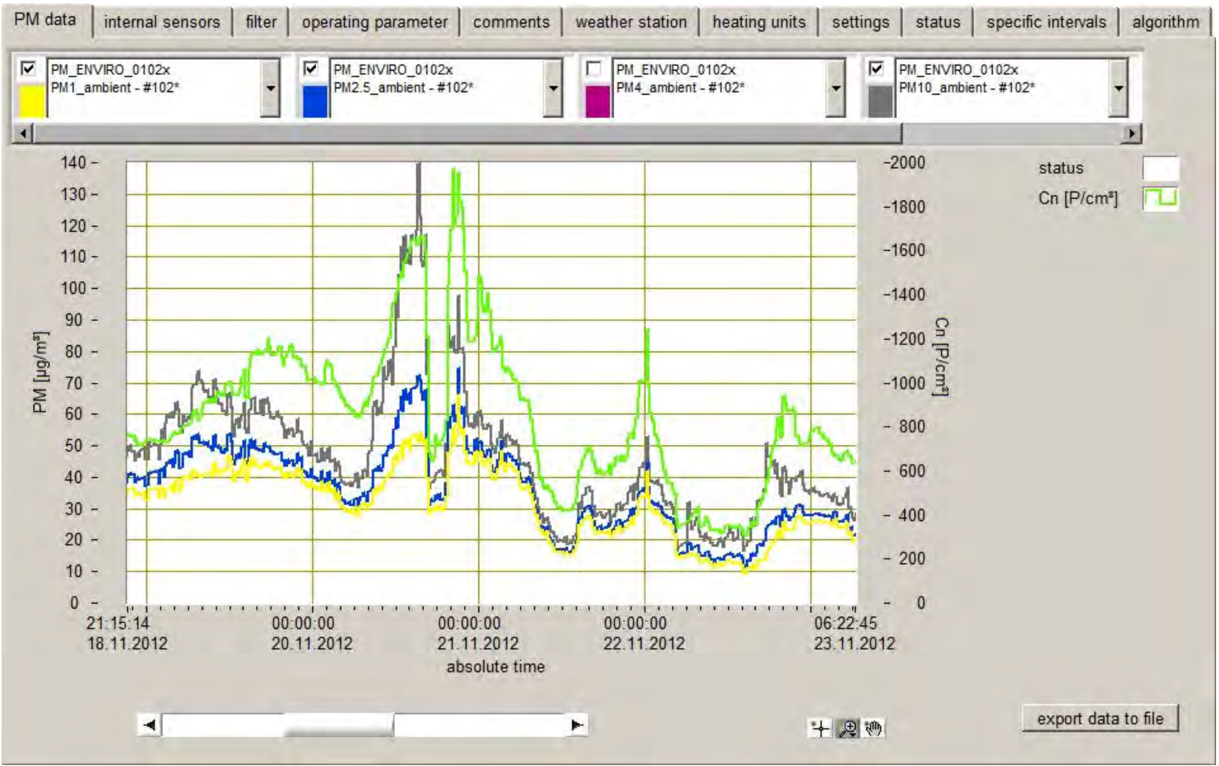



Figure 13: Zooming into the data

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.

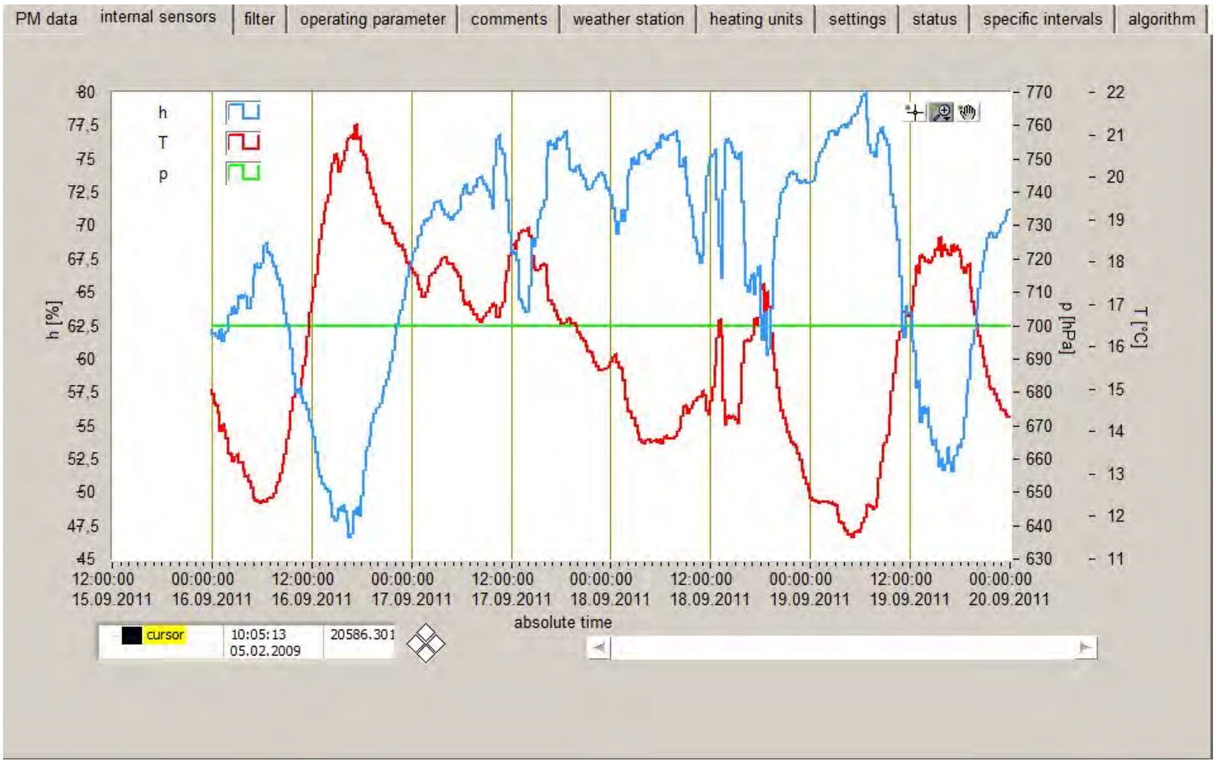



Figure 14: Tab “internal sensors” if a p, T, rH sensor is connected to the instrument

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.

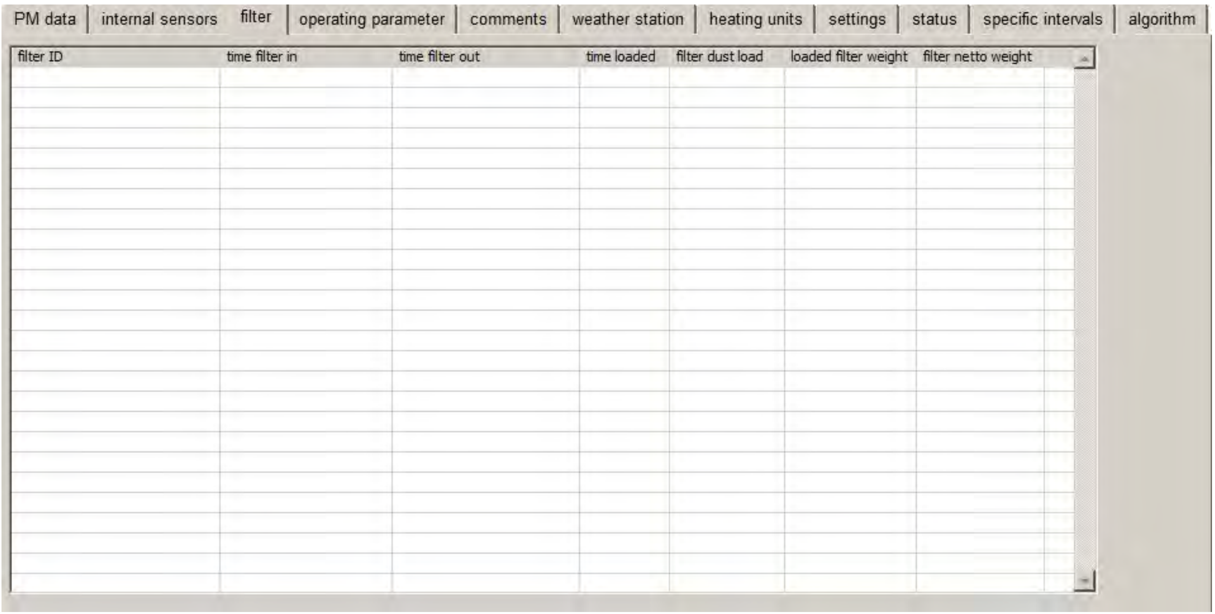



Figure 15: Tab “filter” showing a summary of filter exchanges

## 5.4 Tab "operating parameter"


Figure 16: Tab "operating parameter" showing particle velocity, pump performance, LED temperature and flow rate

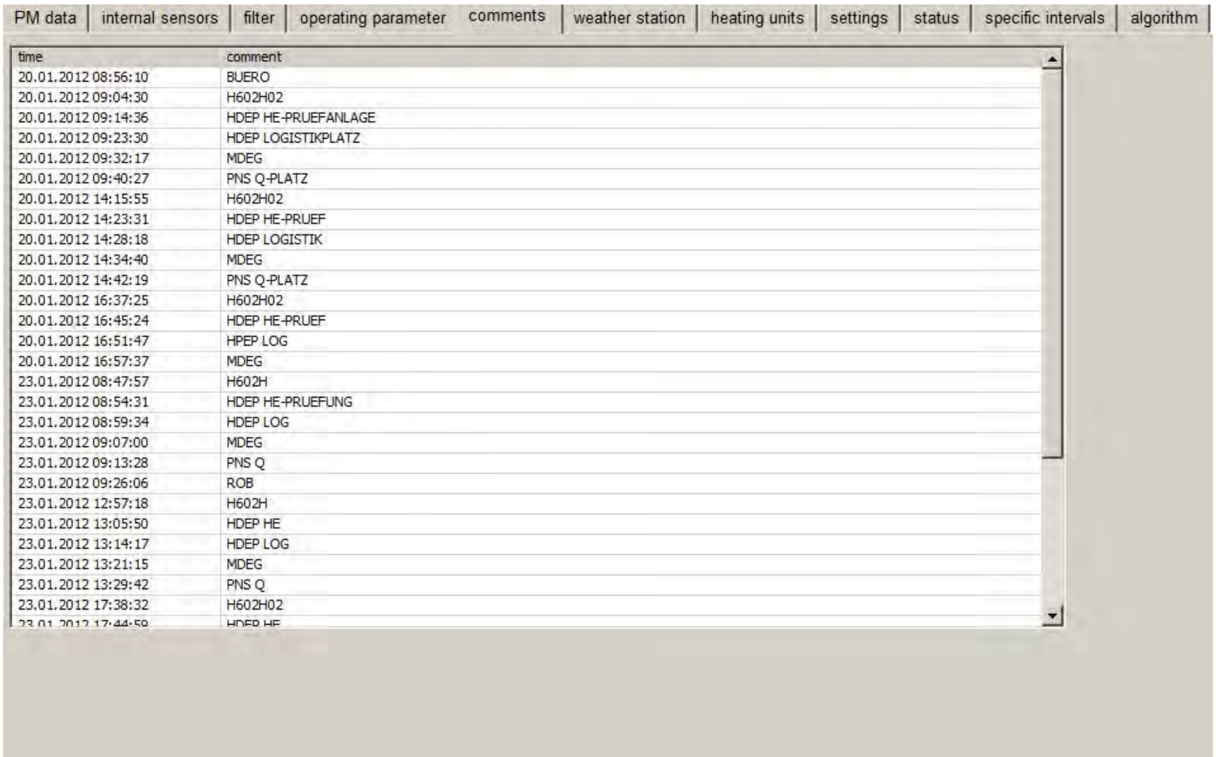
In the graph under this tab important instrument operating parameters are shown for the whole duration of the importet data files.

| | | |
|---|---|---|
| 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”




| 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 | HPEP 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 |

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.

<u>Note:</u> 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.

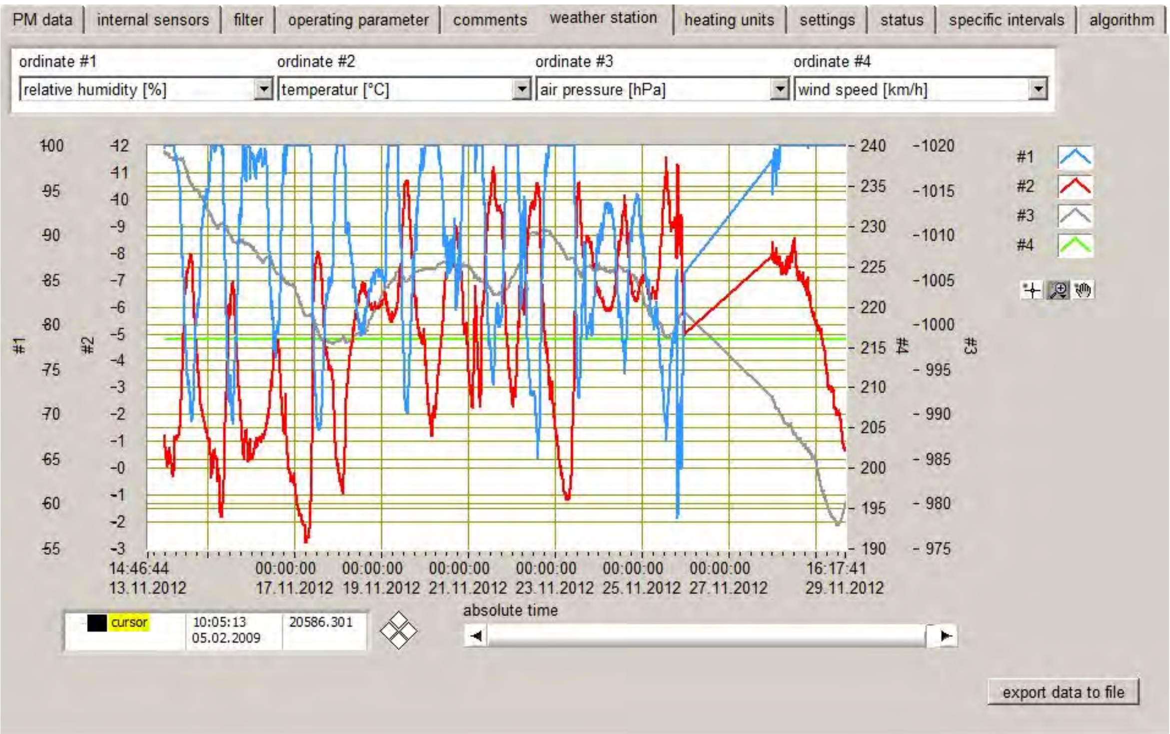



Figure 18: Tab “weather station” displaying weather station data

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:

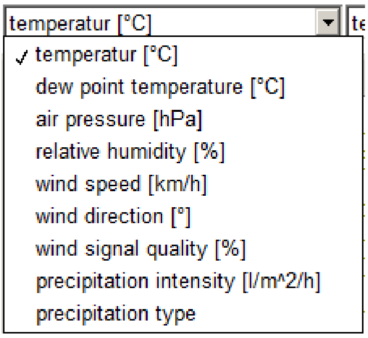



Figure 19: Choice of values to be displayed if available by connected weather station

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).

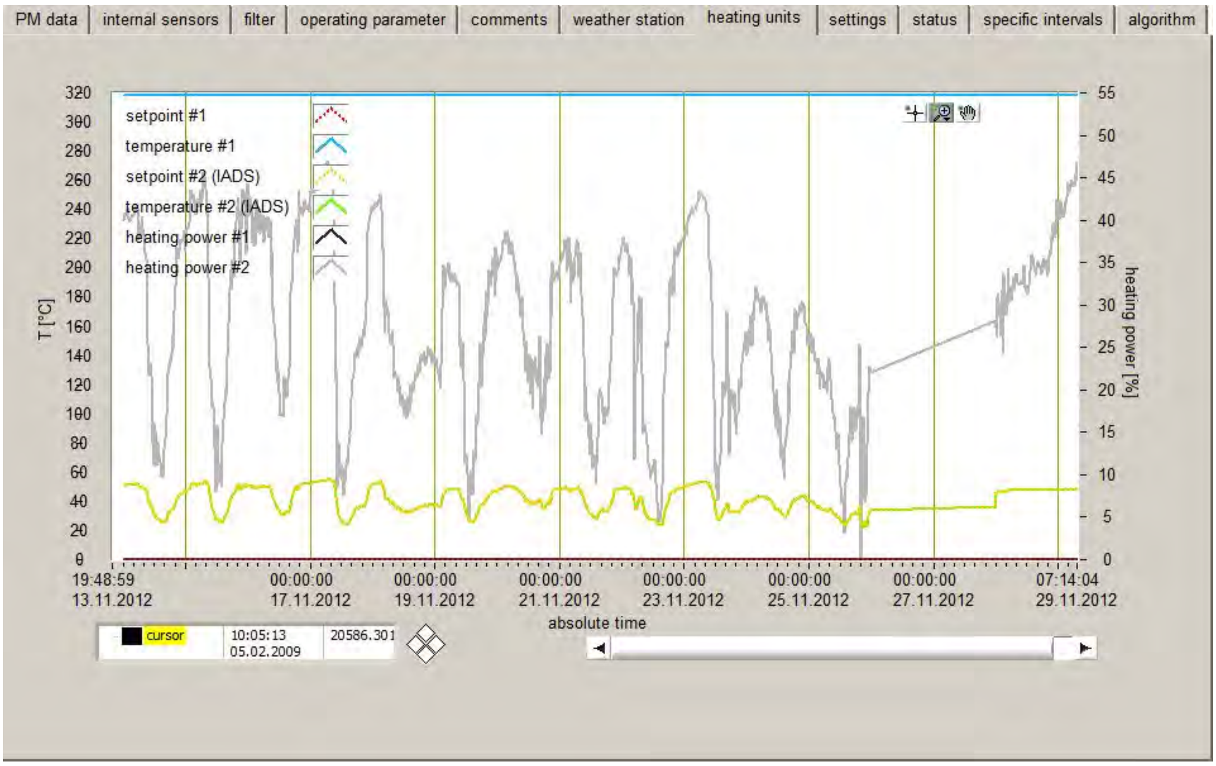



Figure 20: Overview of heating units in the Fidas® 200/200 S, 300/300 S

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”

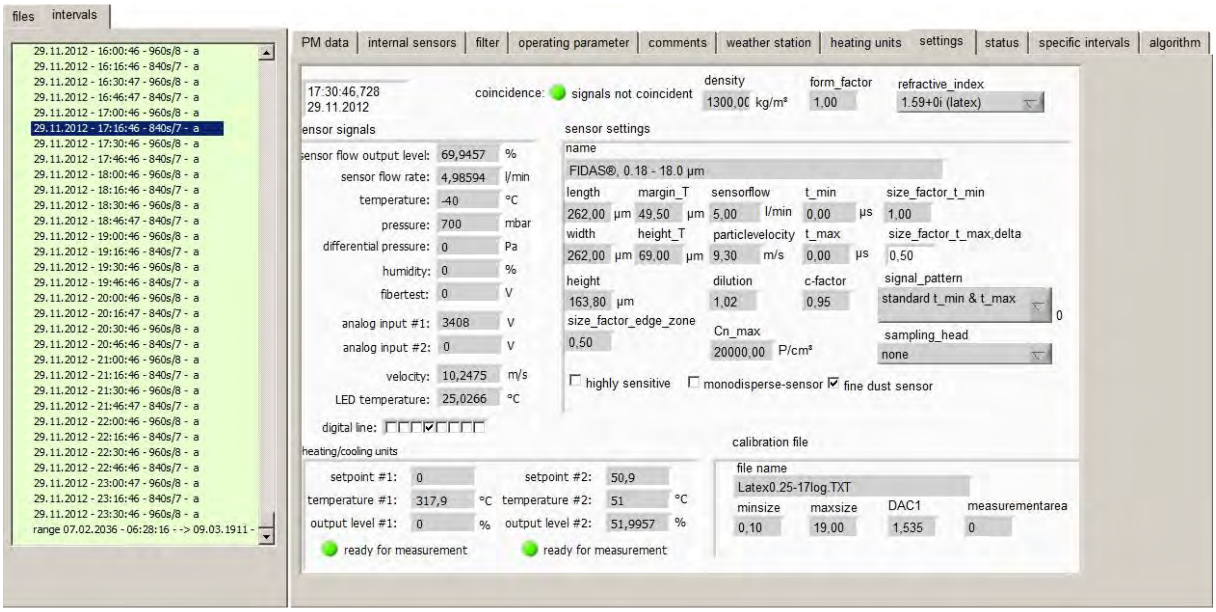



Figure 21: Instrument settings for the measurement

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 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)

<u>**Note:**</u> **if “fine dust monitor” is selected (at bottom of center section) the particle characteristics that are shown are not used, instead a size dependent 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 | volume flow of the sensor, two values are monitored independently:<br>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)<br>2. Velocity of particles through optical detection volume in m/s.<br>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 |
| 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 %.<br>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.<br>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.

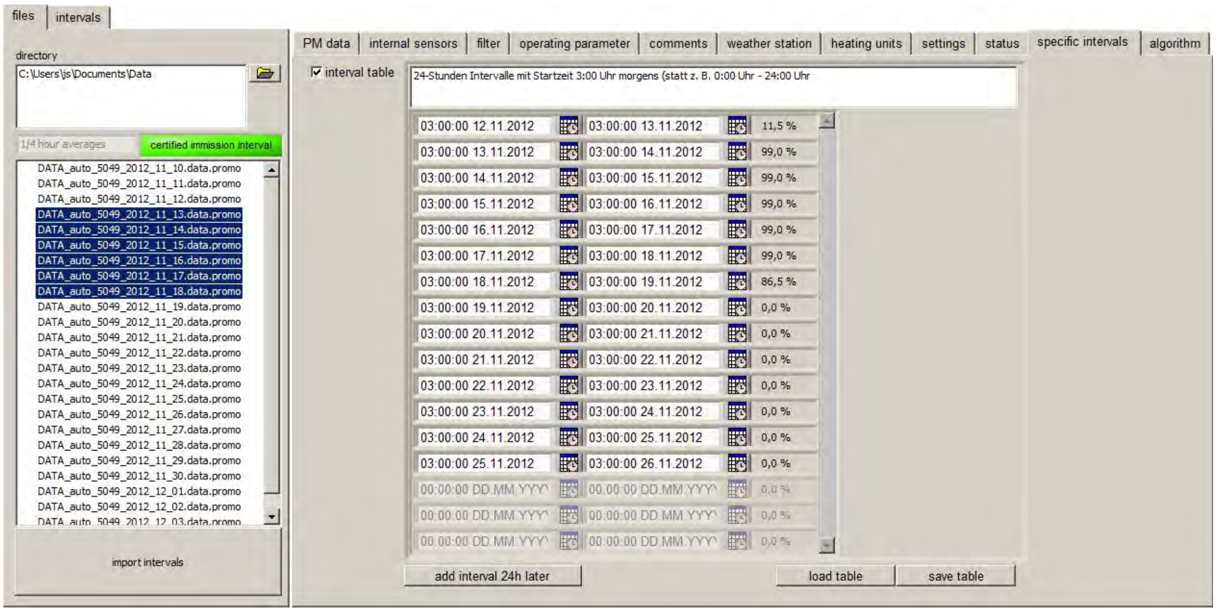


Figure 23: Specifying arbitrary evaluation intervals for data using the interval table

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:

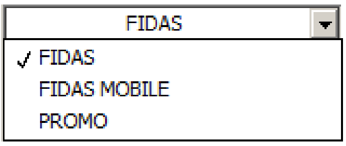


Figure 24: Selecting the instrument

Then select the algorithm:

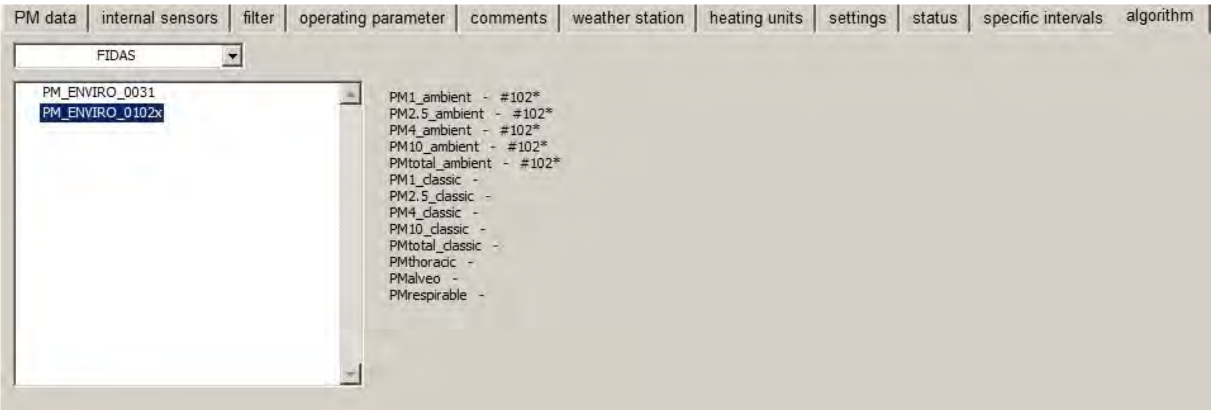



Figure 25: Selecting the algorithm to use for the evaluation of the data

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**

# CONTENTS

# 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 been 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.

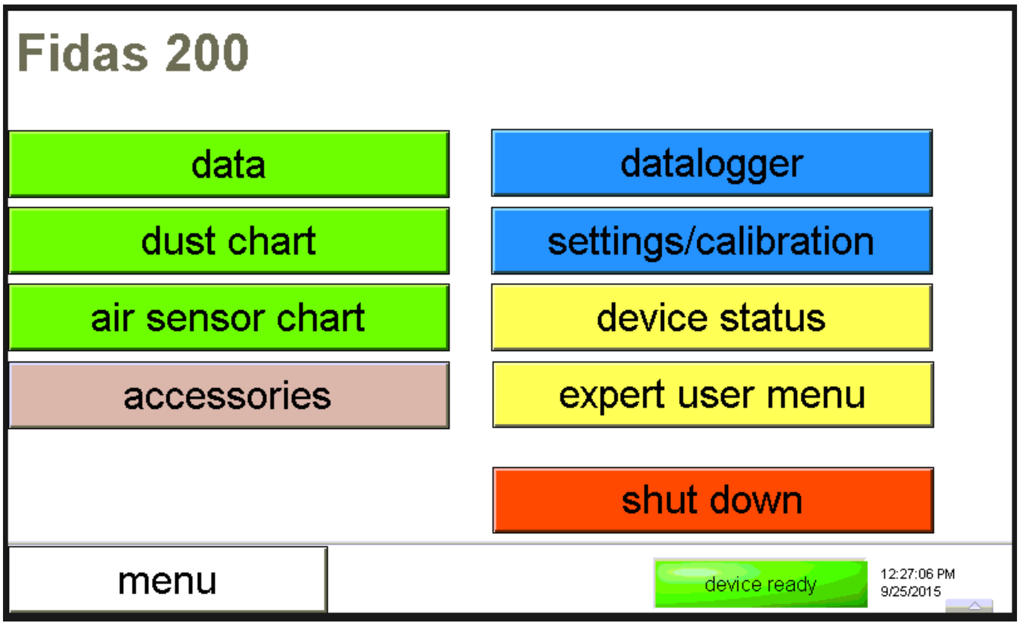



Figure 2: Main menu of the Fidas® user interface

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.<br>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.

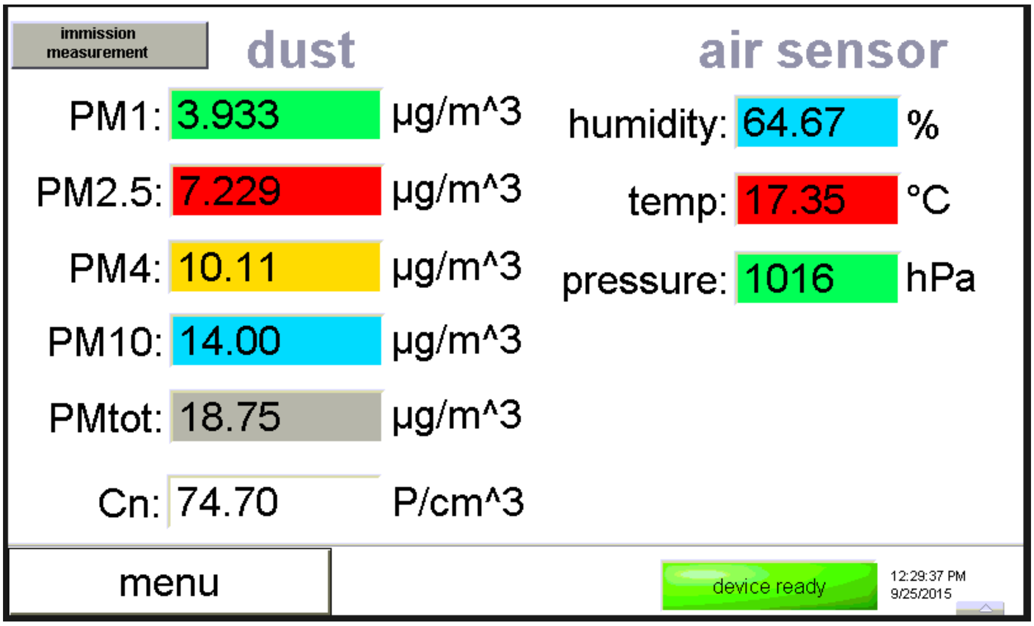



Figure 3: “data” overview

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.

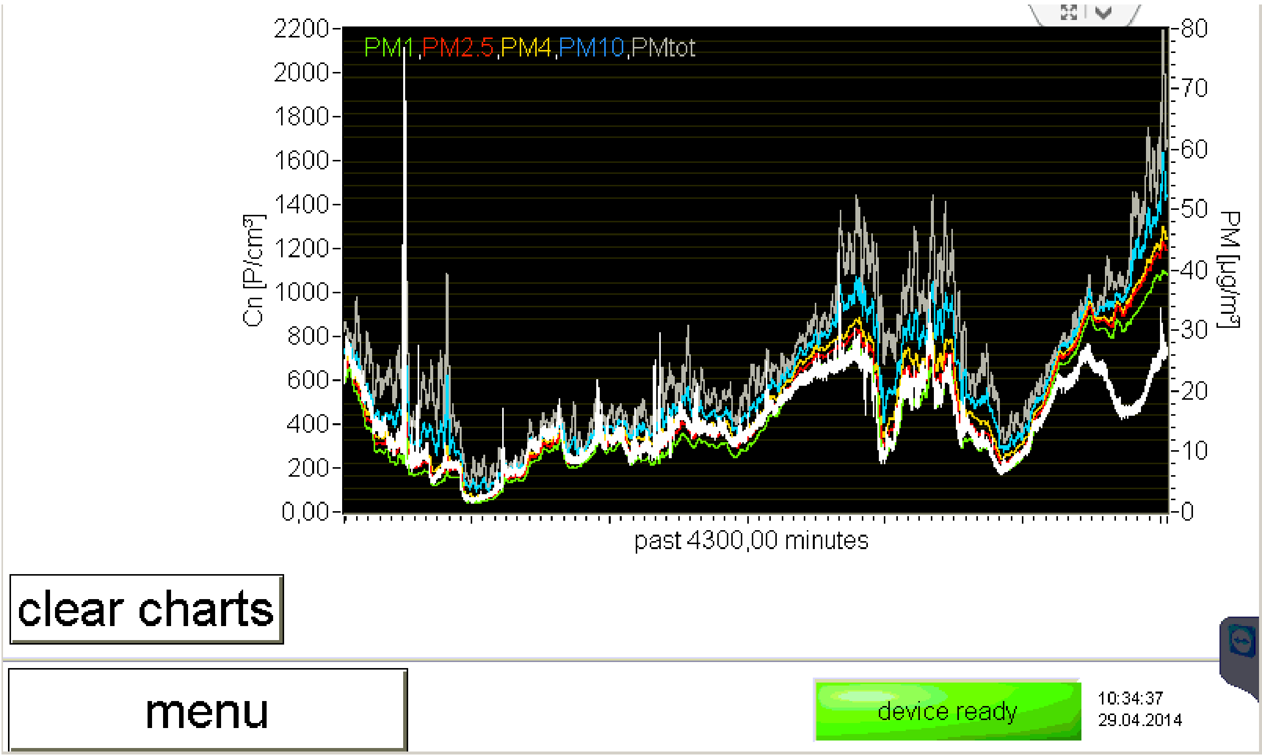



Figure 4: “dust chart” – measured values over time

### 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 |

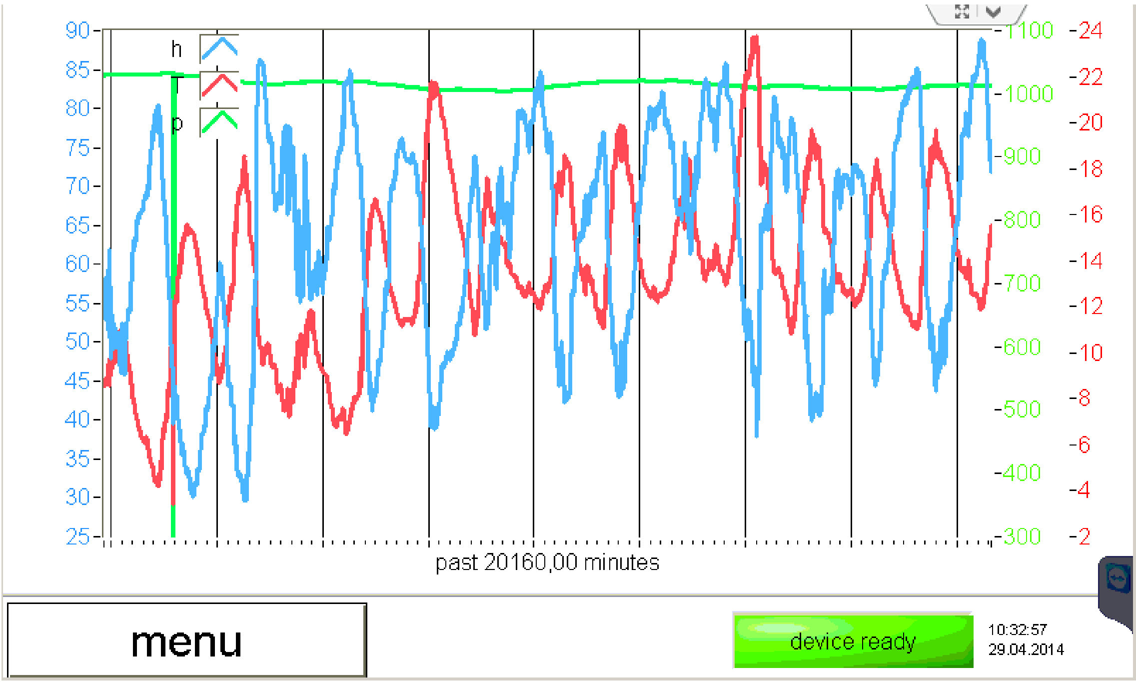



Figure 5: „air sensor chart“ – data from the weather station over time

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“

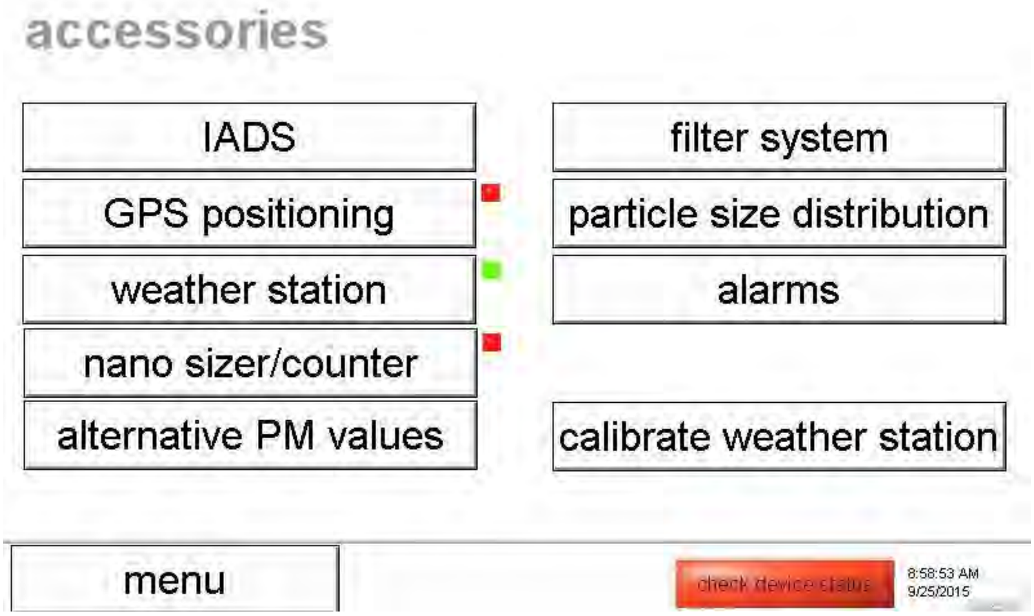


Figure 6: accessories

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<br>Note: 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.

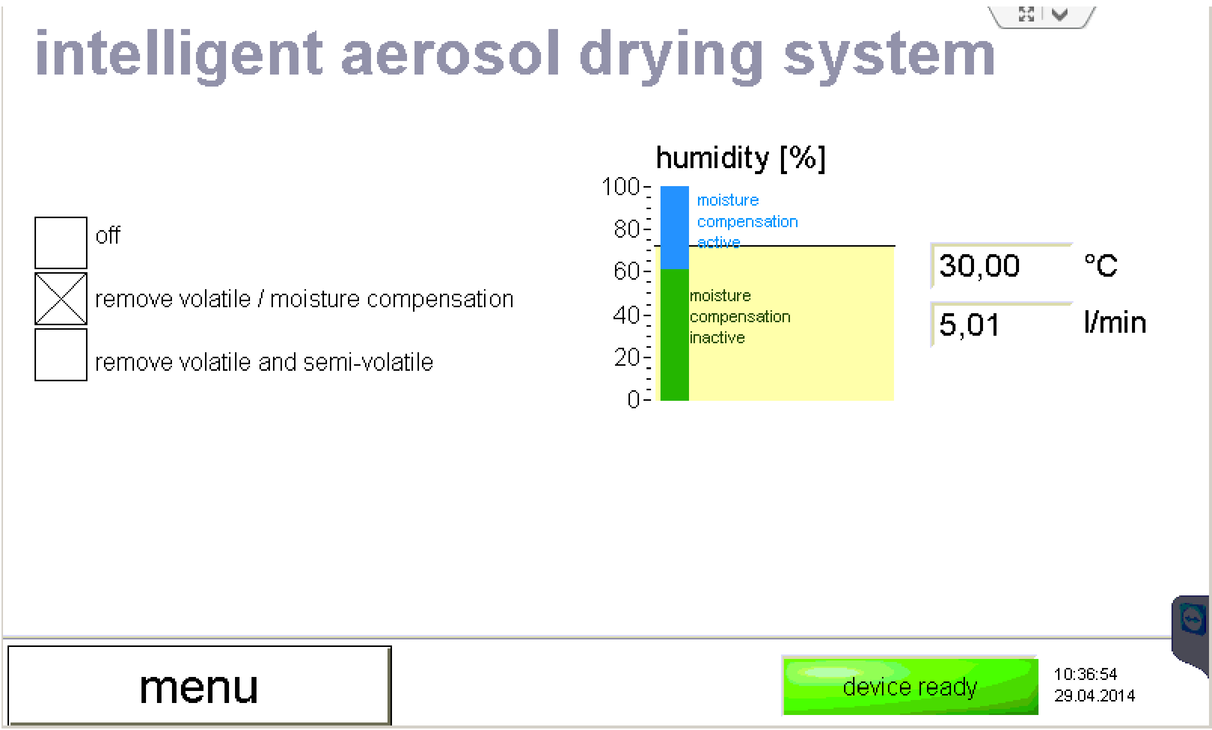



Figure 7: "IADS" – settings of the intelligent aerosol drying system

### 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!

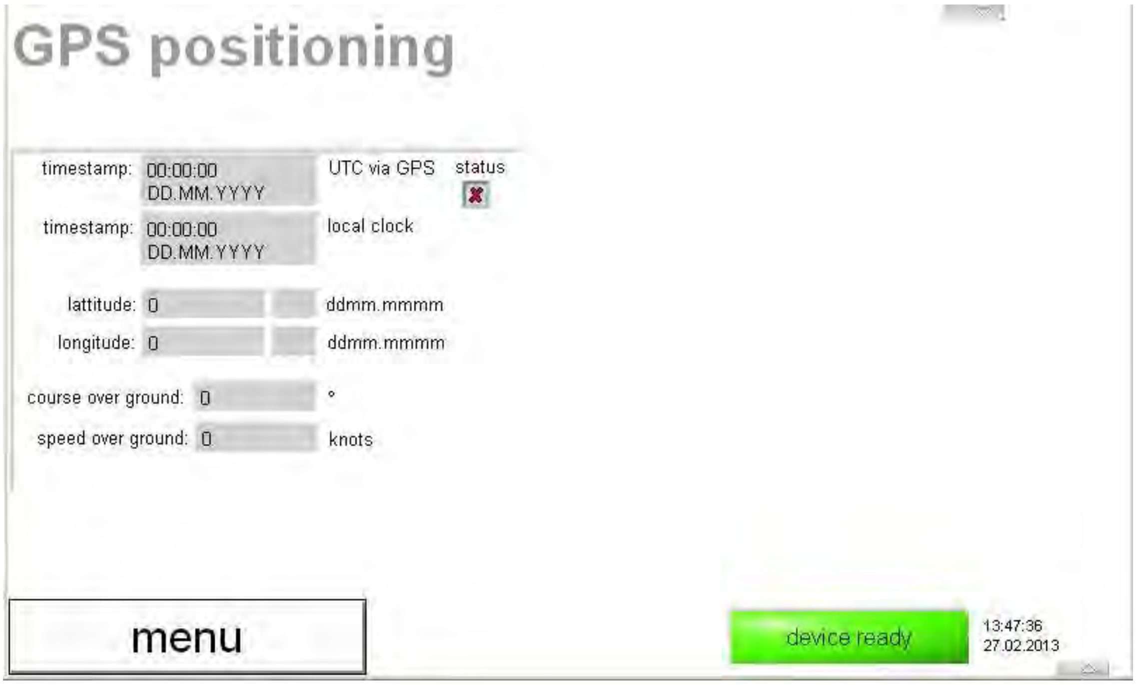



Figure 8: "GPS positioning"

### 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).

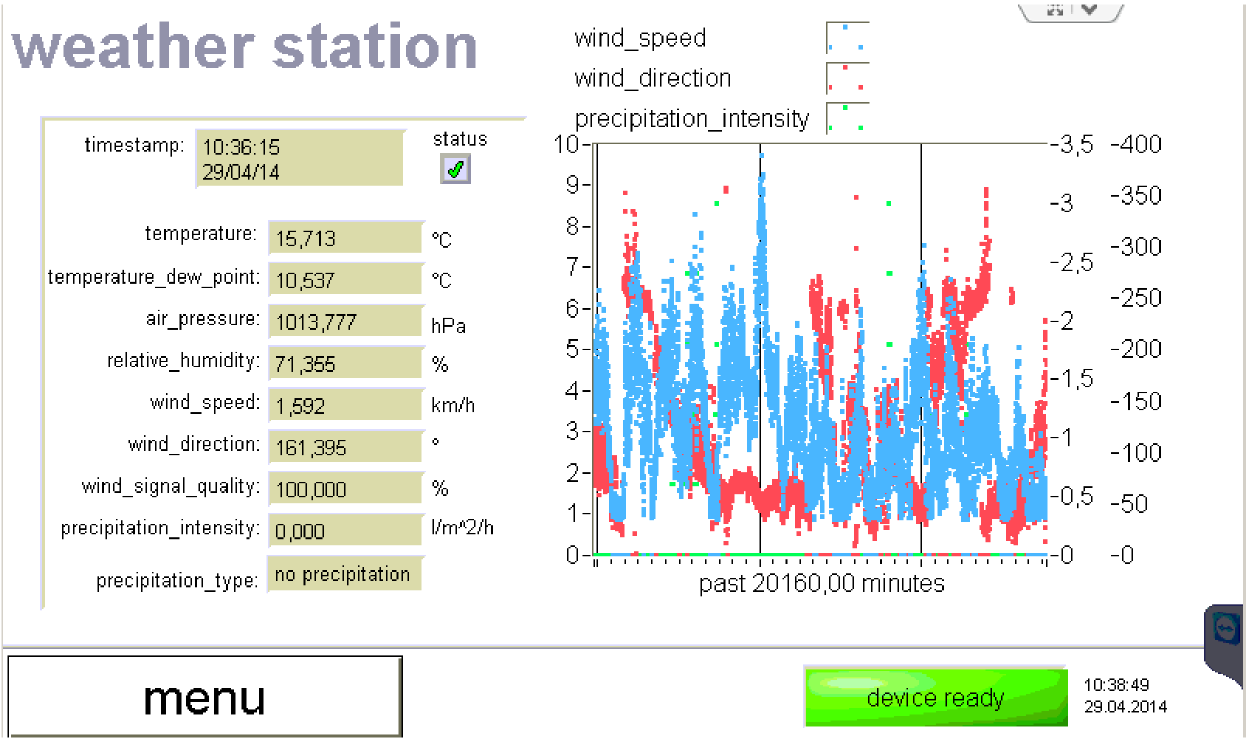



Figure 9: "weather station" – all data of the connected weather station

### 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).

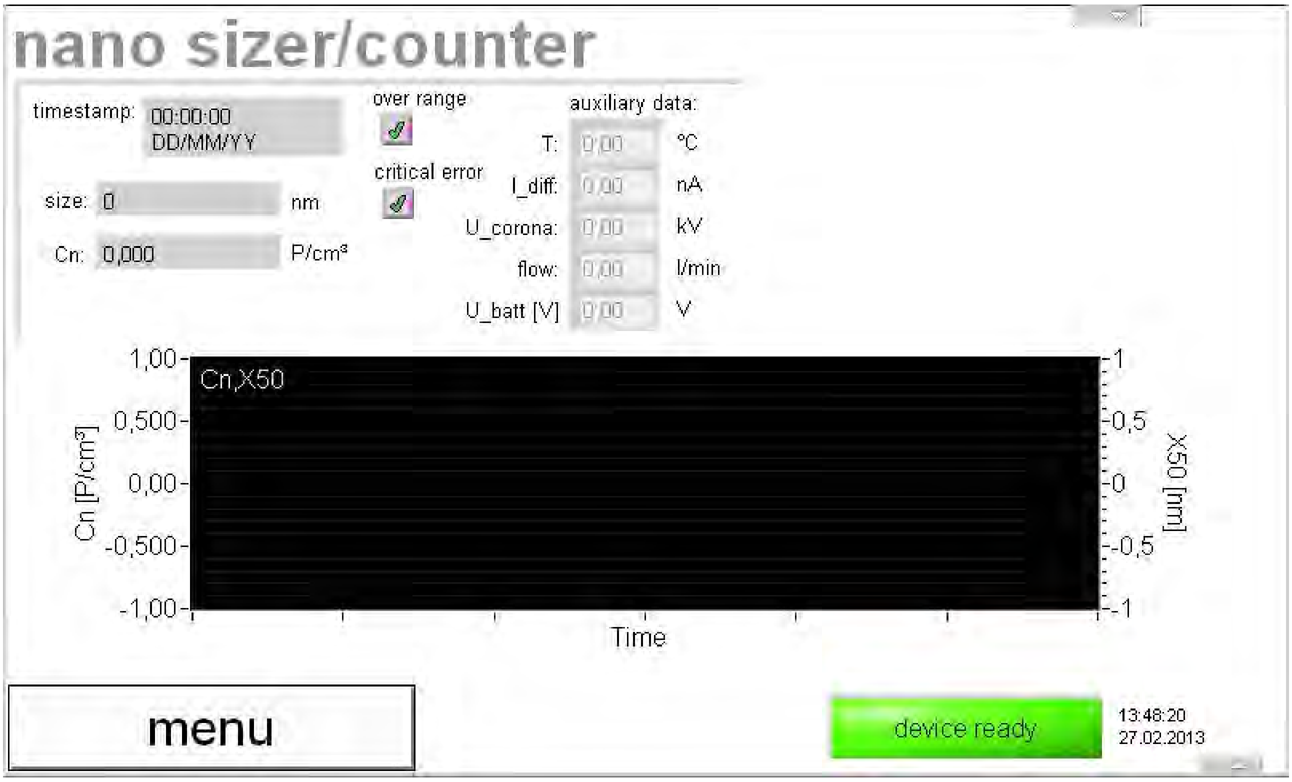



Figure 10: “nano sizer/counter” – additional information on nanoparticles

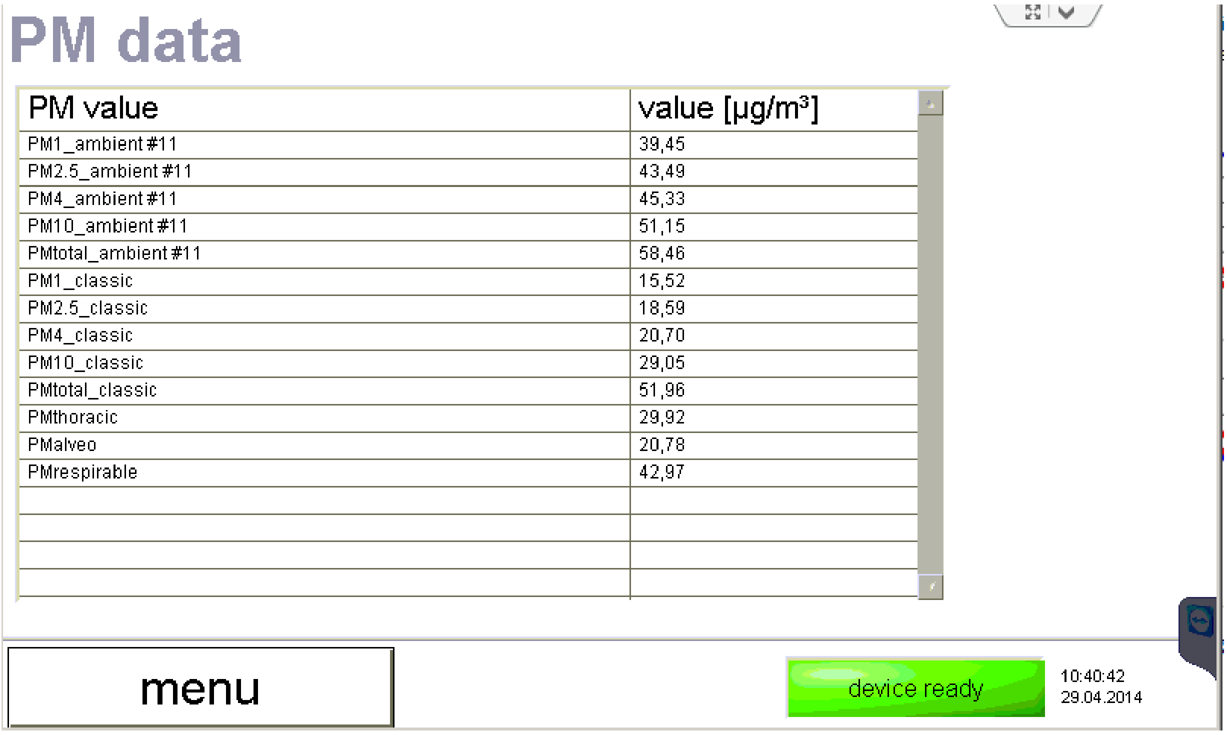
Note: It can be necessary to manually change the Com-port under Windows, if the USB-converter selected an improper com-port.

### 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.




| 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.

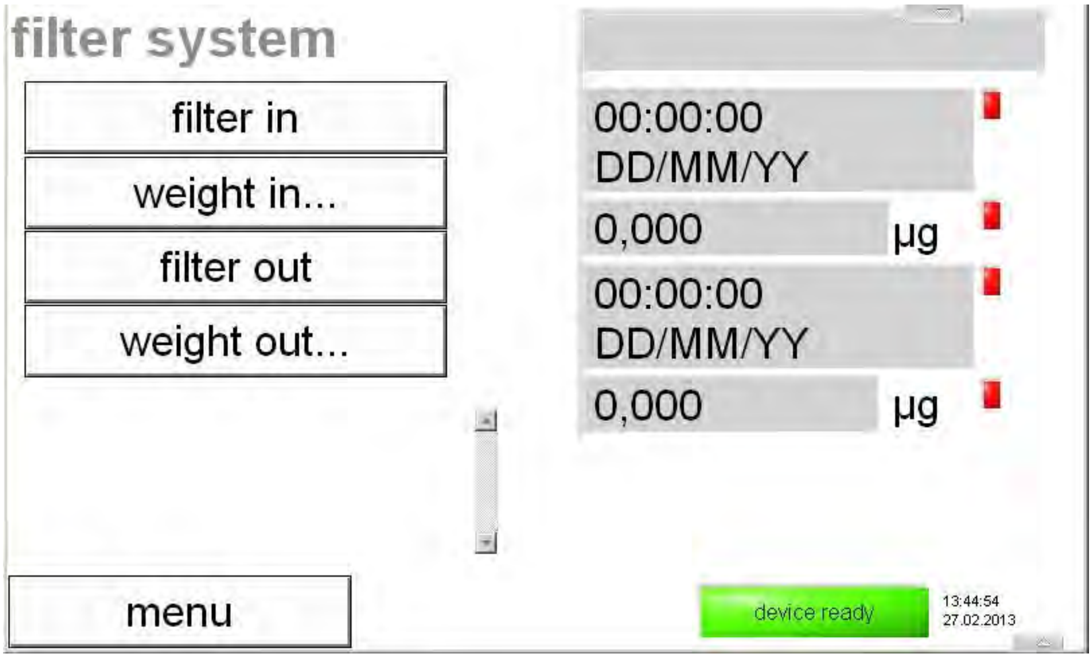



Figure 12: “filter system”

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 PDAnalyze. |

### 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.

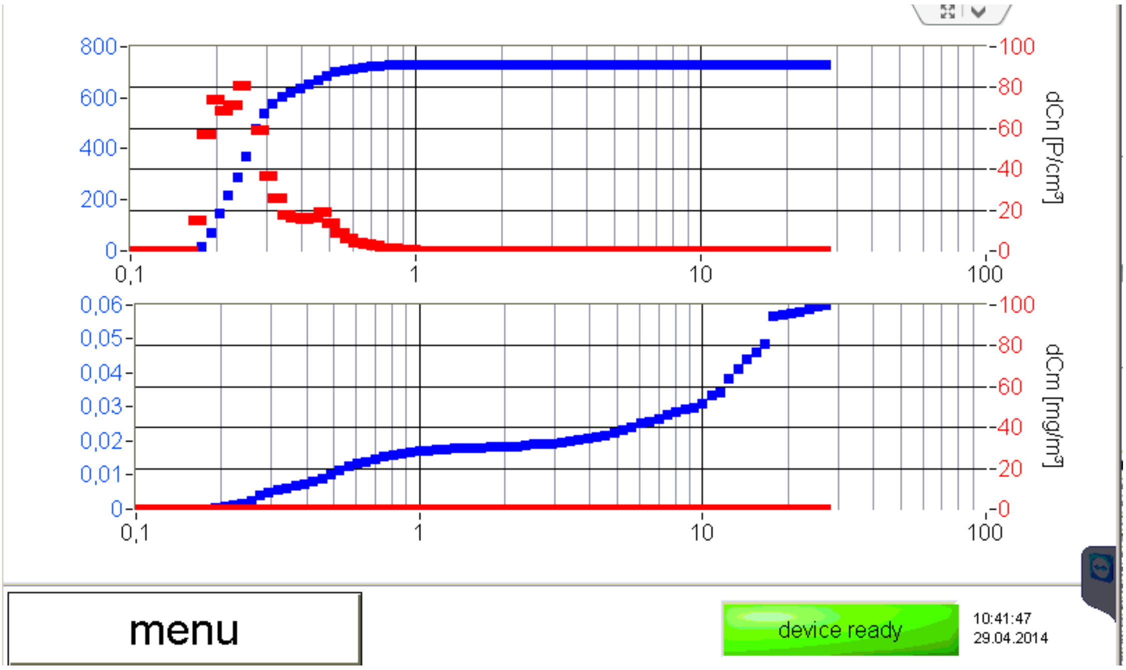



Figure 13: "particle size distribution"

### 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.

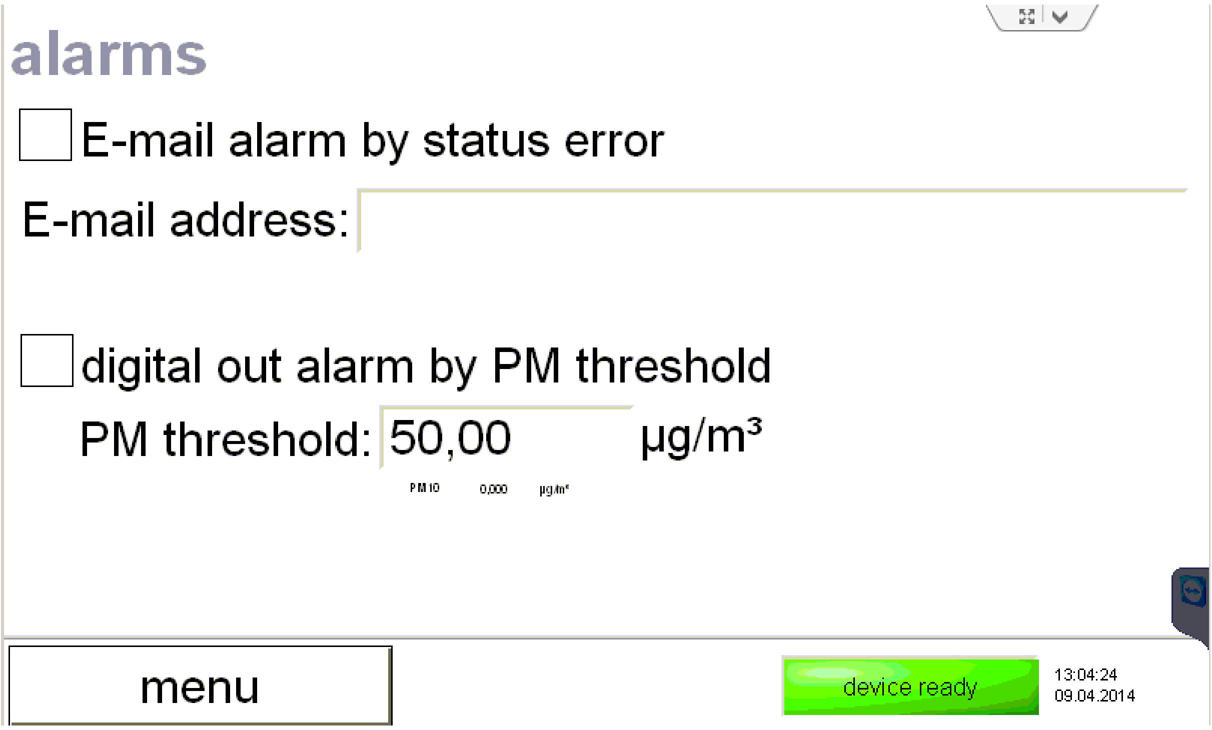



Figure 14: “alarms” – e-mail notification in case of warnings/errors

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.

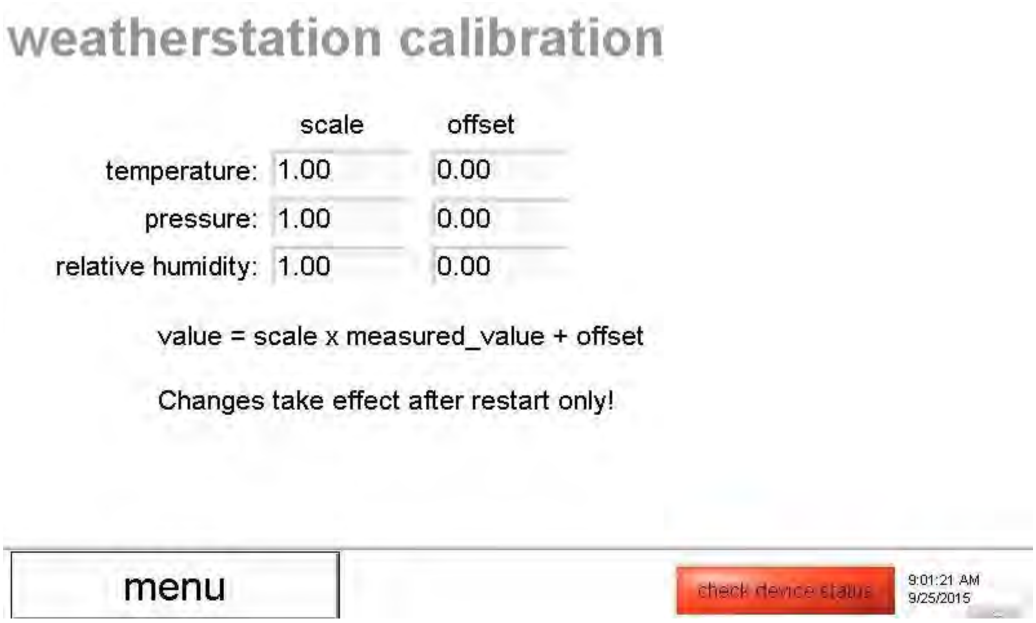



Figure 15: „calibrate weather station" – Adjustment of the weather station

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.

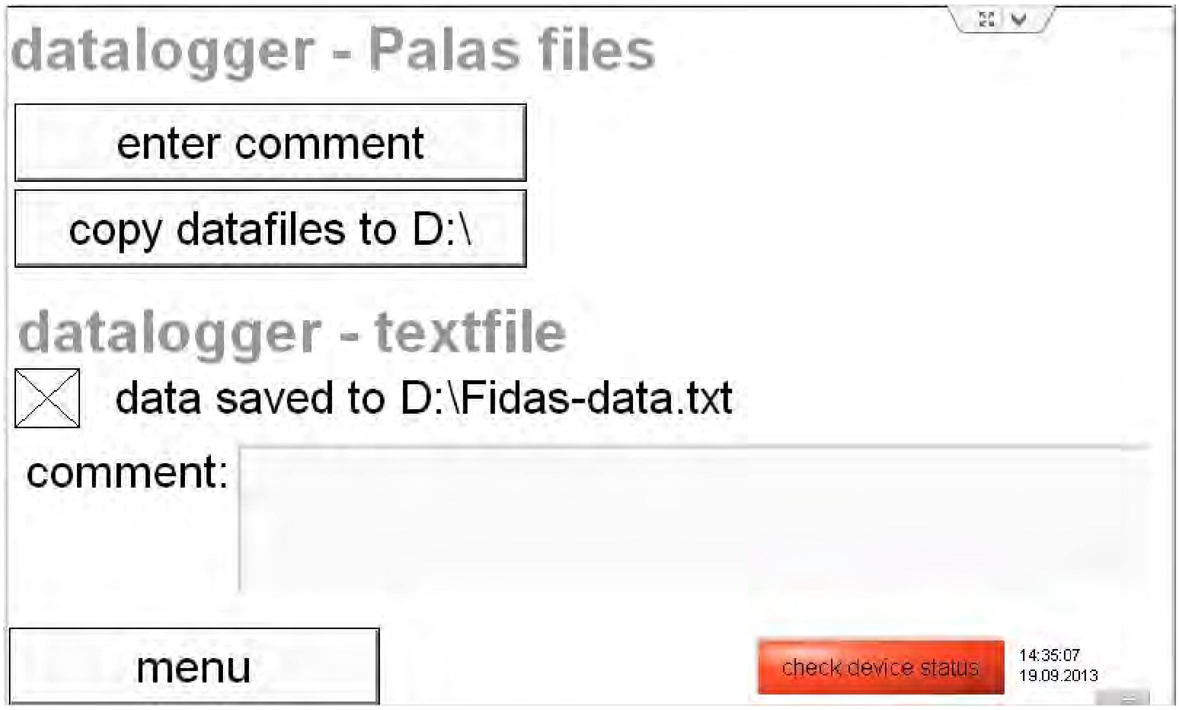



Figure 16: “datalogger” – saving data to internal memory or text file

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

| | | |
|---|---|---|
| PMthoraic | 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.

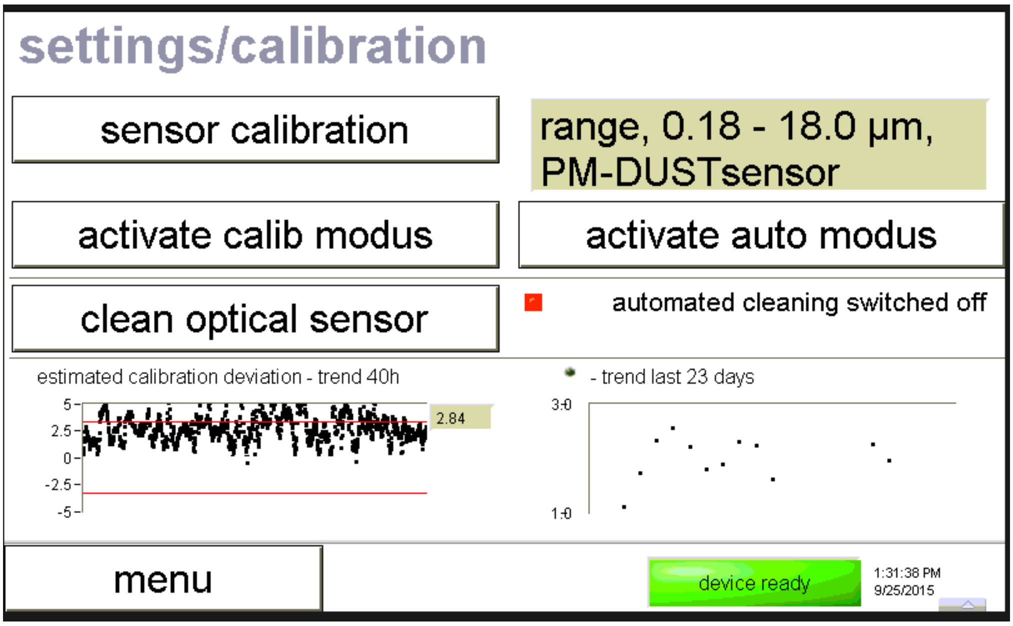



Figure 17: "settings/calibration"

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 PDAnalyze. 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.

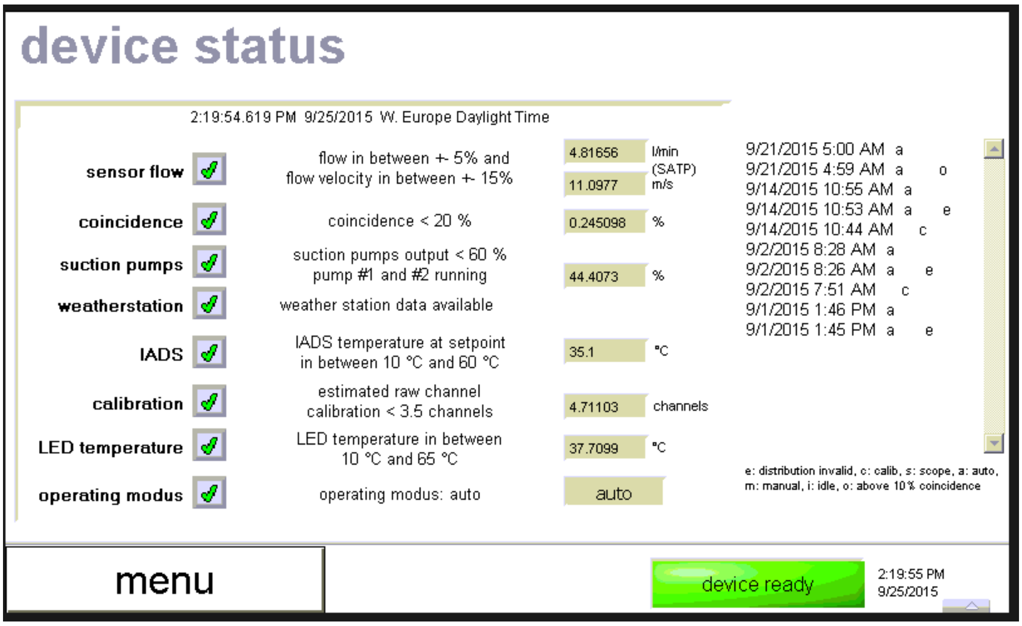


Figure 18: "device status"

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.

**<u>Note:</u> 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.

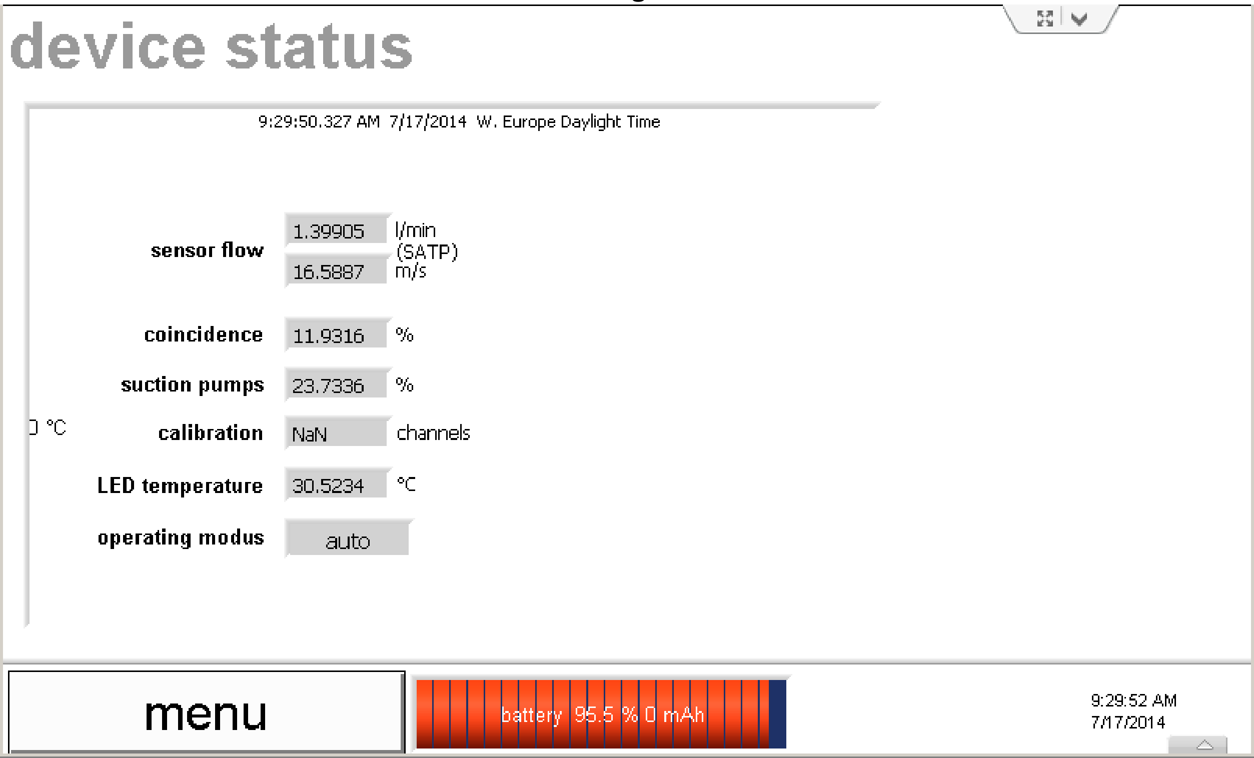



Figure 18a: Simplified "device status" screen for the Fidas® mobile

## 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.

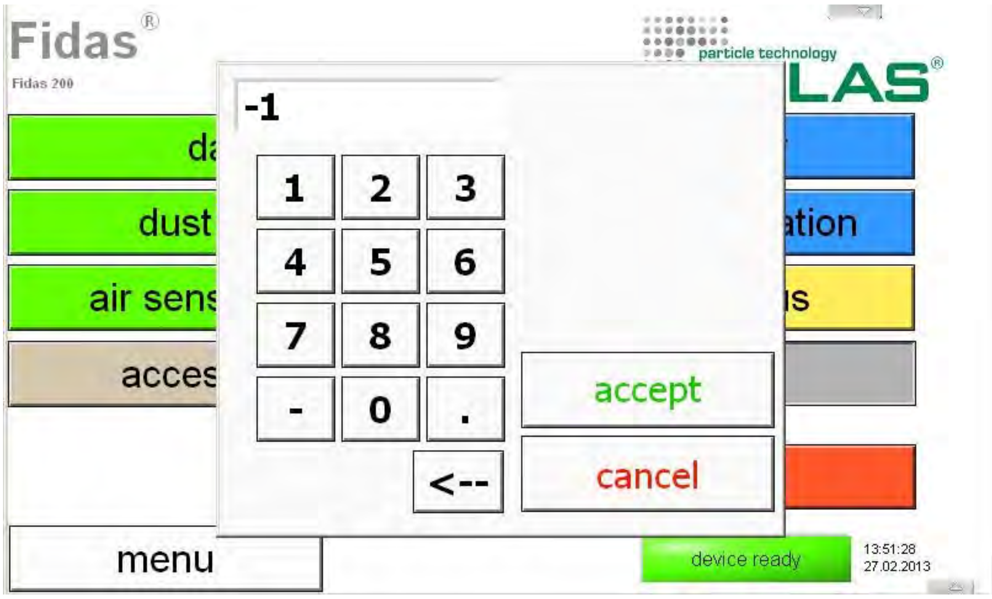



Figure 18: „expert user menu" – changing into the expert user mode


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.

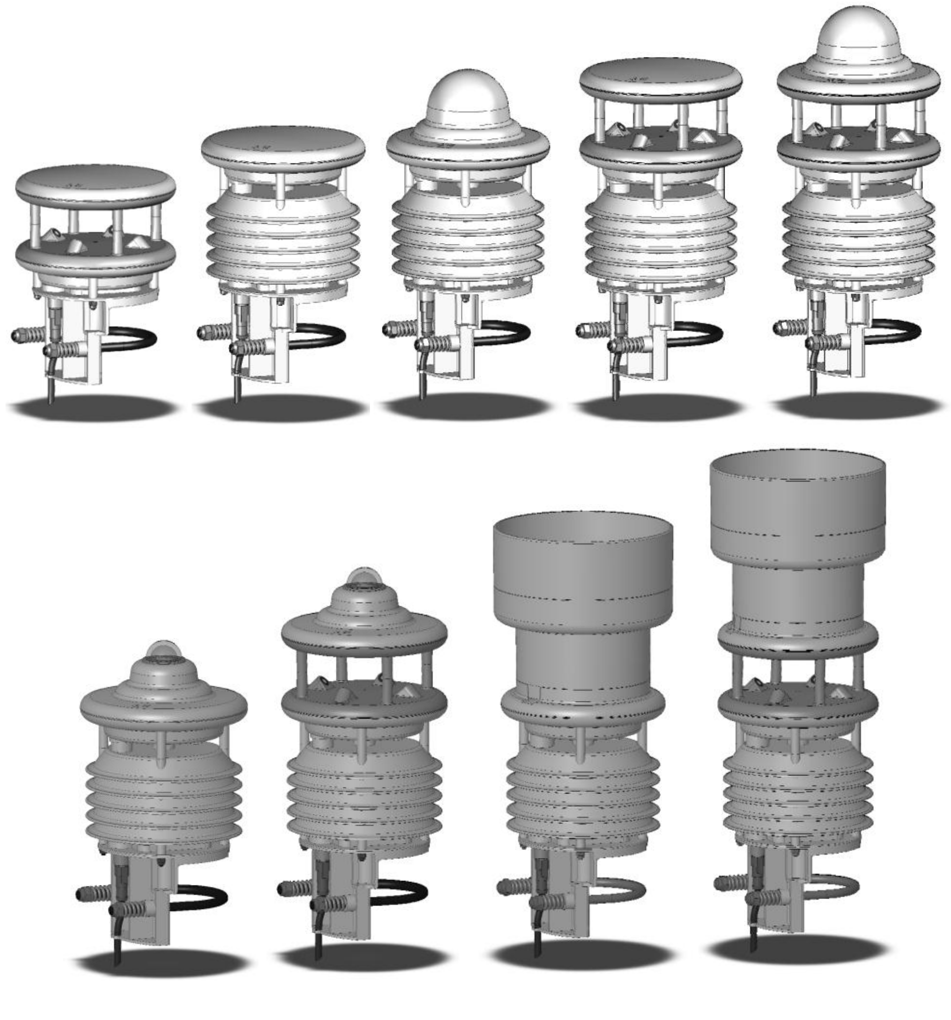
If the "shut down" is initiated, the following popup will appear on the screen:


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.

Operating Manual English

# 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**



UMB

**www.lufft.com** Lufft

# Contents

# 1 Please Read Before Use

**This manual is valid for devices of the Lufft WS family with device version 31 or higher(7/2012).Some functions or features specified in this manual may not be available or may not be valid with older device versions.** The device version is indicated as the last number of the serial number, e.g.: the device with SN: 063.1010.0701.**021**has the device version 21.

If you are using an older device of the WS family, please refer to the manual for device versions prior to 30 (www.lufft.com/en/support/downloads).

## 1.1 Symbols Used

Important information concerning potential hazards to the user

Important information concerning the correct operation of the equipment

## 1.2 Safety Instructions

- Installation and commissioning must be carried out by suitably qualified specialist personnel only.
- Never take measurements on or touch live electrical parts.
- Pay attention to the technical data and storage and operating conditions.

## 1.3 Designated Use

- The equipment must only be operated within the range of the specified technical data.
- The equipment must only be used under the conditions and for the purposes for which it was designed.
- The safety and operation of the equipment can no longer be guaranteed if it is modified or adapted.

## 1.4 Incorrect Use

If the equipment is installed incorrectly

- It may not function.
- It may be permanently damaged.
- Danger of injury may exist if the equipment is allowed to fall.

If the equipment is not connected correctly

- It may not function.
- It may be permanently damaged.
- The possibility of an electrical shock may exist.

## 1.5 Guarantee

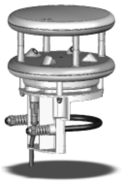
The guarantee period is 12 months from the date of delivery. The guarantee is forfeited if the designated use is violated.

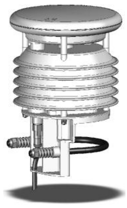
## 1.6 Brand Names

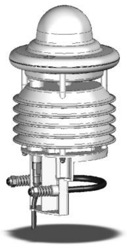
All brand names referred to are subject without limitation to the valid trademark and ownership rights of the respective owner.

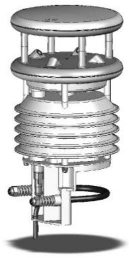
# 2 Scope of Delivery

- Equipment


WS200-UMB


WS300-UMB

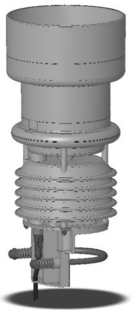

WS400-UMB

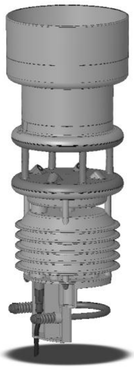

WS500-UMB


WS600-UMB


WS301-UMB


WS501-UMB


WS401-UMB


WS601-UMB

- Connection cable 10m

- Operating manual

# 3 Order Numbers

**WS200-UMB** **8371.U01**

- Wind Direction
- Wind Speed
- Compass

**WS300-UMB** **8372.U01**

- Air Temperature
- Relative Humidity
- Air Pressure

**WS301-UMB** **8374.U01**
**WS302-UMB** **8374.U10**
**WS303-UMB** **8374.U11**
**WS304-UMB** **8374.U12**

- Air Temperature
- Relative Humidity
- Air Pressure
- Global Radiation

**WS400-UMB** **8369.U01** (Europe, USA, Canada)

- Precipitation Radar **8369.U02** (UK)
- Air Temperature
- Relative Humidity
- Air Pressure

**WS401-UMB** **8377.U01**

- Precipitation Rain Gauge
- Air Temperature
- Relative Humidity
- Air Pressure

**WS500-UMB** **8373.U01**

- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass

**WS501-UMB** **8375.U01**
**WS502-UMB** **8375.U10**
**WS503-UMB** **8375.U11**
**WS504-UMB** **8375.U12**

- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass
- Global Radiation

**WS600-UMB** **8370.U01** (Europe, USA, Canada)

- Precipitation Radar **8370.U02** (UK)
- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass

**WS601-UMB** **8376.U01**

- Precipitation Rain Gauge
- Wind Direction
- Wind Speed
- Air Temperature
- Relative Humidity
- Air Pressure
- Compass

### 3.1 Accessories

| | |
|---|---|
| Power supply unit 24V/100VA | 8366.USV1 |
| ISOCON-UMB | 8160.UISO |
| Surge protection | 8379.USP |
| Leaf Wetness Sensor WLW100 (WS401-UMB, WS601-UMB only) | 8358.10 |
| External Rain Gauge WTB100 | 8353.10 |
| External Temperature Sensors | |
| Temperature Sensor WT1 | 8160.WT1 |
| Passive Road Surface Temperature Sensor WST1 | 8160.WST1 |

### 3.2 Spare Parts

| | |
|---|---|
| Connection cable 10m | On enquiry |

### 3.3 Additional Documents and Software

You can download the following documents and software via the Internet at www.lufft.com.

| | |
|---|---|
| Operating Manual | • This document |
| UMB-Config-Tool | • Windows® software for testing, firmware updates and configuration of UMB devices |
| UMB Protocol | • Communications protocol for UMB devices |
| Firmware | • The current device firmware |

# 4 Equipment Description

The WS family is a range of low cost, compact weather stations for the acquisition of a variety of measurement variables, as used for example for environmental data logging in road traffic management systems. Depending on the model, each device has a different combination of sensors for the various measurement variables.

| | WS200-UMB | WS300-UMB | WS301-UMB** | WS400-UMB | WS401-UMB | WS500-UMB | WS501-UMB*** | WS600-UMB | WS601-UMB |
|---|---|---|---|---|---|---|---|---|---|
| **Air temperature** | | ● | ● | ● | ● | ● | ● | ● | ● |
| **Humidity** | | ● | ● | ● | ● | ● | ● | ● | ● |
| **Air pressure** | | ● | ● | ● | ● | ● | ● | ● | ● |
| **Precipitation** | | | | ● | ●* | | | ● | ●* |
| **Wind direction** | ● | | | | | ● | ● | ● | ● |
| **Wind speed** | ● | | | | | ● | ● | ● | ● |
| **Compass** | ● | | | | | ● | ● | ● | ● |
| **Global Radiation** | | | ● | | | | ● | | |
| **Leaf Wetness (ext)** | | | | | ● | | | | ● |
| **Temperature (ext)** | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Rain Gauge (ext)** | ● | ● | ● | | | ● | ● | | |
| **Power Save 2** | ● | ● | ● | | ● | ● | ● | | ● |

*) WS401-UMB and WS601-UMB use a rain gauge for precipitation measurement

**) is also valid for WS302-UMB, WS303-UMB, WS304-UMB

***) is also valid for WS502-UMB, WS503-UMB, WS504-UMB

Sensors marked (ext) in the table are additional accessories and not included with the device. The table shows which external sensors can be connected to the different models.

**Note:** The external temperature sensor and the external rain gauge use the same input, so only one of them can be connected simultaneously.

**Attention:** Please note that, due to the approval of the radar sensor used, there are different country options on equipment which includes precipitation measurement by radar technology.

The equipment is connected by way of an 8 pole screw connector and associated connection cable (length 10m).

The measured values are requested over the RS485 interface in accordance with UMB protocol.

During commissioning, configuration and measurement polling takes place using the UMB-Config-Tool (Windows® PC software).

## 4.1 Air Temperature and Humidity

Temperature is measured by way of a highly accurate NTC-resistor while humidity is measured using a capacitive humidity sensor. In order to keep the effects of external influences (e.g. solar radiation) as low as possible, these sensors are located in a ventilated housing with radiation protection. In contrast to conventional non-ventilated sensors, this allows significantly more accurate measurement during high radiation conditions.

Additional variables such as dewpoint, absolute humidity and mixing ratio are calculated from air temperature and relative humidity, taking account of air pressure.

## 4.2 Air Pressure

Absolute air pressure is measured by way of a built-in sensor (MEMS). The relative air pressure referenced to sea level is calculated using the barometric formula with the aid of the local altitude, which is user-configurable on the equipment.

### 4.3 Precipitation

Tried and tested radar technology from the R2S-UMB sensor is used to measure precipitation. The precipitation sensor works with a 24GHz Doppler radar, which measures the drop speed and calculates precipitation quantity and type by correlating drop size and speed.
WS401-UMB and WS601-UMB are using an unheated rain gauge for precipitation measurement. This version can be recommended for low power application etc.

### 4.4 Wet Bulb Temperature

The wet bulb temperature is the temperature resulting between a wetted or iced surface at a flowing air.

### 4.5 Specific Enthalpy

Parameter of state of the humid air, composed of the specific enthalpies (heat capacity) of the components of the mixture and related to the mass fraction of the dry air (at 0°C).

### 4.6 Air Density

The air density indicates how much mass in a given volume of air is contained and it is calculated from the measured values of air temperature, humidity and air pressure.

### 4.7 Wind

The wind meter uses 4 ultrasonic sensors which take cyclical measurements in all directions. The resulting wind speed and direction are calculated from the measured run-time sound differential. The sensor delivers a quality output signal indicating how many good readings were taken during the measurement interval.

### 4.8 Compass

The integrated electronic compass can be used to check the north – south adjustment of the sensor housing for wind direction measurement. It is also used to calculate the compass corrected wind direction.

### 4.9 Heating

The precipitation sensor and wind meter are heated for operation in winter.

### 4.10 Global Radiation

The global radiation is measured by a pyranometer mounted in the top cover of the compact weather station.

### 4.11 Leaf Wetness

WS401-UMB and WS601-UMB can be equipped with an external sensor for leaf wetness evaluation.

### 4.12 External Temperature Sensor

Optionally all models may be equipped with an external NTC temperature sensor for the acquisition from additional measurement points. The type of NTC is the same as used for the internal air temperature sensor.

External temperature sensor and external rain gauge can **not** be connected at the same time.

### 4.13 External Rain Gauge

Models without integrated precipitation acquisition can be equipped with an external rain gauge.

External rain gauge and external temperature sensor can **not** be connected at the same time.

### 4.14 Sensor Technology (example: WS600-UMB)

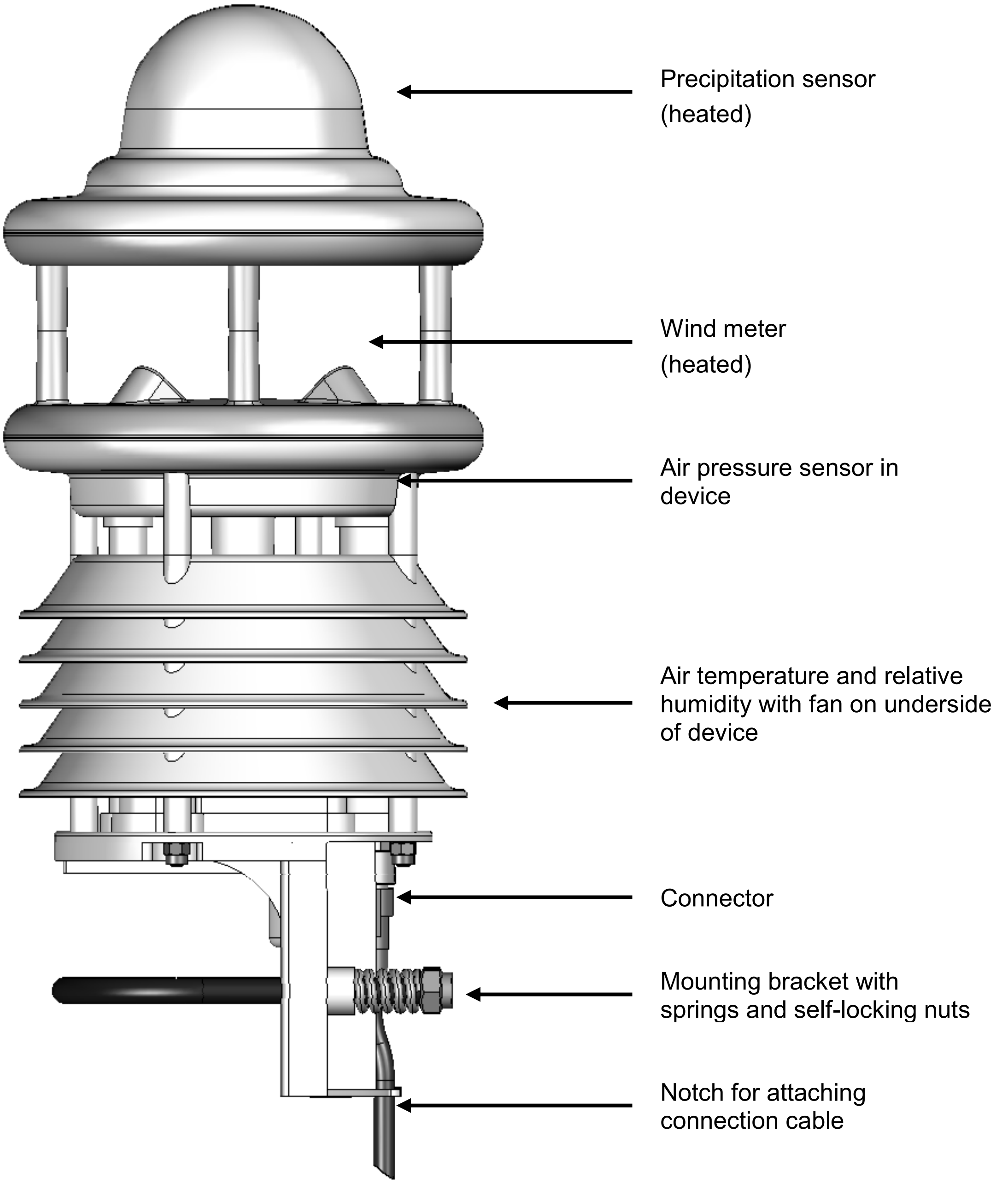



Figure 1: Sensor Technology

# 5 Generation of Measurements

### 5.1 Current Measurement (act)

In accordance with the specified sampling rate, the value of the last measurement is transmitted when the current measurement value is requested. Each measurement is stored in a circular buffer for the subsequent calculation of minimum, maximum and average values.

### 5.2 Minimum and Maximum Values (min and max)

When requesting the minimum and maximum values, the corresponding value is calculated - via the circular buffer at the interval (1 – 10 minutes) specified in the configuration - and transmitted.

**Note:** In the case of wind direction, the minimum / maximum value indicates the direction at which the minimum / maximum wind speed was measured.

### 5.3 Average Value (avg)

When requesting the average value, this is calculated - via the circular buffer at the interval (1 – 10 minutes) specified in the configuration - and transmitted. In this way moving averages can also be calculated.

For some values the standard deviation is calculated for the same interval. The calculation of standard deviation will only be activated after the related UMB channel has been requested for the first time.

### 5.4 Vectorial Average Value (vct)

In the specific case of wind measurement, measurements are calculated vectorially. To this end, the average values of the vectors are generated internally. Hence the value (wind speed) and angle (wind direction) of the vector are calculated.

**Note:** On delivery, the interval for the calculation of minimum, maximum and average values is set at 10 minutes. If necessary, this can be adjusted to the particular requirements (1 – 10 minutes) with the aid of the UMB-Config-Tool (see page 28).

# 6 Measurement Output

Measurements are transmitted in accordance with UMB binary protocol (Factory Settings).

You can find an example of a measurement request in different protocols and a complete summary of the list of channels in the Appendix.

## 6.1 Air and Dewpoint Temperature

Sampling rate 1 minute

Generation of average value 1 – 10 minutes

Units °C; °F

Request channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| **act** | **min** | **max** | **avg** | **Measurement Variable (float32)** | **min** | **max** | **unit** |
| 100 | 120 | 140 | 160 | Air temperature | -50.0 | 60.0 | °C |
| 105 | 125 | 145 | 165 | Air temperature | -58.0 | 140.0 | °F |
| 110 | 130 | 150 | 170 | Dewpoint temperature | -50.0 | 60.0 | °C |
| 115 | 135 | 155 | 175 | Dewpoint temperature | -58.0 | 140.0 | °F |
| 101 | | | | External Temperature Sensor | -40.0 | 80.0 | °C |
| 106 | | | | External Temperature Sensor | -40.0 | 176.0 | °F |

## 6.2 Wind Chill Temperature

Sampling rate 1 minute, computed on base of the average temperature and average wind speed

Units °C; °F

Request channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| **act** | **min** | **max** | **avg** | **Measurement Variable (float32)** | **min** | **max** | **unit** |
| 111 | | | | Wind chill temperature | -60.0 | 70.0 | °C |
| 116 | | | | Wind chill temperature | -76.0 | 158.0 | °F |

## 6.3 Humidity

Sampling rate 1 minute

Generation of average value 1 – 10 minutes

Units %RH; g/m³; g/kg

Request channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| **act** | **min** | **max** | **avg** | **Measurement Variable (float32)** | **min** | **max** | **unit** |
| 200 | 220 | 240 | 260 | Relative humidity | 0.0 | 100.0 | % |
| 205 | 225 | 245 | 265 | Absolute humidity | 0.0 | 1000.0 | g/m³ |
| 210 | 230 | 250 | 270 | Mixing ratio | 0.0 | 1000.0 | g/kg |

## 6.4 Air Pressure

Sampling rate 1 minute

Generation of average value 1 – 10 minutes

Unit hPa

Request channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| **act** | **min** | **max** | **avg** | **Measurement Variable (float32)** | **min** | **max** | **unit** |
| 300 | 320 | 340 | 360 | Absolute air pressure | 300 | 1200 | hPa |
| 305 | 325 | 345 | 365 | Relative air pressure | 300 | 1200 | hPa |

**Note:** For the correct calculation of relative air pressure, the altitude of the location must be entered in the device configuration (see Figure 11 on page 30). The factory setting for altitude is 0m; in this way both measurement variables deliver the same values.

## 6.5 Wet Bulb Temperature

Sampling rate 1 minute

Units °C; °F

Request channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| act | | | | Measurement Variable (float32) | min | max | unit |
| 114 | | | | Wet Bulb Temperature | -50.0 | 60.0 | °C |
| 119 | | | | Wet Bulb Temperature | -58.0 | 140.0 | °F |

## 6.6 Specific Enthalpy

Sampling rate 1 minute

Unit kJ/kg

Request channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| act | | | | Measurement Variable (float32) | min | max | unit |
| 215 | | | | Specific Enthalpy | -100.0 | 1000.0 | kJ/kg |

## 6.7 Air Density

Sampling rate 1 minute

Unit kg/m³

Request channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| act | | | | Measurement Variable (float32) | min | max | unit |
| 310 | | | | Air Density | 0.0 | 3.0 | kg/m³ |

### 6.8 Wind Speed

| | |
|---|---|
| Sampling rate | 10 seconds |
| Generation of average value | 1 – 10 minutes |
| Generation of maximum value | 1 – 10 minutes based on the internal second measurements |
| Units | m/s; km/h; mph; kts |
| Response threshold | 0.3 m/s |

Request channels:

| UMB Channel | | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|---|
| act | min | max | avg | vct | Measurement Variable (float32) | min | max | unit |
| 400 | 420 | 440 | 460 | 480 | Wind Speed | 0 | 75.0 | m/s |
| 405 | 425 | 445 | 465 | 485 | Wind Speed | 0 | 270.0 | km/h |
| 410 | 430 | 450 | 470 | 490 | Wind Speed | 0 | 167.8 | mph |
| 415 | 435 | 455 | 475 | 495 | Wind Speed | 0 | 145.8 | kts |
| 401 | | | | | Wind Speed Fast | 0 | 75.0 | m/s |
| 406 | | | | | Wind Speed Fast | 0 | 270.0 | km/h |
| 411 | | | | | Wind Speed Fast | 0 | 167.8 | mph |
| 416 | | | | | Wind Speed Fast | 0 | 145.8 | kts |
| 403 | | | | | Wind Speed Standard Deviation | 0 | 75.0 | m/s |
| 413 | | | | | Wind Speed Standard Deviation | 0 | 167.8 | mph |

**Note:** The second measurements are averaged over 10 seconds for the output of the current measurement. The 'fast' channels deliver every second a current value, but with reduced accuracy.

### 6.9 Wind Direction

| | |
|---|---|
| Sampling rate | 10 seconds |
| Generation of average value | 1 – 10 minutes |
| Generation of maximum value | 1 – 10 minutes based on the internal second measurements |
| Unit | ° |
| Response threshold | 0.3 m/s |

Request channels:

| UMB Channel | | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|---|
| act | min | max | avg | vct | Measurement Variable (float32) | min | max | unit |
| 500 | 520 | 540 | | 580 | Wind Direction | 0 | 359.9 | ° |
| 501 | | | | | Wind Direction Fast | 0 | 359.9 | ° |
| 502 | | | | | Wind Direction Corrected | 0 | 359.9 | ° |
| 503 | | | | | Wind Direction Standard Deviation | 0 | 359.0 | ° |

**Note:** The second measurements are averaged over 10 seconds for the output of the current measurement. The 'fast' channels deliver every second a current value, but with reduced accuracy.

The minimum / maximum wind direction indicates the direction at which the minimum / maximum wind speed was measured.

The corrected wind direction is calculated from the wind direction measured by the wind sensor and the heading measured by the compass.

Optionally the compass correction of the wind direction can be activated for all wind direction values. (Settings by UMB Config Tool)

**Note:** The correction function is designed for correction of the wind direction of a statically mounted sensor. If the alignment of the sensor changes during the measurement (i.e. if the sensor is mounted on a rotating platform or similar) the correction function will not in all cases work properly, especially not for the vector average.

It is of course possible to use the correction function for mobile measurement units, where the alignment is changed between measurement periods.

## 6.10 Wind Measurement Quality

Sampling rate 10 seconds

Unit %

Request channels:

| UMB Channel | | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|---|
| act | min | max | avg | vct | Measurement Variable (float32) | min | max | unit |
| 805 | | | | | Wind Value Quality | 0 | 100 | % |

**Note:** The value is updated every 10 seconds and transmits the minimum wind measurement quality for the last minute.

This value allows the user to assess how well the measurement system is functioning in the respective ambient conditions. In normal circumstances the value is 90 - 100%. Values up to 50% do not represent a general problem. If the value falls towards zero the measuring system is reaching its limits.

If during critical ambient conditions the system is no longer able to conduct reliable measurements, error value 55h (85d) is transmitted (device unable to execute valid measurement due to ambient conditions).

## 6.11 Compass

(only device version 030 or higher)

Sampling rate: 5 min

Unit °

Request channels:

| UMB Channel | | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|---|
| act | min | max | avg | vct | Measurement Variable (float) | min | max | unit |
| 510 | | | | | Compass Heading | 0 | 359 | ° |

**Note**: Reliable operation of the compass is only possible, if the sensor has been mounted according to the instructions in this manual, i.e. on top of the pole. Should the sensor be mounted on a traverse, the distribution of iron masses will be different from the situation during factory calibration. This may lead to additional deviation of the bearing. This also applies to lightning rods mounted at the pole top!

Dependent on the location of the installation the local declination of the earth magnetic field has to be considered. The declination value is entered using the UMB-Config-Tool (see page 30). The declination for the installation location can be found in the Internet, e.g. at

http://www-app3.gfz-potsdam.de/Declinationcalc/declinationcalc.html

**http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp**

### 6.12 Precipitation Quantity - Absolute

Sampling rate Event-dependent on reaching the response threshold
Response threshold 0.01mm (Radar)
Response threshold 0.2 / 0.5 mm (Rain Gauge)
Units l/m²; mm; in; mil
Request channels:

| UMB Channel | Measurement Variable (float32) | Unit |
|---|---|---|
| 600 | Precipitation Quantity - Absolute | l/m² |
| 620 | Precipitation Quantity - Absolute | mm |
| 640 | Precipitation Quantity - Absolute | in |
| 660 | Precipitation Quantity - Absolute | mil |

**Note:** This measurement indicates the accumulated precipitation quantity since the last device reboot. The measurement is retained for the duration of a short power failure. To reset this value, use the corresponding function in the UMB-Config-Tool (see page 33) or disconnect the device from the power supply for at least one hour.

### 6.13 Precipitation Quantity - Differential

Sampling rate Event-dependent on reaching the response threshold
Response threshold 0.01mm (Radar)
Response threshold 0.2 / 0.5 mm (Rain Gauge)
Units l/m²; mm; in; mil
Request channels:

| UMB Chanel | Measurement Variable (float32) | Unit |
|---|---|---|
| 605 | Precipitation Quantity - Differential | l/m² |
| 625 | Precipitation Quantity - Differential | mm |
| 645 | Precipitation Quantity - Differential | in |
| 665 | Precipitation Quantity - Differential | mil |

**Note:** Each request from a differential channel sets the accumulated quantity back to zero. If the response from the device is lost due to a transmission error (e.g. poor GPRS connection), the quantity accumulated to date is also lost. The quantity accumulated to date is also reset each time the equipment is rebooted.

### 6.14 Precipitation Intensity

Sampling rate 1 minute
Response threshold 0.6 mm/h
Units l/m²/h; mm/h; in/h; mil/h
Request channels:

| UMB Channel | Measurement Variable (float32) | Range | Unit |
|---|---|---|---|
| 800 | Precipitation Intensity | 0 … 200.0 | l/m²/h |
| 820 | Precipitation Intensity | 0 … 200.0 | mm/h |
| 840 | Precipitation Intensity | 0 … 7.874 | in/h |
| 860 | Precipitation Intensity | 0 … 7874 | mil/h |

**Note:** The device versions with radar technology (WS400-UMB, WS600-UMB) calculate the precipitation intensity is always on the basis of the precipitation of the previous minute.

The lower resolution of the rain gauge would lead to high fluctuation of the intensity values, so the rain gauge versions (WS401-UMB and WS601-UMB), as well as the external rain gauge, use the accumulated precipitation of the last 60 minutes before the current measurement for intensity calculation.

### 6.15 Precipitation Type

| | |
|---|---|
| Sampling rate | Event-dependent on reaching the response threshold |
| Response threshold | 0.01mm (Radar) |
| Response threshold | 0.2 / 0.5 mm (Rain Gauge) |
| Follow-up time | 2 minutes |

Request channels:

| UMB Channel | Measurement Variable (uint8) | Coding |
|---|---|---|
| 700 | Precipitation Type | 0 = No precipitation<br>60 = Liquid precipitation, e.g. rain<br>70 = Solid precipitation, e.g. snow<br>40 = unspecified precipitation (WS401-UMB, WS601-UMB, external rain gauge) |

**Note:** A detected precipitation type remains valid for 2 minutes after the end of the precipitation event. In order to record precipitation types which only occur for a short period (e.g. short-term rain), the request time should be at least 1 minute.

Ice, hail and sleet are transmitted as rain (60).

The versions WS401-UMB and WS601-UMB as well as the external rain gauge do not include detection of precipitation type, so in this case only type 40 (unspecified precipitation) is indicated. Due to the function of the rain gauge only liquid or molten precipitation can be recognized.

### 6.16 Heating Temperature

| | |
|---|---|
| Sampling Rate | 1 Minute |
| Units | °C; °F |

Request Channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| act | min | max | avg | Measurement Variable (float32) | min | max | Unit |
| 112 | | | | Heating Temperature Wind Sensor | -50.0 | 150.0 | °C |
| 113 | | | | Heating Temperature Precipitation Sensor | -50.0 | 150.0 | °C |
| 117 | | | | Heating Temperature Wind Sensor | -58.0 | 302.0 | °F |
| 118 | | | | Heating Temperature Precipitation Sensor | -58.0 | 302.0 | °F |

### 6.17 Global Radiation

| | |
|---|---|
| Sampling Rate | 1 minute |
| Generation of average values | 1 – 10 minutes |
| Unit | W/m² |

Request Channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| act | min | max | avg | Measurement Variable (float32) | min | max | unit |
| 900 | 920 | 940 | 960 | Global Radiation | 0.0 | 1400.0 | W/m² |

### 6.18 Leaf Wetness

| | |
|---|---|
| Sampling Rate | 1 minute |
| Generation of average values | 1 – 10min (using the setting for rel. humidity) |
| Unit | mV / code |

Request Channels:

| UMB Channel | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|
| act | min | max | avg | Measurement Variable (float32) | min | max | unit |
| 710 | 730 | 750 | 770 | Leaf Wetness mV | 0.0 | 1500.0 | mV |
| 711 | | | | Leaf Wetness State | 0 = dry<br>1 = wet | | |

The leaf wetness state is evaluated comparing with the adjustable leaf wetness threshold. The setting of this threshold shall be done according to the instructions of the sensor manual and, if necessary, readjusted as part of the maintenance procedure.

# 7 Installation

The sensor bracket is designed to be installed on the top of a mast with a diameter of 60 – 76mm.

The following tools are required for the installation:

- Open-end or ring spanner (SW13)
- Compass for aligning the wind meter to the North

## 7.1 Fastening

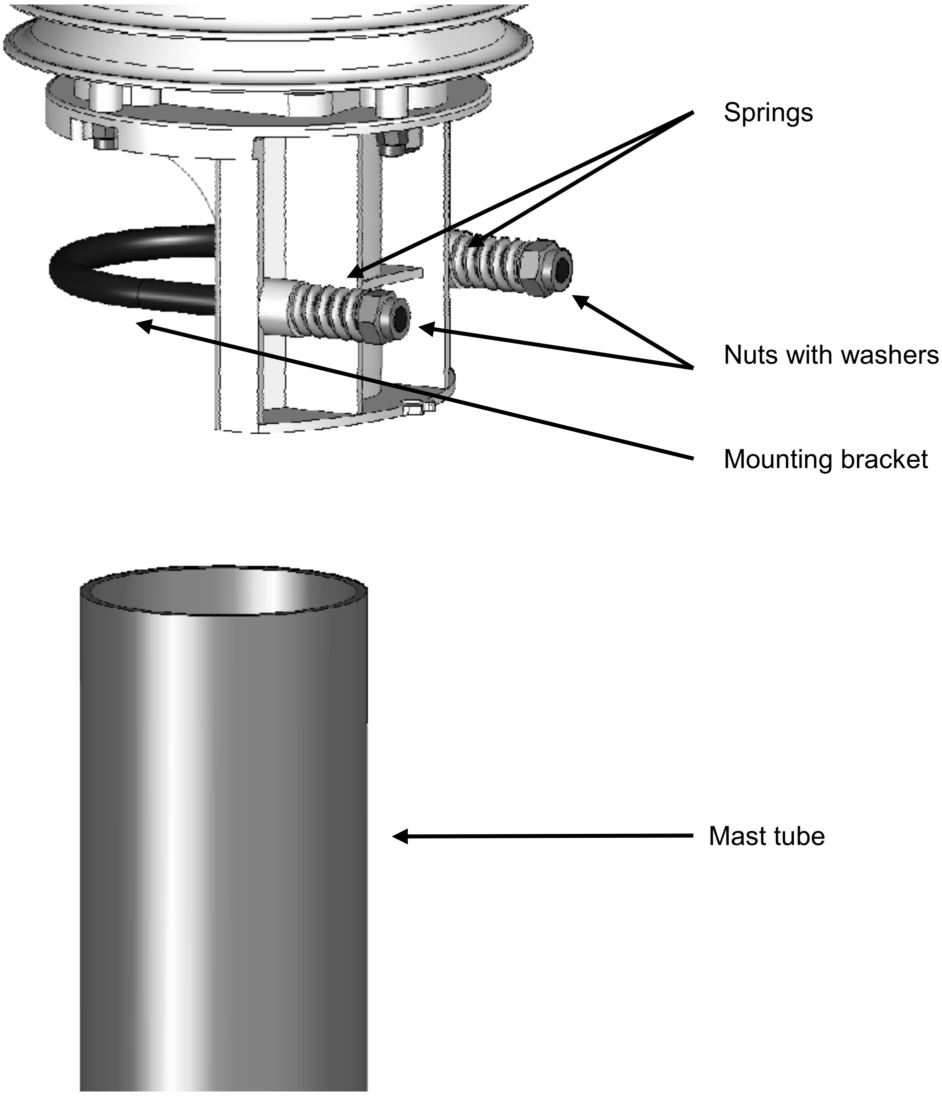
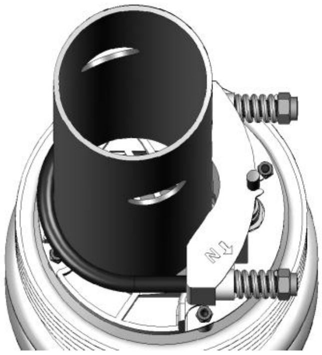



Figure 2: Fastening to the Mast

- Loosen nuts
- Push the sensor onto the top of the mast from above
- Tighten the nuts evenly until contact is made with the springs but the sensor can still be moved easily
- Align the sensor to the North (for wind meters)
- Tighten both nuts with **3 revolutions**

## 7.2 North Alignment

In order for the wind direction to display correctly, the sensor must be aligned to the North. The sensor has a number of directional arrows for this purpose.



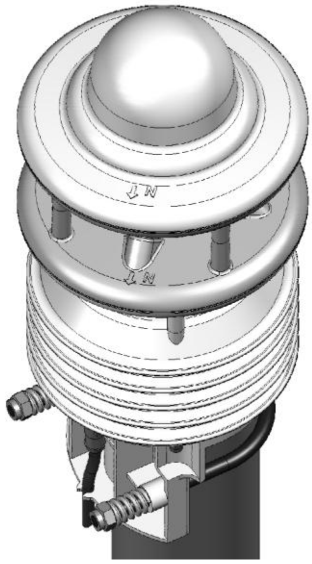


Figure 3: North Markings

Procedure:

- If the sensor is already installed, first loosen both nuts evenly until you can turn the sensor easily
- Using the compass, identify the North and fix a point of reference on the horizon
- Position the sensor in such a way that the South and North sensors are in alignment with the fixed point of reference in the North
- Tighten both nuts with 3 revolutions

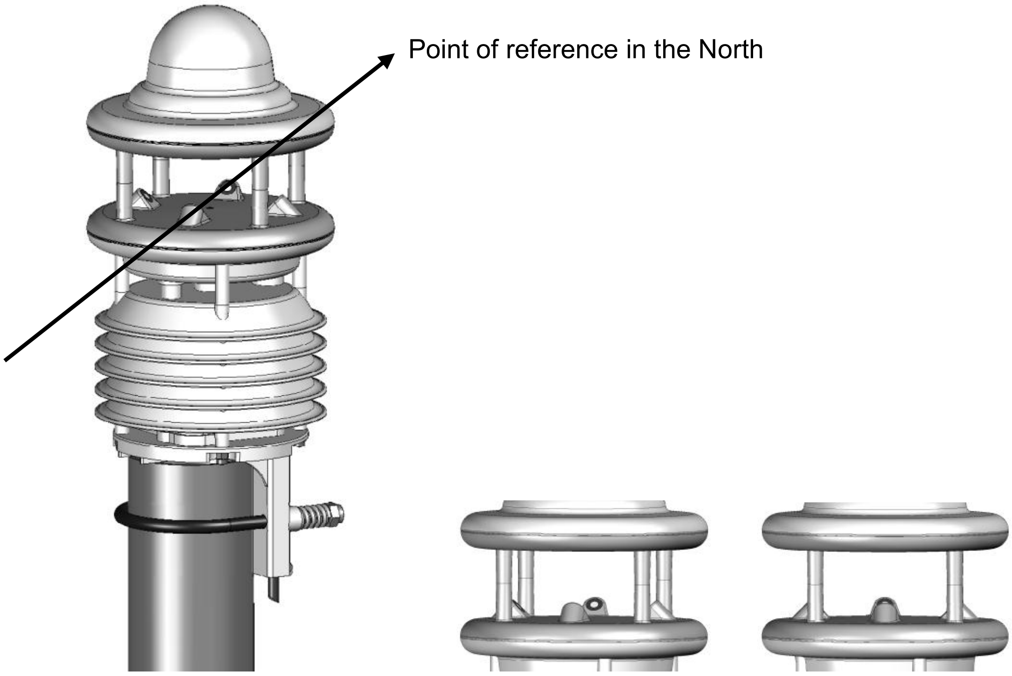



Figure 4: Alignment to North

**Note:** As the magnetic North Pole indicated by the compass differs from the Geographic North Pole, account must be taken of the declination (variation) at the location when aligning the sensor.

Depending on the location, the variation can be more than 15° (in North America for example). In Central Europe the variation can be largely ignored at present (< 3°). You can find further helpful information on this subject on the Internet.

## 7.3 Selecting the Installation Location

In order to guarantee long service life and correct equipment operation, please pay attention to the following points when selecting the installation location.

### 7.3.1 General Instructions

- Stable subsurface for installing the mast
- Free access to the equipment for maintenance works
- Reliable power supply for permanent operation
- Good network coverage when transmitting over a mobile communications network

**Note:** The computed measurements specifically apply to the equipment location only. No conclusions can be drawn with regard to the wider environment or a complete road section.

**ATTENTION:**

- Only approved and tested appliances (conductors, risers etc.) should be used to install the device on the mast.
- All relevant regulations for working at this height must be observed.
- The mast must be sized and anchored appropriately.
- The mast must be earthed in accordance with regulations.
- The corresponding safety regulations for working at road side and in the vicinity of the road carriageway must be observed.

If the equipment is installed incorrectly

- It may not function.
- It may be permanently damaged.
- Danger of injury may exist if the equipment is allowed to fall.

### 7.3.2 Sensors with Wind Measurement / Compass

- Installation at the top of the mast
- Installation height at least 2m above the ground
- Free field around the sensor

**Note:** Buildings, bridges, embankments and trees may corrupt the wind measurement. Equally, passing traffic may cause gusts which may influence the wind measurement.

**Note:** for accurate compass readings, an aluminium mast is recommended.

### 7.3.3 Sensors with Radar Precipitation Measurement

- Installation on the top of the mast
- Installation height at least 4.5m above the ground
- Distance to road carriageway at least 10m
- Distance from moving objects (e.g. trees, bushes and even bridges) at least 10m at the height of the sensor

**Note:** Falling or moving objects, e.g. falling leaves or leaves blowing in the wind, may cause false measurements and/or precipitation types.

**Note:** Strong wind can influence the accuracy of the precipitation measurement.

**Note:** When selecting the installation location please take care to position the device at a suitable distance from other systems incorporating a 24GHz radar sensor, such as traffic counting devices on overhead gantry signs. Otherwise cross effects and system malfunctions may occur. In the final analysis, the distance to other measuring systems also depends on their range of coverage and signal strength.

### 7.3.4 Sensors with Rain Gauge

- Installation on the top of the mast or on crossbar with distance to the mast
- Mast or crossbar mounting shall be exactly perpendicular, otherwise the precision of the rain gauge may be influenced.

Note: The location should be selected so that pollution of the rain gauge funnel by falling leaves etc. can be avoided as far as possible.

### 7.3.5 Sensors with Global Radiation Measurement

- Installation on top of the pole
- Shadow free location, if possible 360° free view to the horizon at the height of the pyranometer
- Distance to shadow casting objects (trees, buildings) at least 10 times of the object height relative to the sensor.

### 7.3.6 Installation Sketch

Example WS600-UMB:

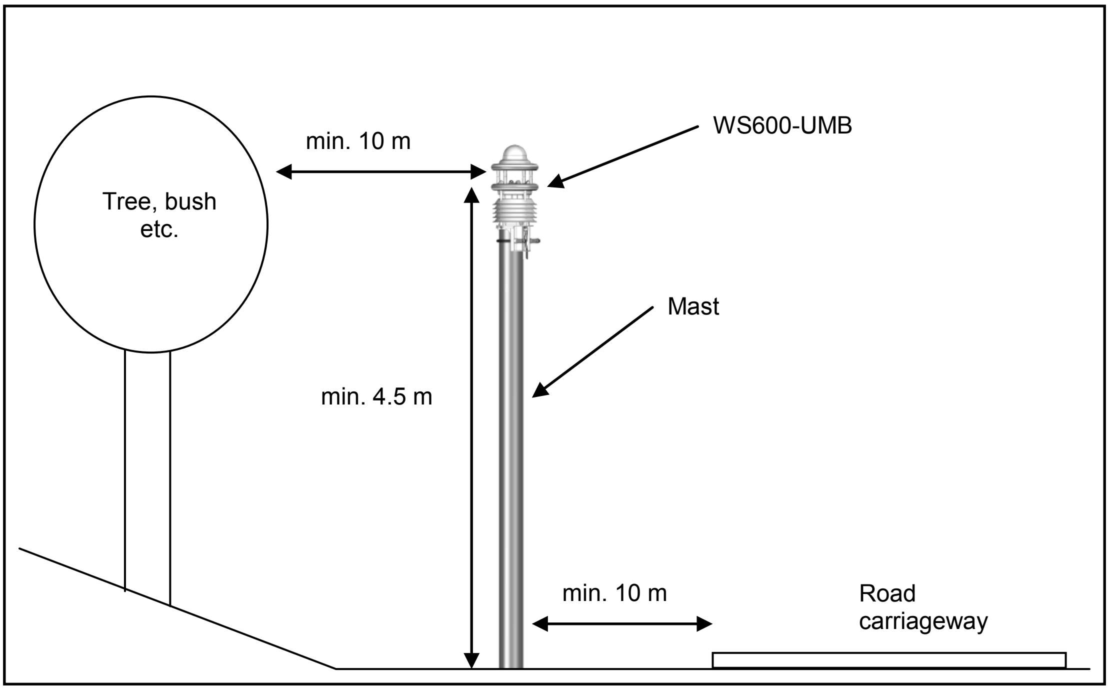
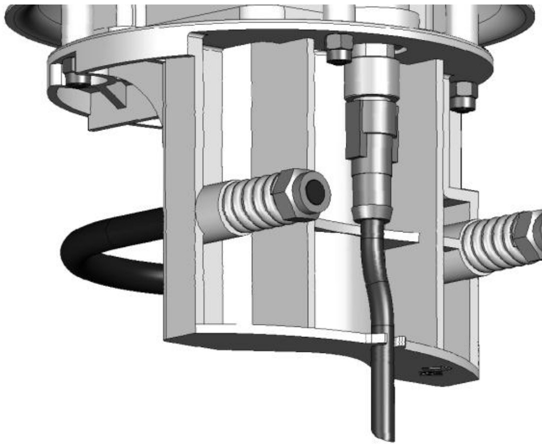



Figure 5: Installation Sketch

# 8 Connections

There is an 8 pole screw connector on the underside of the equipment. This serves to connect the supply voltage and interfaces by way of the supplied connection cable.

Equipment connector:



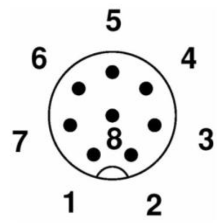



Figure 6: Connections

View on sensor connection

Pin assignment:

| | | |
|---|---|---|
| 1 | White | Supply voltage ground |
| 2 | Brown | Positive supply voltage |
| 3 | Green | RS485_A / SDI-12 GND |
| 4 | Yellow | RS485_B / SDI-12 Data Line |
| 5 | Grey | External Sensor a |
| 6 | Pink | External Sensor b |
| 7 | Blue | Heating voltage ground |
| 8 | Red | Positive heating voltage |

The cable marking is in accordance with DIN 47100.

**Note:** The yellow protective cap must be removed before plugging in the equipment.

If the equipment is not connected correctly

- It may not function
- It may be permanently damaged
- The possibility of an electrical shock may exist

**When connecting the heating voltage the correct polarity must be strictly observed. Wrong polarity of the heating voltage, as well as wrong polarity of the supply voltage will cause damage of the instrument.**

## 8.1 Supply Voltage

The supply voltage for the compact weather station is 12 - 24V DC. The power supply unit used must be approved for operation with equipment of protection class III (SELV).

### 8.1.1 Limitations in 12V mode

If the heating is operated on 12V DC, account must be taken of the functional restrictions in winter operation.

**Note:** A heating voltage of 24V DC is recommended to guarantee full heating duty.

## 8.2 RS485 Interface

The equipment has an electrically isolated, half-duplex, 2 wire RS485 interface for configuration, measurement polling and the firmware update.

See page 41 for technical details.

### 8.3 Connection to ISOCON-UMB (8160.UISO)

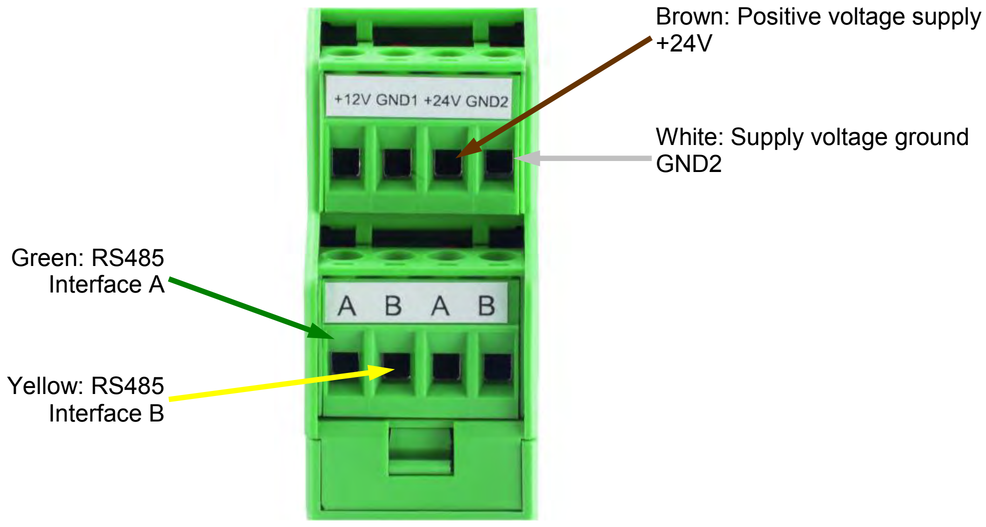



Figure 7: Connection to ISOCON-UMB

**Warning:** The heating voltage (red = positive heating voltage; blue = heating voltage ground) is **not** connected to the ISOCON-UMB but wired direct to the power supply unit.

During installation please also refer to the operating manual for the ISOCON-UMB.

### 8.4 Use of Surge Protection (8379.USP)

When using surge protection (Order No.: 8379.USP), please pay attention to the connection example in the surge protection operating instructions.

### 8.5 Connection of the Leaf Wetness Sensor

The sensor versions WS401-UMB and WS601-UMB (precipitation measurement by rain gauge) can be equipped with an optional external leaf wetness sensor.

The connection terminals for the leaf wetness sensor are located inside the rain gauge module. The sensor connection cable is put through the cable bushing in the wall of the rain gauge module and connected to the terminals (see Chap. 18.1).

Terminal assignment for Leaf Wetness Sensor WLW100:

| | | |
|---|---|---|
| 1 | blank (shield) | Ground |
| 2 | red | Signal Voltage |
| 3 | white | Sensor Supply Voltage 5V |

### 8.6 Connection of External Temperature and Precipitation Sensors

External sensors are to be connected to pins 5 and 6 of the plug connector, i.e. to the gray and pink wires of the cable delivered with the compact weather station.

The temperature sensors as well as the external rain gauge are unipolar, so any connection sequence can be chosen.

The type of external sensor has to be set using the UMB Config Tool.

For details please refer to Chapter18.

# 9 Commissioning

After the equipment has been installed and connected correctly, the sensor begins autonomously to take measurements. A Windows® PC with serial interface, UMB-Config-Tool software and interface cable (SUB-D 9 pole; jack - socket; 1:1) are required for configuration and test purposes.

Attention must be paid to the following points:

Check for correct equipment operation on site by carrying out a measurement request with the aid of the UMB-Config-Tool (see page 34).

- Configure the local altitude in order to ensure the correct calculation of relative air pressure (see page 30).
- The device must be aligned to the North in order to ensure correct wind measurement (see page 22), or the automatic compass correction must be activated (see page 30).
- In order to get correct compass headings the local declination must be configured (see page 17and 30).
- If several compact weather stations are operated on a UMB network, a unique device ID must be assigned to each device (see page 29).

There is no protective cover to remove on the sensor itself.

# 10 Configuration and Test

Lufft provides Windows® PC software (UMB-Config-Tool) for configuration purposes. The sensor can also be tested and the firmware updated with the aid of this software.

## 10.1 Factory Settings

The compact weather station is delivered with the following settings:

| | |
|---|---|
| Class ID: | 7 (cannot be modified) |
| Device ID: | 1 (gives address 7001h = 28673d) |
| Baud rate: | 19200 |
| RS485 protocol: | Binary |
| Calculation interval: | 10 measurements |
| Local altitude: | 0 m |

**Note:** The device ID must be changed if several compact weather stations are operated on a UMB network, as each device requires a unique ID. It makes sense to start from ID 1 and continue in ascending order.

## 10.2 Configuration with the UMB-Config-Tool

The operation of the UMB-Config-Tool is described in detail in the operating instructions for the Windows® PC software. For this reason only the menus and functions specific to the compact weather station are described here.

### 10.2.1 Sensor Selection

The compact weather station is shown here with sensor selection WSx-UMB (Class ID 7).


Figure 8: Sensor Selection

**Note:** You do require the current version of the UMB-Config-Tool to configure the compact weather station.

**Note:** All other devices which are used in the polling process, e.g. modems, LCOM etc., must be disconnected from the UMB network during configuration.

### 10.2.2 Configuration

After a configuration has been loaded, all relevant settings and values can be adjusted. Depending on the device type, only the settings pertinent to the respective available sensors are relevant.

### 10.2.3 General Settings

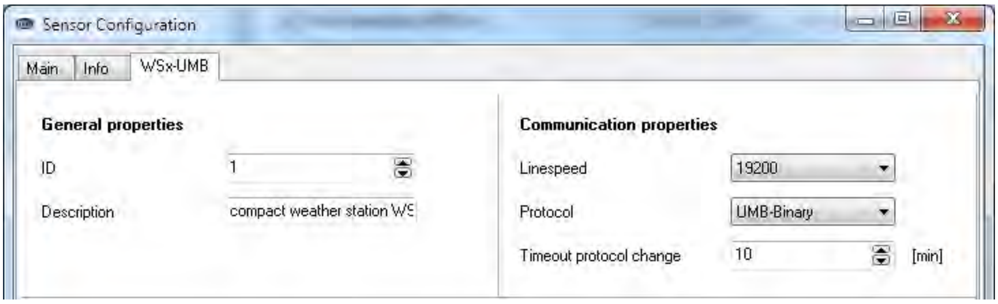



Figure 9: General Settings

ID: Device ID (factory setting 1; assign device IDs to additional devices in ascending order).

Description: In order to differentiate the devices you can enter a description here, e.g. the location.

Linespeed: Transmission speed of the RS485 interface (factory setting 19200; **DO NOT CHANGE for operation with ISOCON-UMB**).

Protocol: Communications protocol of the sensor (UMB-Binary, UMB-ASCII, SDI-12, Modbus-RTU, Modbus-ASCII, Terminal-Mode).

Timeout: In the event of a temporary changeover of the communications protocol, the system switches back to the configured protocol after this time (in minutes)

**Important note:** If the baud rate is changed, after saving the configuration on the sensor, the sensor communicates at the new baud rate. When operating the sensor in a UMB network with ISOCON-UMB, **this baud rate must not be changed**; otherwise the sensor **is no longer addressable** and can no longer be configured.

### 10.2.4 Temperature, Humidity and Fan Settings

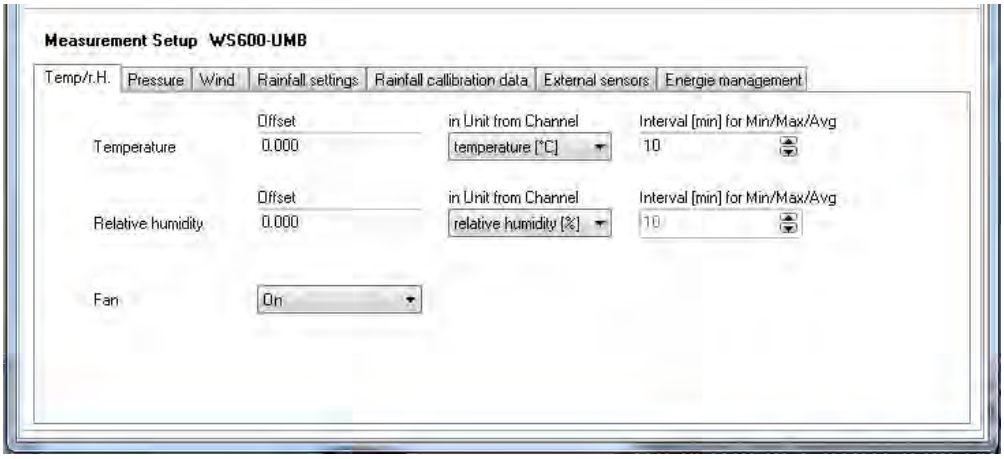



Figure 10: Temperature, Humidity and Fan Settings

Offset: Absolute offset on the measurement in the unit of the accompanying channel (for on-site calibration).

Interval: Time in minutes for the minimum, maximum and average value calculation interval.

Fan: to reduce electrical power consumption, the fan can be switched off. **Note: if the fan is switched off, all heaters will also be switched off! With the fan switched off deviations in temperature and humidity measurement can occur by solar radiation!**

**Note:** In order to calculate dew point, absolute humidity and mixing ratio, the temperature and humidity measurement always requires the same interval. For this reason different intervals cannot be set.

### 10.2.5 Pressure,

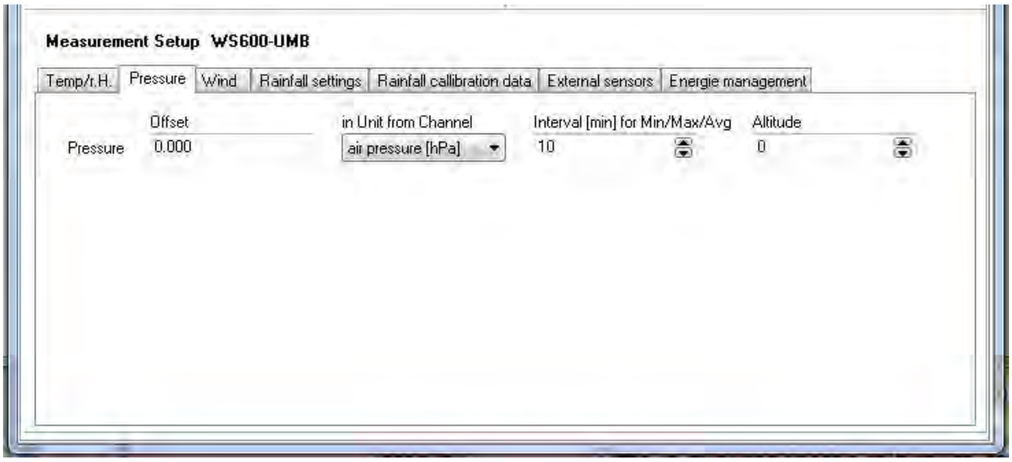



Figure 11: Pressure Settings

Offset: Absolute offset on the measurement in the unit of the accompanying channel.

Interval: Time in minutes for the minimum, maximum and average value calculation interval.

Altitude: Enter the local altitude in meters here for the correct calculation of relative air pressure (referenced to sea level).

### 10.2.6 Wind and Compass Settings

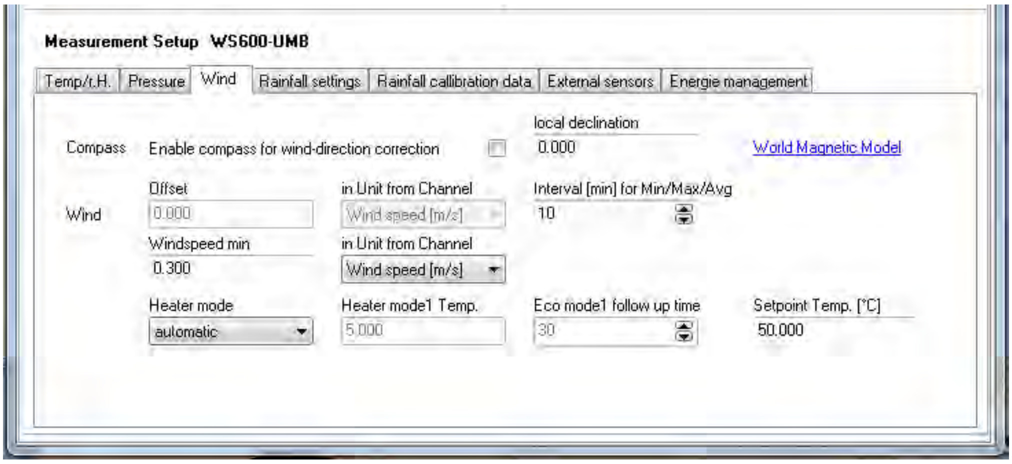



Figure 12: Wind Settings

Offset: Absolute offset on the measurement in the unit of the accompanying channel.

Interval: Time in minutes for the minimum, maximum and average value calculation interval.

Windspeed min: Approach velocity onto the wind meter with effect from which a measurement is transmitted, in the unit of the accompanying channel.

Heater mode: The device can be configured for heating in different operating modes. Configure as ‘automatic’ in normal operating mode. You can find a precise description of the operating modes on page 37.

Local declination: Dependent on the location of the installation; the local declination of the earth magnetic field has to be considered.

Enable Compass for wind-direction correction:
With activated compass correction all wind direction values will be corrected according to the alignment of the sensor, as evaluated by the compass.

**Note:** The offset is not used for the wind meter at present because on-site calibration is not possible in this case.

### 10.2.7 Precipitation Sensor Settings (Radar)

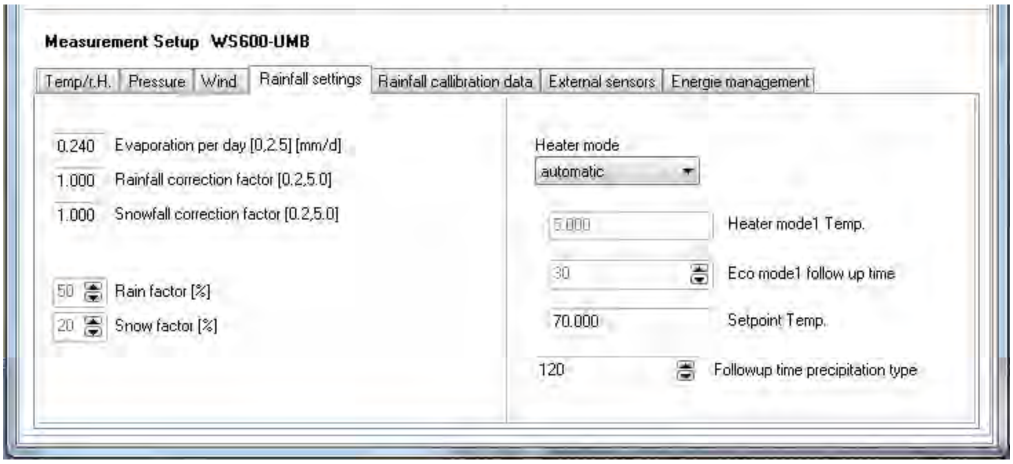



Figure 13: Precipitation Sensor Settings (Radar)

Heater mode: The device can be configured for heating in different operating modes. Configure as 'automatic' in normal operating mode. You can find a precise description of the operating modes on page 37.

Followup time precipitation type: for this time (in seconds) the detected precipitation type is shown; to cover all events, this time must be adjusted to the poll rate.

**Note:** All other parameters, especially those in the 'Rainfall calibration data' tab, may only be changed after consultation with the manufacturer, as they have a major influence on the functioning and accuracy of the sensor.

### 10.2.8 Precipitation Sensor Settings (Rain Gauge)

The rain gauge module can be operated with resolutions 0.2mm or 0.5mm. The setting ofthe resolution is to be done in two steps:

- Mechanical setting
- Configuration setting

The mechanical setting works by modifying the effective area of the funnel. The sensor is delivered with a reduction ring, which can be mounted on the funnel to reduce the area.

| | |
|---|---|
| Funnel with reduction ring | resolution 0.5mm |
| Funnel without reduction ring | resolution 0.2mm |

Then the resolution is set in the sensor configuration using the UMB Config Tool.

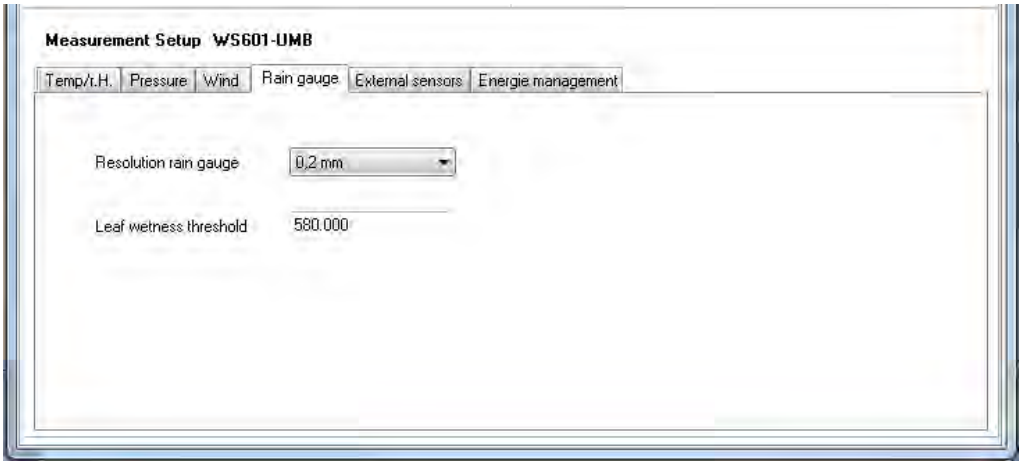



Figure 14: Precipitation Sensor Settings (Rain Gauge)

**Caution:** If mechanical setting and configuration setting do not conform, the sensor will deliver wrong precipitation values!

### 10.2.9 Energy Management

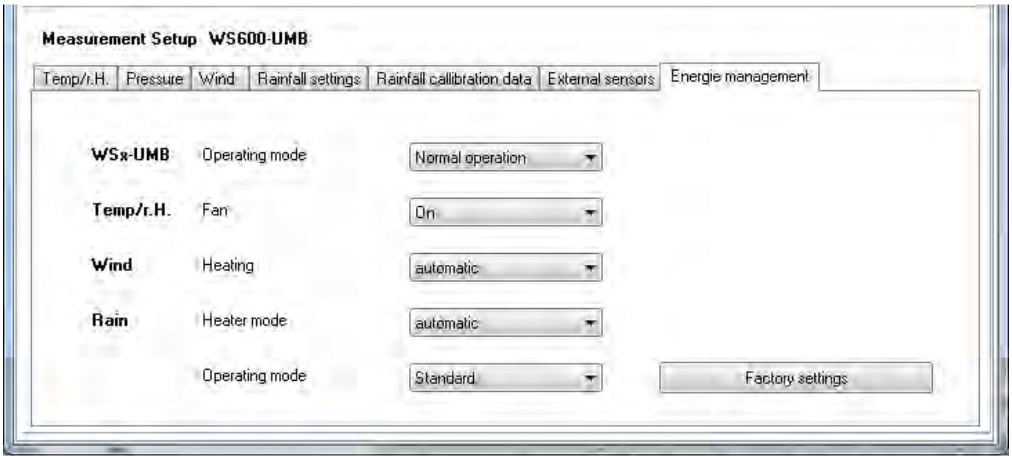



Figure 15: Energy Management Settings

By setting the operating and heating mode, the energy consumption of the weather station can be adapted to the circumstances of the installation.

The different settings are described in the following chapters:

- operating modes of compact weather station from page 35
- operating modes of the heating from page 37

### 10.2.10 Reset Precipitation Quantity

To reset the accumulated absolute precipitation quantity the UMB-Config-Tool offers the following function:

Options →WSx-UMB reset rain

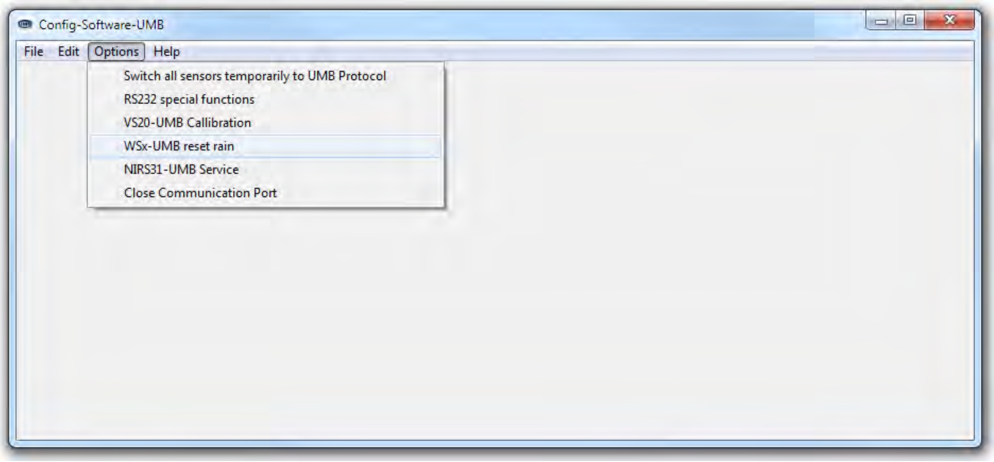
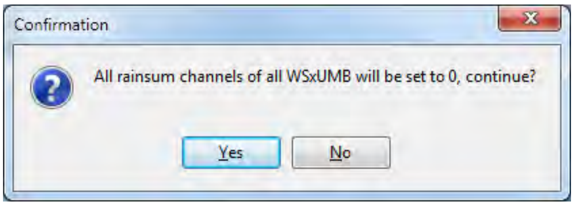



Figure 16: Reset Precipitation Quantity

Confirm the reset with 'Yes'




**Note:** The precipitation quantities are reset in ALL compact weather stations on the respective UMB network. The devices reboots after this function has been used.

### 10.3 Function Test with UMB-Config-Tool

The functions of the compact weather station can be tested with the UMB-Config-Tool by polling various channels.

**Note:** All other devices which are used in the polling process, e.g. modems, LCOM etc., must be disconnected from the UMB network during configuration.

#### 10.3.1 Channels for Measurement Polling

You can select the channel for measurement polling by the UMB-Config-Tool by clicking on the respective channel.

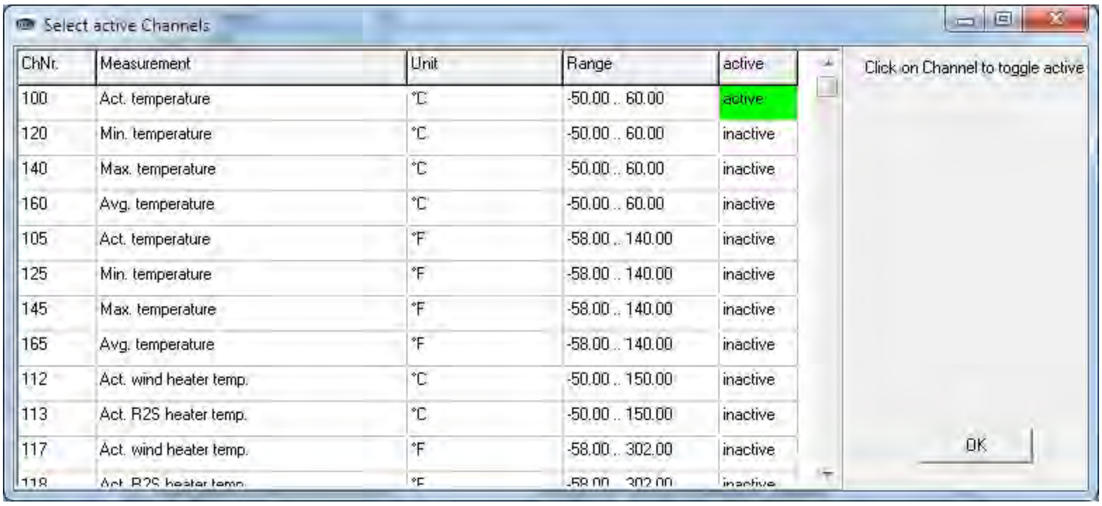



Figure 17 Measurement Polling Channels

#### 10.3.2 Example of Measurement Polling

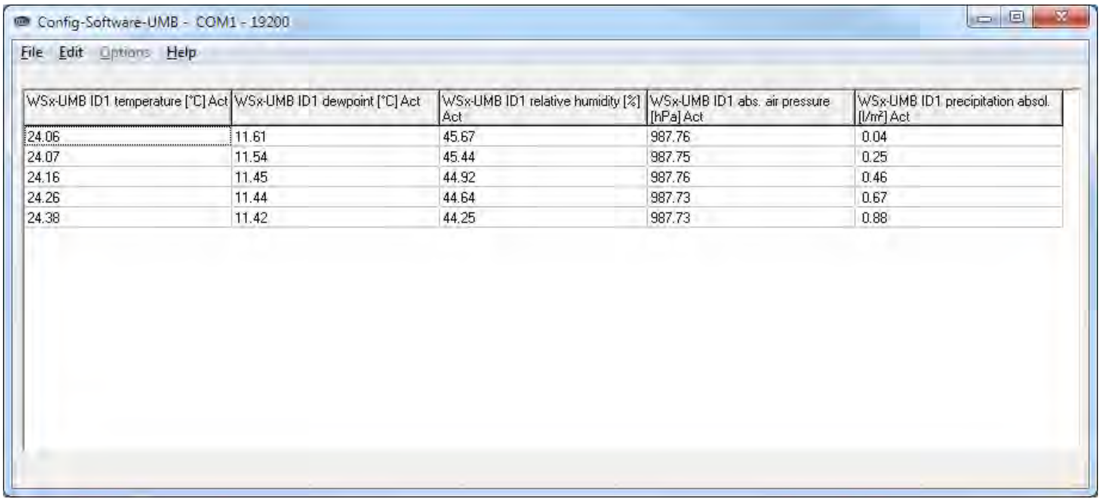



Figure 18 Example of Measurement Polling

**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 reduced to 10% even neglecting the heating. (during precipitation events the consumption is slightly higher, due to the rain sensor then permanently switched on, about 20% compared to normal operation).

### 10.4.2 Power Saving Mode 2

Power saving mode 2 permits another relevant reduction of the power consumption, but adds on the other hand more severe restrictions.

In this operation mode the station will be almost completely switched off and will wake up only by the data request for one measurement cycle. During measurement and data transmission the station will be switched on for about 10 – 15 sec. The total consumption will be mostly determined by the data request interval.

**Note:** This operating mode has following restrictions:

- All restrictions of power saving mode 1
- Power saving mode 2 is not available for devices with radar rain sensor (WS600-UMB, WS400-UMB). We recommend devices with tipping bucket rain gauge for low power applications.
- The calculation of average, minimum and maximum as well as precipitation intensity are not available. Only instantaneous values will be transmitted
- Communication protocol Modbus is not available
- When using the UMB protocol a certain request sequence and timing is required (s. Chap. 19.3.7). The interval length must be at least 15sec to make sure that the measurement and transmission cycle can be completed. Shorter interval could cause the device to stay in transmission state without starting a new measurement.

- The joint operation with other sensor in an UMB network is possible, but it has to be considered, that each telegram (even when addressed to another station) will cause the compact weather station to wake up for at least several seconds, thus increasing the total power consumption. The minimum interval length must be hold up under consideration of the telegrams with other addresses. Mixed operation of devices in power saving mode 2 with station in normal operation and fast request rates within the same UMB network is not possible.

### 10.5 Operating Modes for Equipment Heating

Heating is configured to 'Automatic' when the product is delivered. This is the recommended operating mode for heating the sensor.

You can set the following operating modes:

| Heater Mode | WS200-UMB | WS400-UMB | WS500-UMB | WS501-UMB *) | WS600-UMB | WS601-UMB |
|---|---|---|---|---|---|---|
| Automatic | ● | ● | ● | ● | ● | ● |
| Off | ● | ● | ● | ● | ● | ● |
| Mode 1 | | ● | ● | ● | ● | ● |
| Eco-Mode 1 | | ● | | | ● | |

*) is also valid for WS502-UMB, WS503-UMB, WS504-UMB

**Note:** Model WS30x-UMB and WS401-UMB are not heated.

The rain sensor and wind meter settings must be adjusted in the respective configuration mask. The examples show the wind meter setting.

#### 10.5.1 Automatic

In this operating mode, the sensor is maintained constantly at the control temperature, generally in order to prevent the effects of snow and ice.

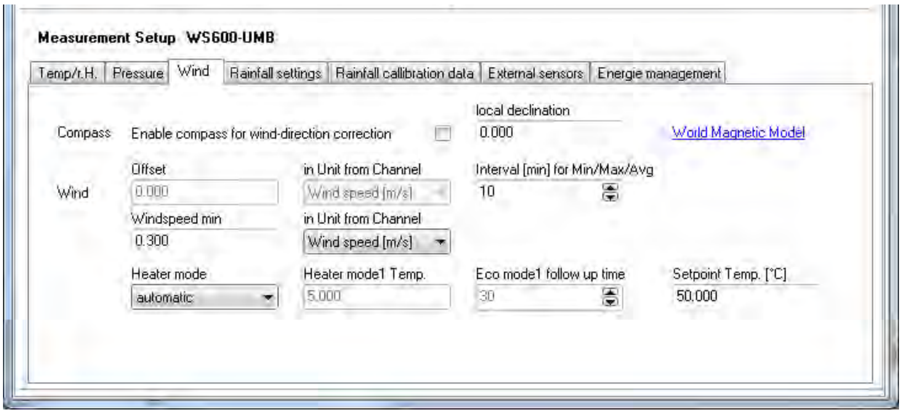



Figure 19: Operating Modes for Equipment Heating

Setpoint Temp.: The heating controls at this temperature (in °C)

The settings for the other values are not relevant.

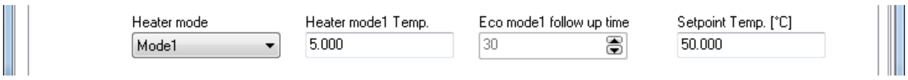
#### 10.5.2 Off

In the 'Off' operating mode heating is completely disabled. Winter operation is not possible in this operating mode because any icing might prevent the correct operation of the rain sensor or wind meter.


The value settings are not relevant.

#### 10.5.3 Mode 1

In 'Mode 1' operating mode heating is only enabled when the outside temperature falls below the HeatingMode1 temperature (in °C). In this mode power consumption can be reduced in frost-free situations with no great restriction on winter operation.




Setpoint Temp.: The heating controls at this temperature (in °C)

Heating mode1 Temp.: Threshold temperature (in °C) with effect from which air temperature heating is enabled

The 'Eco Mode1 follow-up time' setting is not relevant.

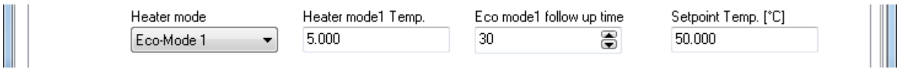
### 10.5.4 Eco-Mode 1

Eco Mode1 is an advanced energy saving mode.

Heating is only switched on when the following conditions are met:

- The outside temperature is below the threshold temperature and precipitation was detected. Heating then runs at the control temperature for 30 minutes (after the last precipitation event).
- When the outside temperature lies constantly below the threshold temperature and there was no heating for more than 20h, heating is switched on for 30 minutes as a precautionary measure in order to thaw any icing.

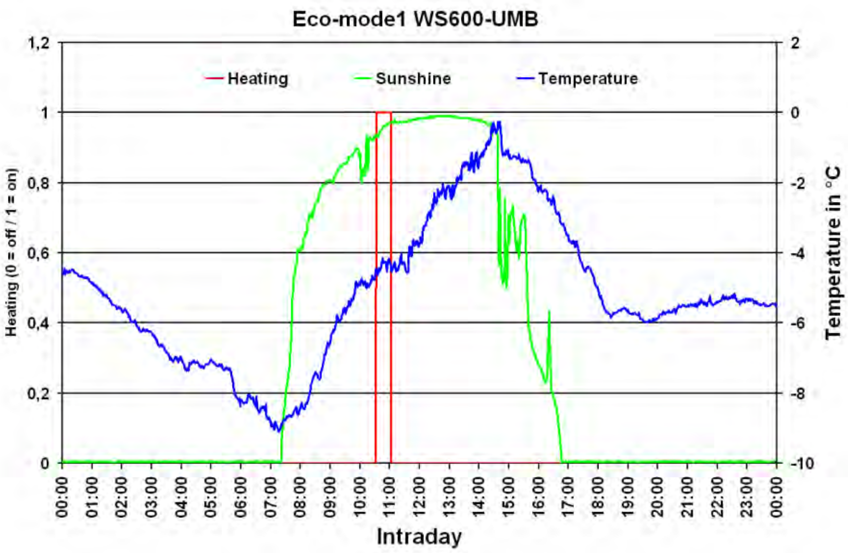
However, the precautionary 20h-heating only runs if the outside temperature was measured at below the threshold temperature for the entire period and conditions were constantly bright for at least 3 hours.



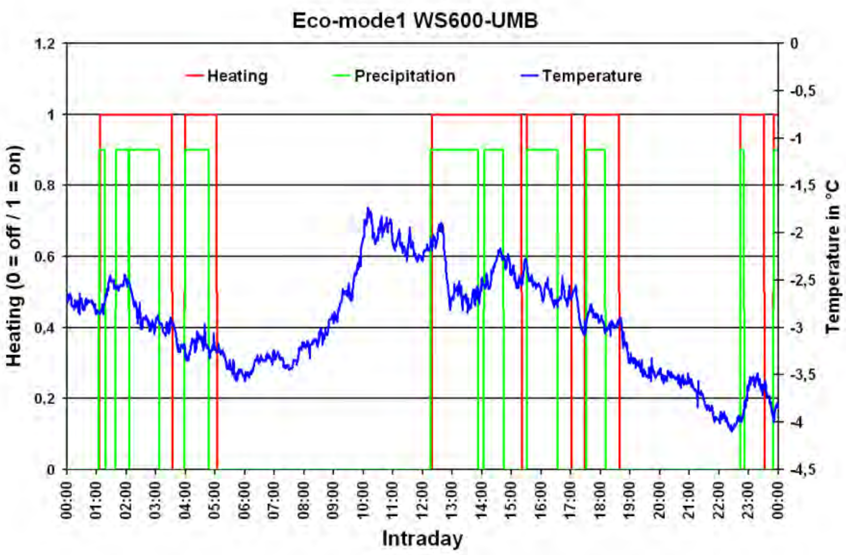

| | |
|---|---|
| Setpoint Temp.: | The heating controls at this temperature (in °C) |
| Heating mode1 Temp.: | Threshold temperature (in °C) with effect from which heating is enabled |
| Eco mode1 follow-up time: | Follow-up time (in minutes) |

**Examples:**

Outside temperature constantly below 5°C; no precipitation for more than 24h




Outside temperature constantly below 5°C; with precipitation

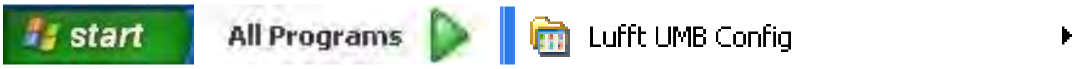


## 11 Firmware Update

To keep the sensor in accordance with the latest state-of-the-art, it is possible to carry out a firmware update on site with no need to remove the sensor and return it to the manufacturer.

The firmware update is carried out with the aid of the UMB-Config-Tool.

The description of the firmware update can be found in the instructions for the UMB-Config-Tool. Please download the latest firmware and UMB-Config-Tool from our website www.lufft.com and install it on a Windows® PC. You can find the instructions here:




**Note:** When a firmware update takes place, under certain circumstances the absolute precipitation quantities are reset (channel 600 – 660).

There is one firmware for the entire product family which supports all models (WSx_Release_Vxx.mot).

**Important Note: please read the included text file in WSx_Release_Vxx.zip; it contains important information about the update!**

## 12 Maintenance

In principle the equipment is maintenance-free.

However, it is recommended to carry out a functional test on an annual basis. When doing so, pay attention to the following points:

- Visual inspection of the equipment for soiling
- Check the sensors by carrying out a measurement request
- Check the operation of the fan (not on WS200-UMB)

In addition, an annual calibration check by the manufacturer is recommended for the humidity sensor (not on WS200-UMB). It is not possible to remove or replace the humidity sensor. The complete compact weather station must be sent to the manufacturer for testing.

Cleaning of the glass dome at regular intervals is suggested for devices with global radiation measurement. The length of the interval should be adapted to the local degree of pollution.

Devices with precipitation measurement by rain gauge (WS401-UMB, WS601-UMB): The rain gauge funnel needs to be cleaned at regular intervals (see below). The length of the interval should be adapted to the local degree of pollution.

Devices with leaf wetness sensor: Cleaning of the leaf wetness sensor at regular intervals is suggested. The length of the interval should be adapted to the local degree of pollution. A check and, if necessary, adjustment of the “Wet” threshold is recommended to include into the maintenance procedure.

### 12.1 Maintenance of the Rain Gauge

The function of the rain gauge will be significantly influenced by pollution of the funnel or the tipping bucket mechanism. Regular check and, if necessary, cleaning is required. The maintenance interval depends very much on local conditions and also on seasons (leaves, pollen, etc.) and therefore cannot be exactly defined here (it may be in the range of weeks).

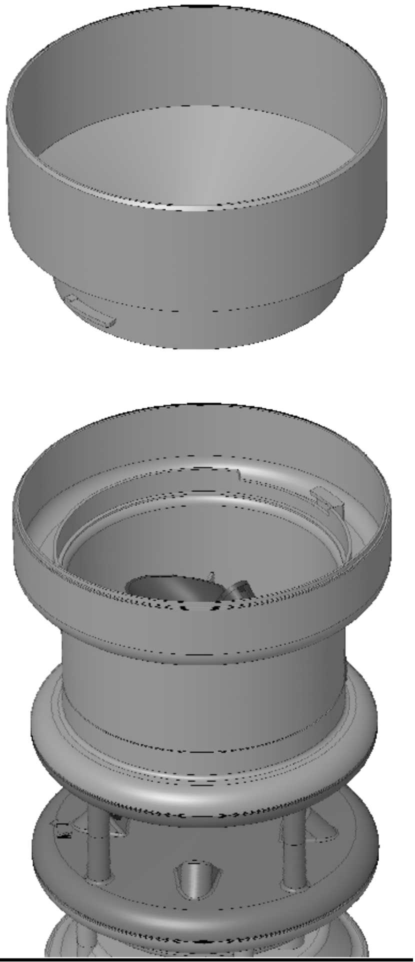


Figure 20: WS601-UMB with removed funnel

- Only clean when obviously polluted
- Avoid moving the tipping mechanism (otherwise wrong counts will occur)
- Use water, soft cloth and / or a soft brush for cleaning
- Unlock funnel by turning it to the left and lift it off
- Clean funnel, specially the sieve slots
- Check the inside of the rain gauge module for pollution, especially for spider webs and insects, if necessary, clean it
- Check tipping bucket for pollution, if necessary wash carefully with clean water. Caution: each movement of the bucket generates a counting pulse and thus may cause faulty precipitation amounts
- Check water drain, clean if necessary
- Put funnel back in place and lock it by turning it to the right

# 13 Technical Data

Power supply: 24VDC +/- 10%
12VDC with restrictions (see page 25)

Current consumption - sensor:

| Mode[1] | Standard | | Power Saving Mode 1 | | Power Saving Mode 2 | |
|---|---|---|---|---|---|---|
| **Supply** | **24VDC[2]** | **12VDC** | **24VDC** | **12VDC** | **24VDC** | **12VDC** |
| WS200-UMB | 16 mA | 25 mA | 15 mA | 24 mA | 4 mA | 2 mA |
| WS300-UMB | 135 mA | 70 mA | 7 mA | 7 mA | 4 mA | 2 mA |
| WS301-UMB<br>WS302-UMB<br>WS303-UMB<br>WS304-UMB | 135 mA | 70 mA | 8 mA | 8 mA | 4 mA | 2 mA |
| WS400-UMB | 160 mA | 110 mA | 7 mA | 7 mA | -- | -- |
| WS401-UMB | 130 mA | 65 mA | 6 mA | 6 mA | 4 mA | 2 mA |
| WS500-UMB | 140 mA | 80 mA | 16 mA | 25 mA | 4 mA | 2 mA |
| WS501-UMB<br>WS502-UMB<br>WS503-UMB<br>WS504-UMB | 145 mA | 85 mA | 16 mA | 25 mA | 4 mA | 2 mA |
| WS600-UMB | 160 mA | 130 mA | 16 mA | 25 mA | -- | -- |
| WS601-UMB | 140 mA | 85 mA | 15 mA | 24 mA | 4 mA | 2 mA |

Current consumption and power input - heating:

| | |
|---|---|
| WS200-UMB | 833 mA / 20VA at 24VDC |
| WS400-UMB | 833 mA / 20VA at 24VDC |
| WS500-UMB, WS501-UMB, WS502-UMB<br>WS503-UMB, WS504-UMB | 833 mA / 20VA at 24VDC |
| WS600-UMB | 1,7 A / 40VA at 24VDC |
| WS601-UMB | 833mA / 20VA at 24VDC |

Dimensions including mounting bracket:

| | |
|---|---|
| WS200-UMB | Ø 150mm, height 194mm |
| WS300-UMB | Ø 150mm, height 223mm |
| WS301-UMB | Ø 150mm, height 268mm |
| WS302-UMB | Ø 150mm, height 253mm |
| WS303-UMB | Ø 150mm, height 328mm |
| WS304-UMB | Ø 150mm, height 313mm |
| WS400-UMB | Ø 150mm, height 279mm |
| WS401-UMB | Ø 164mm, height 380mm |
| WS500-UMB | Ø 150mm, height 287mm |
| WS501-UMB | Ø 150mm, height 332mm |
| WS502-UMB | Ø 150mm, height 377mm |
| WS503-UMB | Ø 150mm, height 392mm |
| WS504-UMB | Ø 150mm, height 317mm |
| WS600-UMB | Ø 150mm, height 343mm |
| WS601-UMB | Ø 164mm, height 445mm |

Weight including mounting bracket, excluding connection cable:

| | |
|---|---|
| WS200-UMB | ca. 0.8 kg |
| WS300-UMB | ca. 1.0 kg |
| WS400-UMB, WS301-UMB, WS302-UMB,<br>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,<br>WS503-UMB, WS504-UMB | ca. 1.5 kg |
| WS601-UMB | ca. 1.7 kg |

[1] Description of operating modes, see page 35
[2] Factory default, recommended setting

| | |
|---|---|
| Fastening: | Stainless steel mast bracket for Ø 60 - 76mm |

| | |
|---|---|
| Protection class: | III (SELV) |
| Protection type: | IP66 |

Storage Conditions

| | |
|---|---|
| Permissible storage temperature: | -50°C ... +70°C |
| Permissible relative humidity: | 0 ... 100% RH |

Operating Conditions

| | |
|---|---|
| Permissible operating temperature: | -50°C ... +60°C |
| Permissible relative humidity: | 0 ... 100% RH |
| Permissible altitude above sea level: | N/A |

RS485 interface, 2 wire, half-duplex

| | | |
|---|---|---|
| Data bits: | 8 | (SDI-12 mode: 7) |
| Stop bit: | 1 | |
| Parity: | No | (SDI-12 mode: even, Modbus mode none or even) |
| Tri-state: | 2 bits after stop bit edge | |
| Adjustable baud rates: | 1200, 2400, 4800, 9600, 14400, 19200[3], 28800, 57600 | |

(In SDI-12 mode, the interface is changed to meet the requirements of the standard.)

| | |
|---|---|
| Housing: | Plastic (PC) |

[3]Factory setting; baud rate for operation with ISOCON-UMB and firmware update.

## 13.1 Measuring Range / Accuracy

### 13.1.1 Air temperature

| | |
|---|---|
| Measurement process: | NTC |
| Measuring range: | -50°C ... +60°C |
| Resolution: | 0.1°C (-20°C...+50°C), otherwise 0.2°C |
| Sensor accuracy: | +/- 0.2°C (-20°C ... +50°C), otherwise +/-0.5°C (>-30°C) |
| Sampling rate: | 1 minute |
| Units: | °C; °F |

### 13.1.2 Humidity

| | |
|---|---|
| Measurement process: | Capacitive |
| Measuring range: | 0 ... 100% RH |
| Resolution: | 0.1% RH |
| Accuracy: | +/- 2% RH |
| Sampling rate: | 1 minute |
| Units: | % RH; g/m³; g/kg |

### 13.1.3 Dewpoint Temperature

| | |
|---|---|
| Measurement process: | Passive, calculated from temperature and humidity |
| Measuring range: | -50°C ... +60°C |
| Resolution: | 0.1°C |
| Accuracy: | Computed +/- 0.7°C |
| Units: | °C; °F |

### 13.1.4 Air Pressure

| | |
|---|---|
| Measurement process: | MEMS sensor - capacitive |
| Measuring range: | 300 ... 1200hPa |
| Resolution: | 0.1hPa |
| Accuracy: | +/- 0.5hPa (0 … +40°C) |
| Sampling rate: | 1 minute |
| Unit: | hPa |

### 13.1.5 Wind Speed

| | |
|---|---|
| Measurement process: | Ultrasonic |
| Measuring range: | 0 … 75m/s (WS601-UMB: 0 … 30m/s) |
| Resolution: | 0.1m/s |
| Accuracy: | ±0.3 m/s or ±3% (0...35 m/s)<br>±5% (>35m/s) RMS |
| Response threshold: | 0.3 m/s |
| Sampling rate: | 10 seconds / 1 second with restrictions |
| Units: | m/s; km/h; mph; kts |

### 13.1.6 Wind Direction

| | |
|---|---|
| Measurement process: | Ultrasonic |
| Measuring range: | 0 – 359.9° |
| Resolution: | 0.1° |
| Accuracy: | < 3° (> 1m/s) RMSE |
| Response threshold: | 0.3 m/s |
| Sampling rate: | 10 seconds / 1 second with restrictions |

### 13.1.7 Precipitation

#### 13.1.7.1 WS400-UMB / WS600-UMB

| | |
|---|---|
| Measurement process: | Radar sensor |
| Measuring range (drop size): | 0.3 mm ... 5.0 mm |
| Liquid precipitation resolution: | 0.01 mm |
| Precipitation types: | Rain, snow |
| Repeatability: | Typically > 90% |
| Response threshold: | 0.01 mm |
| Sampling rate: | Event-dependent on reaching response threshold |
| Precipitation intensity: | 0 … 200 mm/h; Sampling rate 1 minute |

#### 13.1.7.2 WS401-UMB / WS601-UMB

| | |
|---|---|
| Measurement process: | Rain Gauge |
| Liquid precipitation resolution: | 0.2 mm / 0.5mm (adjustable by reduction ring) |
| Precipitation types: | Rain |
| Accuracy: | 2% |
| Sampling rate: | 1 minute |

### 13.1.8 Compass

| | |
|---|---|
| Measurement process: | Integrated electronic compass |
| Measurement range: | 0 ... 359° |
| Resolution: | 1.0° |
| Accuracy: | +/- 10° |
| Sampling rate: | 5 minutes |

### 13.1.9 Global Radiation

| | |
|---|---|
| Measurement Process | Thermopile pyranometer |
| Measurement Range | 0.0 ... 1400.0 W/m² |
| Resolution | < 1W/m² |
| Sampling Rate | 1 minute |

#### 13.1.9.1 WS301-UMB / WS501-UMB

| | |
|---|---|
| Response time (95%) | 18s |
| Non-stability(change/year) | <1% |
| Non-linearity (0 to 1000 W/m²) | <1% |
| Directional error (at 80° with 1000 W/m²) | <20 W/m² |
| Temperature dependence of sensitivity | <5% (-10 to +40°C) |
| Tilt error (at 1000 W/m²) | <1% |
| Spectral range (50% points) | 300 ... 2800nm |

#### 13.1.9.2 WS302-UMB / WS502-UMB

| | |
|---|---|
| Response time (95%) | <1s |
| Spectral range (50% points) | 300 ... 1100nm |

### 13.1.10 Leaf Wetness WLW100

| | |
|---|---|
| Measurement process: | capacitive |
| Measuring range: | 0 ... 1500 mV |
| Sampling rate: | 1 minute |

### 13.1.11 External Temperature SensorWT1 / WST1

| | |
|---|---|
| Measurement process: | NTC |
| Measuring range: | -40°C ... +80°C |
| Resolution: | 0.25°C |
| Sensor accuracy: | +/- 1°C (WST1: +/-0.3°C between -10°C ...+10°C) |
| Sampling rate: | 1 minute |
| Units: | °C; °F |

### 13.1.12 External Rain GaugeWTB100

| | |
|---|---|
| Measurement process: | Rain Gauge with bounce-free reed contact (normally closed) |
| Liquid precipitation resolution: | 0.2 mm / 0.5mm (adjustable by reduction ring) |
| Precipitation types: | Rain |
| Accuracy: | 2% |
| Sampling rate: | 1 minute |

In principle, all rain sensors with bounce-free reed contact (normally open or normally closed) and with a resolution of 0.1 mm, 0.2 mm, 0.5 mm or 1.0 mm can be used.

### 13.2 Drawings

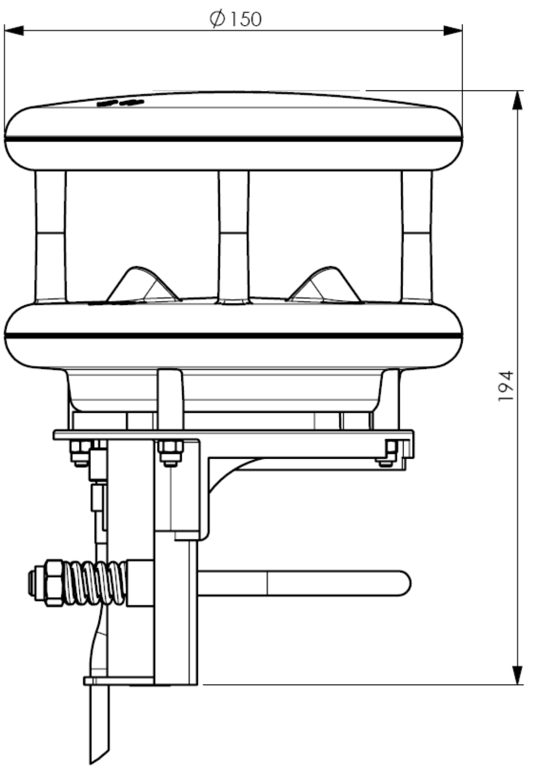



Figure 21: WS200-UMB

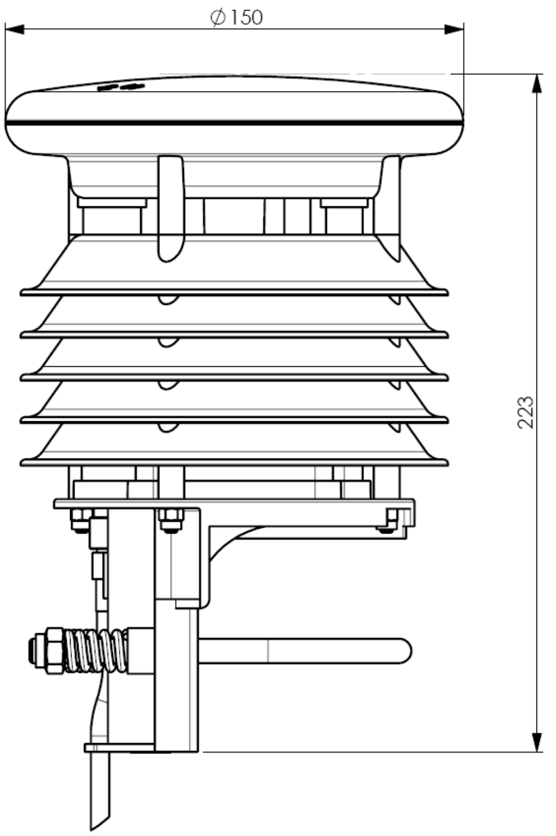



Figure 22: WS300-UMB

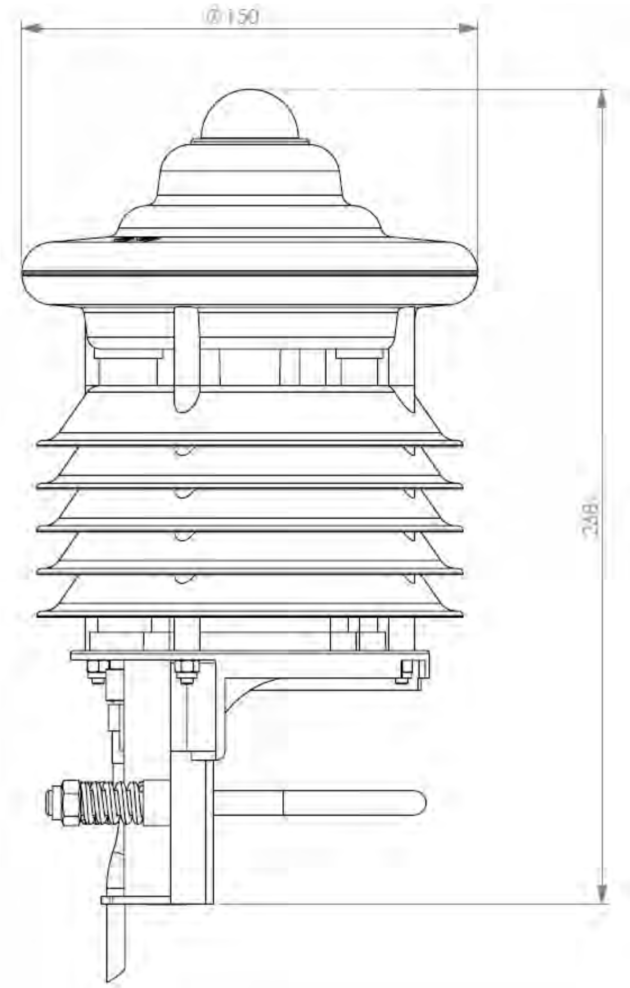



Figure 23: WS301-UMB

WS302-UMB, WS303-UMB und WS304-UMB are similar.

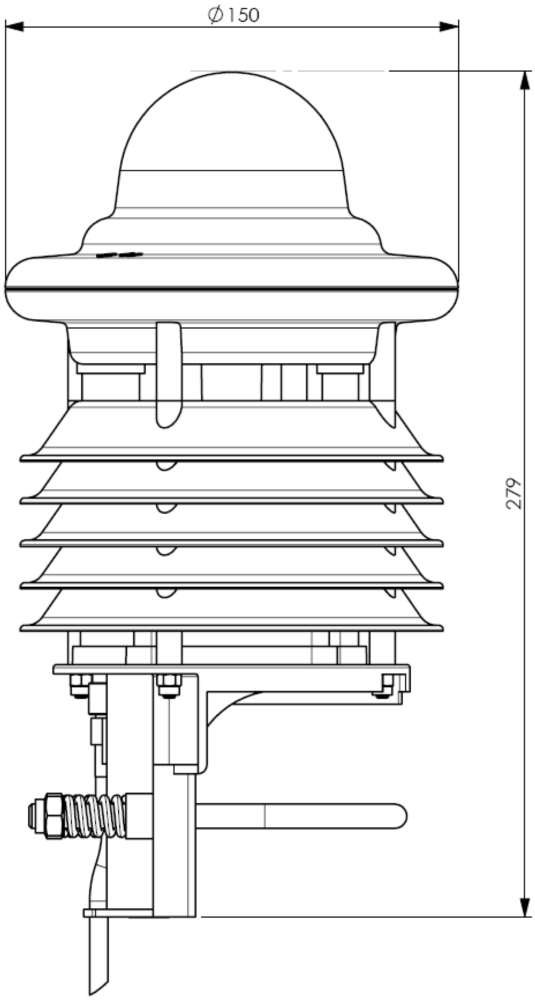



Figure 24: WS400-UMB

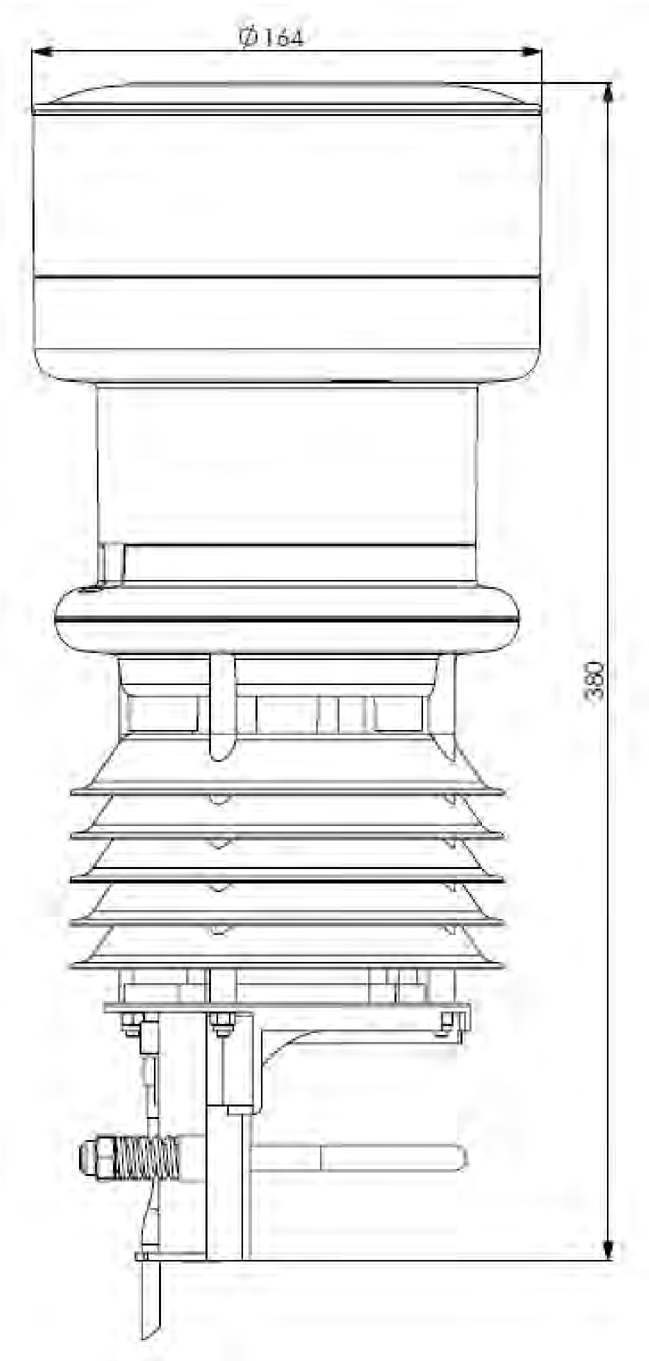



Figure 25: WS401-UMB

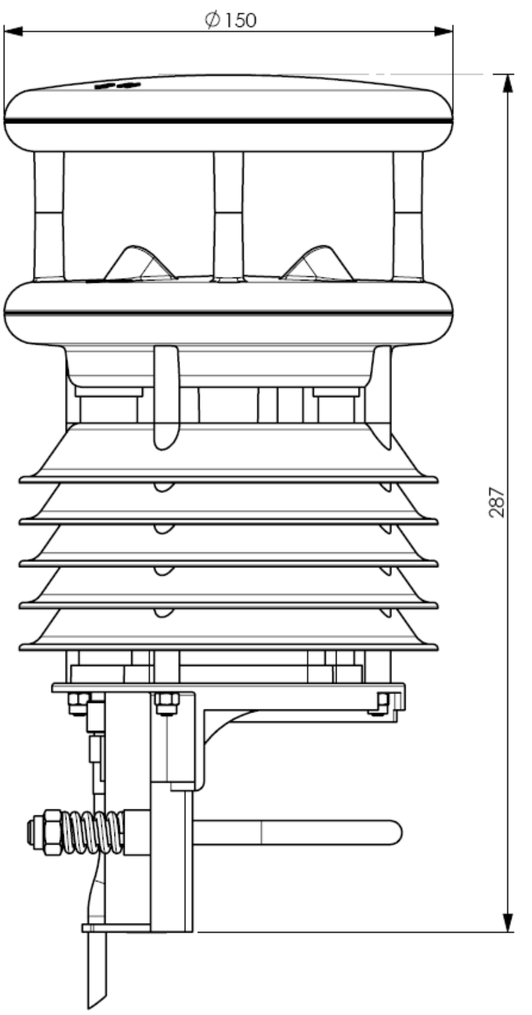



Figure 26: WS500-UMB

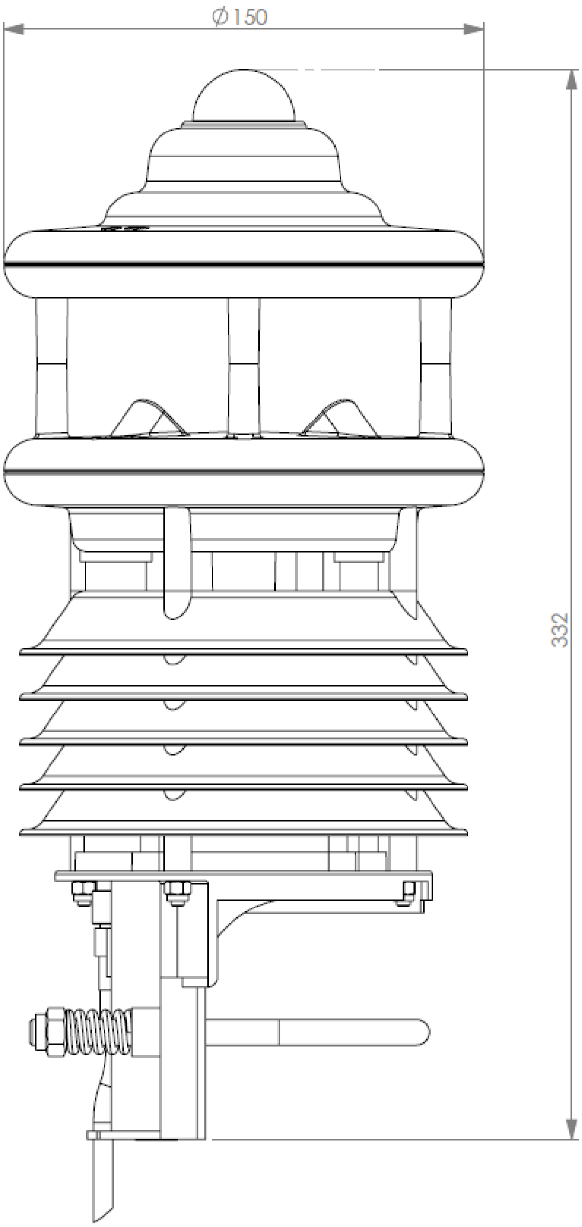



Figure 27: WS501-UMB

WS502-UMB, WS503-UMB und WS504-UMB are similar.

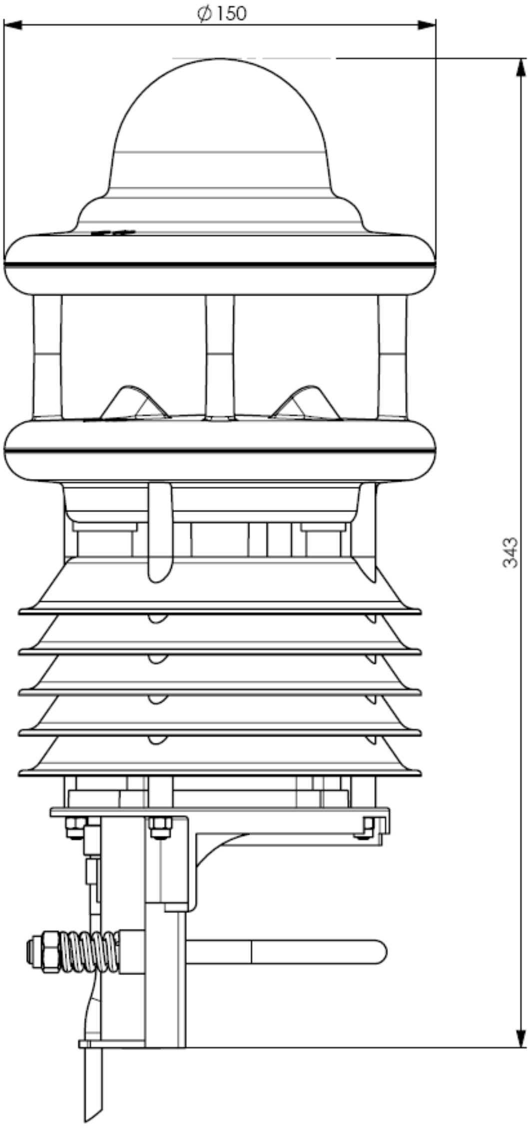



Figure 28: WS600-UMB

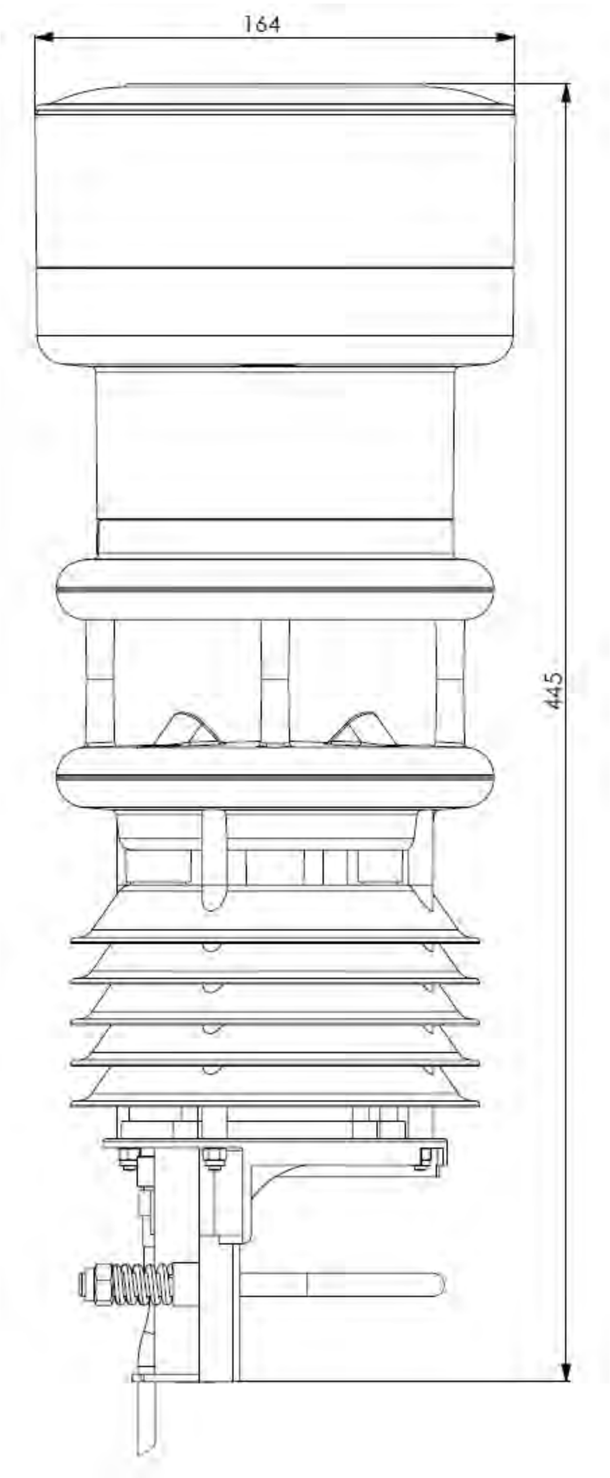



Figure 29: WS601-UMB

# 14 EC Certificate of Conformity

| | |
|---|---|
| **Product:** | **Compact Weather Station** |
| **Type:** | **WS200-UMB (Order No.: 8371.U01)** |
| | **WS300-UMB (Order No.: 8372.U01)** |
| | **WS301-UMB (Order No.: 8374.U01)** |
| | **WS302-UMB (Order No.: 8374.U10)** |
| | **WS303-UMB (Order No.: 8374.U11)** |
| | **WS304-UMB (Order No.: 8374.U12)** |
| | **WS400-UMB (Order No.: 8369.U01 / 8369.U02)** |
| | **WS401-UMB (Order No.: 8377.U01)** |
| | **WS500-UMB (Order No.: 8373.U01)** |
| | **WS501-UMB (Order No.: 8375.U01)** |
| | **WS502-UMB (Order No.: 8375.U10)** |
| | **WS503-UMB (Order No.: 8375.U11)** |
| | **WS504-UMB (Order No.: 8375.U12)** |
| | **WS600-UMB (Order No.: 8370.U01 / 8370.U02)** |
| | **WS601-UMB (Order No.: 8376.U01)** |

We herewith certify that the above mentioned equipment complies in design and construction with the Directives of the European Union and specifically the EMC Directive in accordance with 2004/108/EC and the RoHSDirective 2011/65/EU.

The above mentioned equipment conforms to the following specific EMC Standards:

<u>EN 61000-6-2:2005Part 6-2: Generic Standards - Immunity for Industrial Environments</u>

| | |
|---|---|
| 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 |

<u>EN 61000-6-3:2007Part 6-4: Generic Standards - Emission Standard for Industrial Environments</u>

| | |
|---|---|
| EN 55011:2009 + A1:2010 (2011) | Line-conducted disturbances |
| IEC / CISPR 11:2009 and changes 1:2010 Class B | |
| prEN 50147-3:2000 | Radiated emission |

Fellbach, 02.03.2012 Axel Schmitz-Hübsch

# 15 Fault Description

| Error description | Cause - Remedy |
|---|---|
| Device does not allow polling / does not respond | - Check power supply<br>- Check interface connection<br>- Incorrect device ID → check ID; devices are delivered with ID 1. |
| The device measures precipitation but it is not raining | Check that the sensor was installed correctly in accordance with the instructions. |
| The measured temperature appears too high / measured humidity appears too low | Check the operation of the fan on the underside of the device. |
| Wind direction values are incorrect | Device is not correctly aligned → check that the device is aligned to the North. |
| Device transmits error value 24h (36d) | A channel is being polled that is not available on this device type; e.g. Channel 200 = humidity is being polled on a WS200-UMB. |
| Device transmits error value 28h (40d) | The device is in the initialization phase following startup→ the device delivers measurements after approx. 10 seconds. |
| Device transmits error value 50h (80d) | The device is being operated above the limit of the specified measuring range. |
| Device transmits error value 51h (81d) | The device is being operated below the limit of the specified measuring range. |
| Device transmits error value 55h (85d) during wind measurement | The device is unable to execute a valid measurement due to the ambient conditions.<br>This may be due to the following reasons:<br>- The device is being operated well above the limit of the specified measuring range<br>- Very strong horizontal rain or snow<br>- The wind meter sensors are very dirty → clean sensor<br>- The wind meter sensors are iced over → check heating mode in the configuration and check heating function / connection<br>- There are foreign objects within the measuring section of the wind meter<br>- One of the wind meter's sensors is faulty → return device to manufacturer for repair |
| The quality of the wind measurement is not always100% | In normal operation the device should always transmit 90 – 100%. Values up to 50% do not represent a general problem.<br>When the error value 55h (85d) is transmitted this value is 0%.<br>If the device permanently transmits values below 50% this may mean that there is a fault. |
| Device transmits an error value not listed here | This may be due to a number of reasons → contact the manufacturer's technical support department. |

# 16 Disposal

## 16.1 Within the EC

The device must be disposed of in accordance with European Directives 2002/96/EC and 2003/108/EC (waste electrical and electronic equipment). Waste equipment must not be disposed of as household waste! For environmentally sound recycling and the disposal of your waste equipment please contact a certified electronic waste disposal company.

## 16.2 Outside the EC

Please comply with the applicable regulations for the proper disposal of waste electrical and electronic equipment in your respective country.

# 17 Repair / Corrective Maintenance

Please arrange for any faulty equipment to be checked and, if necessary, repaired by the manufacturer exclusively. Do not open the equipment and do not under any circumstances attempt to carry out your own repairs.

In matters of guarantee or repair please contact:

**G. Lufft Mess- und Regeltechnik GmbH**

Gutenbergstraße 20
70736 Fellbach

P.O. Box 4252
70719 Fellbach

Germany

Phone: +49 711 51822-0
Hotline: +49 711 51822-52
Fax: +49 711 51822-41

E-mail: info@lufft.de

or your local distributor.

## 17.1 Technical Support

Our Hotline is available for technical questions via the following e-mail address:

hotline@lufft.de

You can also consult frequently asked questions at http://www.lufft.com/ (menu header: SUPPORT / FAQs).

# 18 External Sensors

## 18.1 Leaf Wetness Sensor WLW100

### 18.1.1 Connection of the Leaf Wetness Sensor

The optional leaf wetness sensor is connected inside the rain gauge module. The cable should not be shortened and be connected with the cable shoes as delivered to avoid contact corrosion.

- Unlock funnel by turning it left and lift it off
- Insert cable (A)
- Connect wires with cable shoes (B)
  Blank 1
  Red 2
  White 3
- Check that the tipping bucket is free to move; if necessary pull the cable back to the appropriate length
- Put funnel back in place and lock it by turning it to the right


Figure 30: Connection of the Leaf Wetness Sensor

### 18.1.2 Setting the Leaf Wetness Threshold

The leaf wetness sensor will, depending on the degree of wetness on the surface of the sensor leaf, output a voltage between ca. 500mV and 1200mV (UMB-Channel 710). The state wet / dry (UMB- Channel 711) is evaluated from this voltage using an adjustable threshold.

The threshold is pre-set to 580mV (factory setting). It should be checked after installation and, if necessary, adjusted.

Use the UMB Config Tool to measure channel 710 and collect values of the dry sensor for about 10min (see chapter 10.3 Function Test with UMB Config Tool).

The dry leaf value measured should be constant over the measurement interval. We re recommend to set the threshold about 20mV higher than the dry leaf voltage:

Example: measured (dry leaf): 577mV threshold setting**597mV**

The threshold value thus evaluated is set into the configuration using the UMB Config Tool.

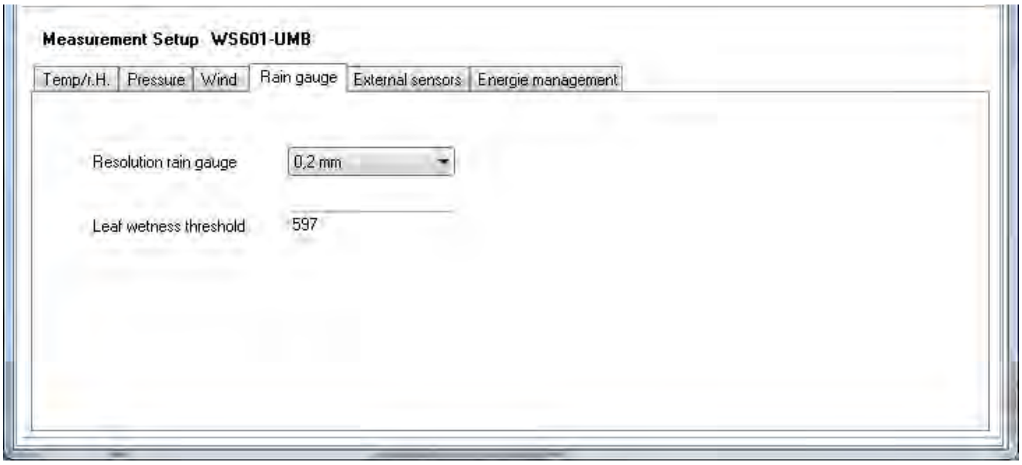



Figure 31: Setting the Leaf Wetness Threshold

**Note:** We recommend to check the threshold during maintenance and to adjust it if necessary. For the dry leaf measurement the sensor should be cleaned with clear water and carefully dried.

## 18.2 External Temperature and Precipitation Sensors

### 18.2.1 Connection of Temperature and Precipitation Sensors

Additional external sensor can cover the requirements of special measurement requirements or extend the functionality of compact weather stations.

Currently the accessory list includes external temperature sensors and the precipitation detection by tipping bucket rain gauge.

One input is available for this extension, so alternatively one temperature sensor or one precipitation sensor may be used.

The connection uses the standard connector plug of the weather station, so normally the external device will be connected at the end of the cable included with the delivery, in the control cabinet. As this cable is part of the measuring line care shall be taken when designing the cabling to avoid parasitic coupling etc. The cable should be as short as possible. In special cases, e.g. when the external sensor is mounted near to the compact weather station while the control cabinet is distant, the installation of an additional distribution box should be considered.

The external sensor is connected to pins 5 and 6 of the connector plug, i.e. the grey and pink wires of the standard cable.

All currently available sensors are unipolar, so the connection sequence is not relevant.

The weather station must be configured for the selected type of external sensor (temperature or precipitation) to enable the correct evaluation of the measurement data. The selection of the sensor type is done through the UMB Config Tool.

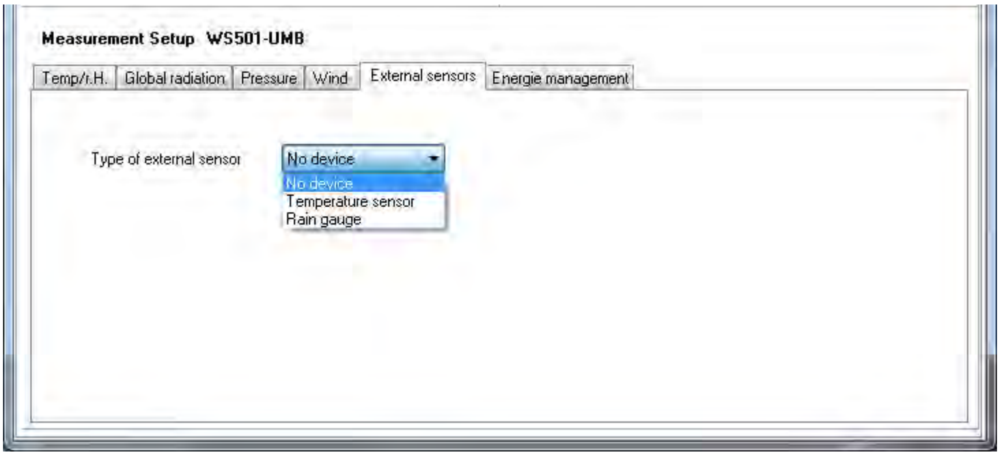



Figure 32: Setting type of external sensor

If the data from the channels of the sensor type currently not selected are requested, the station will respond with “invalid channel”.

### 18.2.2 External Temperature Sensor

All models of the WS family can be used with an external temperature sensor.

For different application various types of NTC sensor are in supply:

- WT1 for temperature acquisition of devices and surfaces
- WST1 for mounting in the road surface (road surface temperature)

Mounting / installation of the temperature sensors is shown in the sensor manual.

### 18.2.3 External Rain Gauge

All models of the WS family without integrated precipitation detection can be used with an external rain gauge. Models WS400-UMB, WS600-UMB, WS401-UMB, WS601-UMB with R2S sensor resp. integrated tipping bucket **cannot** be equipped with an external rain gauge.

The measurement values of the external rain gauge are on the same channels as the data of the internal precipitation sensors of WS400-UMB, WS600-UMB, WS401-UMB, and WS601-UMB.

The external rain gauge WTB100 uses the same technology as the integrated rain gauge of models WS401-UMB and WS601-UMB.

The resolution of the rain gauge WTB100can be modified by the reduction ring delivered with the sensor from 0.2mm to 0.5mm.

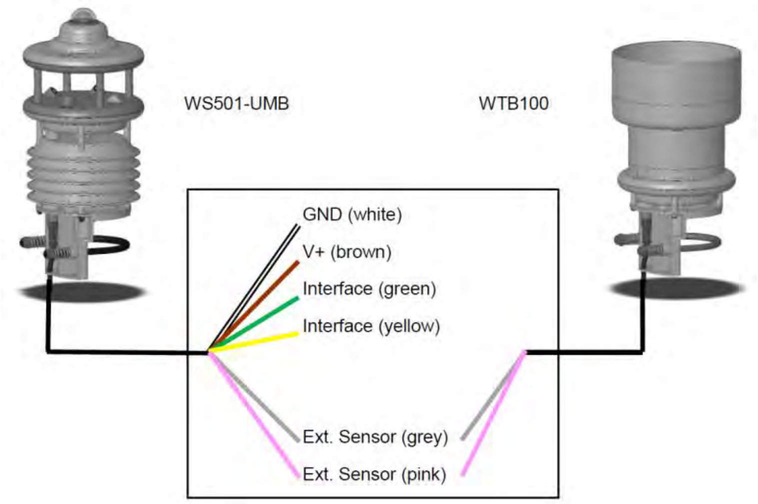
In principle, all rain sensors with bounce-free reed contact (normally open or normally closed) and with a resolution of 0.1 mm, 0.2 mm, 0.5 mm or 1.0 mm can be used.

**Note:** To get the correct amount of rain this “mechanical” selection must be also be set in compact weather stations configuration.

The setting is done with the UMB Config Tool by the same procedure as with WS401-UMB and WS601-UMB (s. Chap.10.2.8).

The WS601/401-UMB’s advices for installation (Chap.7.3.4) and maintenance (Chap.12.1) are as well valid for the external rain gauge.

Example with WS501-UMB and WTB100 without reduction ring:



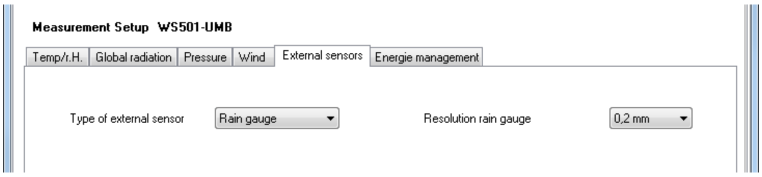




Figure 33: Example WS501-UMB and WTB100

# 19 Appendix

## 19.1 Channel List Summary

The channel assignment applies to online data requests in binary and ASCII protocol.

| UMB Channel | | | | | | Measuring Range | | |
|---|---|---|---|---|---|---|---|---|
| act | min | max | avg | special | Measurement Variable (float32) | min | max | unit |
| **Temperatures** | | | | | | | | |
| 100 | 120 | 140 | 160 | | temperature | -50.0 | 60.0 | °C |
| 105 | 125 | 145 | 165 | | temperature | -58.0 | 140.0 | °F |
| 101 | | | | | external temperature | -40.0 | 80.0 | °C |
| 106 | | | | | external temperature | -40.0 | 176.0 | °F |
| 110 | 130 | 150 | 170 | | dewpoint | -50.0 | 60.0 | °C |
| 115 | 135 | 155 | 175 | | dewpoint | -58.0 | 140.0 | °F |
| | | | | | | | | |
| 111 | | | | | wind chill temperature | -60.0 | 70.0 | °C |
| 116 | | | | | wind chill temperature | -76.0 | 158.0 | °F |
| | | | | | | | | |
| 114 | | | | | wet bulb temperature | -50.0 | 60.0 | °C |
| 119 | | | | | wet bulb temperature | -58.0 | 140.0 | °F |
| | | | | | | | | |
| 112 | | | | | wind heater temp. | -50.0 | 150.0 | °C |
| 113 | | | | | R2S heater temp. | -50.0 | 150.0 | °C |
| 117 | | | | | wind heater temp. | -58.0 | 302.0 | °F |
| 118 | | | | | R2S heater temp. | -58.0 | 302.0 | °F |
| **Humidity** | | | | | | | | |
| 200 | 220 | 240 | 260 | | relative humidity | 0.0 | 100.0 | % |
| 205 | 225 | 245 | 265 | | absolute humidity | 0.0 | 1000.0 | g/m³ |
| 210 | 230 | 250 | 270 | | mixing ratio | 0.0 | 1000.0 | g/kg |
| **Enthalpy** | | | | | | | | |
| 215 | | | | | specific enthalpy | -100.0 | 1000.0 | kJ/kg |
| **Pressure** | | | | | | | | |
| 300 | 320 | 340 | 360 | | abs. air pressure | 300 | 1200 | hPa |
| 305 | 325 | 345 | 365 | | rel. air pressure | 300 | 1200 | hPa |
| **Air Density** | | | | | | | | |
| 310 | | | | | air density | 0.0 | 3.0 | kg/m³ |
| **Wind** | | | | | | | | |
| | | | | **vect. avg** | | | | |
| 400 | 420 | 440 | 460 | 480 | wind speed | 0 | 75.0 | m/s |
| 405 | 425 | 445 | 465 | 485 | wind speed | 0 | 270.0 | km/h |
| 410 | 430 | 450 | 470 | 490 | wind speed | 0 | 167.8 | mph |
| 415 | 435 | 455 | 475 | 495 | wind speed | 0 | 145.8 | kts |
| 401 | | | | | wind speed fast | 0 | 75.0 | m/s |
| 406 | | | | | wind speed fast | 0 | 270.0 | km/h |
| 411 | | | | | wind speed fast | 0 | 167.8 | mph |
| 416 | | | | | wind speed fast | 0 | 145.8 | kts |
| | | | | | | | | |
| 403 | | | | | wind speed standard deviation | 0 | 75.0 | m/s |
| 413 | | | | | wind speed standard deviation | 0 | 167.8 | mph |
| | | | | | | | | |
| 500 | 520 | 540 | | 580 | wind direction | 0 | 359.9 | ° |
| 501 | | | | | wind direction fast | 0 | 359.9 | ° |
| 502 | | | | | wind direction corr. | 0 | 359,9 | ° |
| 503 | | | | | wind direction standard deviation | 0 | 359.0 | ° |
| 805 | | | | | wind value quality | 0 | 100.0 | % |
| **Compass** | | | | | | | | |
| 510 | | | | | compass heading | 0 | 359 | ° |

| Precipitation Quantity | | | Range | Unit |
|---|---|---|---|---|
| 600 | float32 | Precipitation Quantity - Absolute | 0 … 100000 | liters/m² |
| 620 | float32 | Precipitation Quantity - Absolute | 0 … 100000 | mm |
| 640 | float32 | Precipitation Quantity - Absolute | 0 … 3937 | inches |
| 660 | float32 | Precipitation Quantity - Absolute | 0 … 3937008 | mil |
| 605 | float32 | Precipitation Quantity - Differential | 0 … 100000 | liters/m² |
| 625 | float32 | Precipitation Quantity - Differential | 0 … 100000 | mm |
| 645 | float32 | Precipitation Quantity - Differential | 0 … 3937 | inches |
| 665 | float32 | Precipitation Quantity - Differential | 0 … 3937008 | mil |
| **Precipitation Type** | | | | |
| 700 | uint7 | Precipitation Type | 0 = No precipitation<br>40 = unspecified precipitation<br>60 = Liquid precipitation, e.g. rain<br>70 = Solid precipitation, e.g. snow | |
| **Precipitation Intensity** | | | **Range** | **unit** |
| 800 | float32 | Precipitation Intensity | 0 … 200.0 | l/m²/h |
| 820 | float32 | Precipitation Intensity | 0 … 200.0 | mm/h |
| 840 | float32 | Precipitation Intensity | 0 … 7.874 | in/h |
| 860 | float32 | Precipitation Intensity | 0 … 7874 | mil/h |

| act | min | max | avg | special | Measurement Variable (float32) | min | max | unit |
|---|---|---|---|---|---|---|---|---|
| **Global Radiation** | | | | | | | | |
| 900 | 920 | 940 | 960 | | Global Radiation | 0 | 1400 | W/m² |
| **Leaf Wetness** | | | | | | | | |
| 710 | 730 | 750 | 770 | | Leaf Wetness mV | 0.0 | 1500.0 | mV |
| 711 | | | | | Leaf Wetness State | 0 = dry<br>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<br>0.0 = 0d = 0000h<br>-0.1 = -1d = FFFFh<br>-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<br>200.0 = 2000d = 07D0h |
| 54 | 1054 | Result message Air Pressure LD | 16 bit | 800...1200 hPa | 1 hPa | 800 = 800d = 0320h<br>1200 = 1200d = 04B0h |
| 55 | 1055 | Result message Relative Humidity RLF | 8 bit | 10% ... 100% | 1% RH | 10% = 10d = 0Ah<br>100% = 100d = 64h |
| 56 | 1056 | Result message Wind Direction WR | 16 bit | 0 ... 359° | 1° | 0° (N) = 0d = 0000h<br>90° (O) = 90d = 005Ah<br>180° (S) = 180d = 00B4h<br>270° (W) = 270d = 010Eh<br>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<br>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<br>60.0 = 600d = 0258h |
| 66 | 1066 | Result message Dewpoint Temperature TPT | 16 bit | -30 ... +60°C | 0.1°C | 60.0 = 600d = 0258h<br>0.0 = 0d = 0000h<br>-0.1 = -1d = FFFFh<br>-30.0 = -300d = FED4h |
| 71 | 1071 | Result message Precipitation Type NS | 8 bit | | | 0 = No precipitation<br>40 = unspecified precipitation<br>60 = Liquid precipitation, e.g. rain<br>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 | | I |
| X | Switches to binary protocol | | k |
| R | Triggers software reset | ● | k |
| D | Software reset with delay | ● | k |
| I | Device information | | k |

These operating instructions describe the online data request only. You can find the description of the other commands in the UMB protocol.

### 19.4.3 Online Data Request (M)

**Description:** By way of this command, a measurement value is requested from a specific channel.

**Request:** ‘&’_<ID>$^5$_‘M’_<channel>$^5$ CR

**Response:** ‘$’_<ID>$^5$_‘M’_<channel>$^5$_<value>$^5$ CR

*<ID>*$^5$ Device address (5 decimal places with leading zeros)

*<channel>*$^5$ Indicates the channel number (5 decimal places with leading zeros)

*<value>*$^5$ Measurement value (5 decimal places with leading zeros); a measurement value standardized to 0 – 65520d. Various error codes are defined from 65521d – 65535d.

**Example:**

Request: &_28673_M_00100

By way of this request, channel 100 of the device with address 28673 is interrogated (compact weather station with device ID 001).

Response: $_28673_M_00100_34785

This channel outputs a temperature from –50 to +60°C, which is calculated as follows:

| | | |
|---|---|---|
| 0d | corresponds to | -50°C |
| 65520d | corresponds to | +60°C |
| 36789d | corresponds to | [+60°C – (-50°C)] / 65520 * 34785 +(-50°C) = 8.4°C |

**Note:** TLS channels are not available in ASCII protocol.

### 19.4.4 Standardization of Measurement Values in ASCII Protocol

The standardization of measurement values from 0d – 65520d corresponds to the measuring range of the respective measurement variable.

| Measurement Variable | Measuring Range | | |
|---|---|---|---|
| | Min | Max | Unit |
| **Temperature** | | | |
| Temperature | -50.0 | 60.0 | °C |
| Dew point<br>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<br>Mixing ratio | 0.0 | 1000.0 | g/m³<br>g/kg |
| Specific Enthalpy | -100.0 | 1000.0 | kJ/kg |
| **Pressure** | | | |
| Relative air pressure<br>Absolute air pressure | 300.0 | 1200.0 | hPa |
| **Air Density** | | | |
| air density | 0.0 | 3.0 | kg/m³ |
| **Wind** | | | |
| Wind speed | 0.0 | 75.0 | m/s |
| | 0.0 | 270.0 | km/h |
| | 0.0 | 167.8 | mph |
| | 0.0 | 145.8 | kts |
| Wind direction | 0.0 | 359.9 | ° |
| wind value quality | 0.0 | 100.0 | % |
| **Rain** | | | |
| Quantity | 0.0 | 6552.0 | litres / m² |
| | 0.0 | 6552.0 | mm |
| | 0.0 | 257.9 | inches |
| | 0.0 | 257952.7 | mil |
| Quantity since last request | 0.0 | 655.2 | litres / m² |
| | 0.0 | 655.2 | mm |
| | 0.0 | 25.79 | inches |
| | 0.0 | 25795.2 | mil |
| Precipitation type | 0 = No precipitation<br>40 = Precipitation<br>60 = Liquid precipitation, e.g. rain<br>70 = Solid precipitation, e.g. snow | | |
| Precipitation intensity | 0.0 | 200.0 | l/m²/h |
| | 0.0 | 200.0 | mm/h |
| | 0.0 | 7.874 | in/h |
| | 0.0 | 7874 | mil/h |
| **Global Radiation** | | | |
| Global Radiation | 0.0 | 1400.0 | W/m² |
| **Leaf Wetness** | | | |
| Leaf Wetness mV | 0.0 | 1500.0 | mV |
| Leaf Wetness State | 0 = dry<br>1 = wet | | |

### 19.4.5 Error Codes in the ASCII Protocol

Various error codes are defined from 65521d – 65535d in addition to the standardisation for the transmission of measurement values.

| <code> | Description |
|---|---|
| 65521d | Invalid Channel |
| 65523d | Value Overflow |
| 65524d | Value Underflow |
| 65525d | Error in measurement data or no valid data available |
| 65526d | Device / sensor is unable to execute valid measurement due to ambient conditions |
| 65534d | Invalid Calibration |
| 65535d | Unknown Error |

### 19.5 Communication in Terminal Mode

It is possible to communicate with a device in a very simple text-based manner using the terminal mode.

To do this, in the device configuration, interface settings, the protocol mode must be set to terminal (see page 29).

**Note:** In the case of communication in the terminal mode, only one single unit may be connected to the interface, as this protocol is **NOT** network-compatible. It is used for very simple measurement value requests.

**Note:** The use of binary protocol is recommended for lengthy transmission routes (e.g. network, GPRS/UMTS), as it is not possible to detect transmission errors in terminal mode (not CRC-secured).

**Note:** In the terminal mode, measurement values are not available in all units. Furthermore, status and error messages are not transmitted.

#### 19.5.1 Structure

A terminal consists of an ASCII character and a numeric character. The command is completed with the <CR> sign. There is no echo on entry.

The individual values in the response are separated by a semi-colon (;). The response is completed with <CR><LF>.

An invalid terminal command is acknowledged with ‘FAILED’. Control commands are acknowledged with ‘OK’.

The command to which the response relates is given at the beginning of each response.

**Note:** No response times are specified in the terminal mode.

### 19.5.2 Terminal Commands

The terminal commands transmit the following values or have the following functions:

| | | | | |
|---|---|---|---|---|
| `E0<CR>` | Temperature in °C | Ta | C | (Channel 100) |
| | Dew point temperature in °C | Tp | C | (Channel 110) |
| | Wind chill temperature in °C | Tw | C | (Channel 111) |
| | Relative humidity in % | Hr | P | (Channel 200) |
| | Relative air pressure in hPa | Pa | H | (Channel 305) |
| | Wind speed in m/s | Sa | M | (Channel 400) |
| | Wind direction in ° | Da | D | (Channel 500) |
| | Precipitation quantity in mm | Ra | M | (Channel 620) |
| | Precipitation type | Rt | N | (Channel 700) |
| | Precipitation intensity in mm/h | Ri | M | (Channel 820) |
| `E1<CR>` | Temperature in °F | Ta | F | (Channel 105) |
| | Dew point temperature in °F | Tp | F | (Channel 115) |
| | Wind chill temperature in °F | Tw | F | (Channel 116) |
| | Relative humidity in % | Hr | P | (Channel 200) |
| | Relative air pressure in hPa | Pa | H | (Channel 305) |
| | Wind speed in mph | Sa | S | (Channel 410) |
| | Wind direction in ° | Da | D | (Channel 500) |
| | Precipitation quantity in inches | Ra | I | (Channel 640) |
| | Precipitation type | Rt | N | (Channel 700) |
| | Precipitation intensity in inches/h | Ri | I | (Channel 840) |
| `E2<CR>` | Act. wind speed in m/s | Sa | M | (Channel 400) |
| | Min. wind speed in m/s | Sn | M | (Channel 420) |
| | Max. wind speed in m/s | Sx | M | (Channel 440) |
| | Avg. wind speed in m/s | Sg | M | (Channel 460) |
| | Vct. wind speed in m/s | Sv | M | (Channel 480) |
| | Act. wind direction in ° | Da | D | (Channel 500) |
| | Min. wind direction in ° | Dn | D | (Channel 520) |
| | Max. wind direction in ° | Dx | D | (Channel 540) |
| | Vct. wind direction in ° | Dv | D | (Channel 580) |
| `E3<CR>` | Act. wind speed in mph | Sa | S | (Channel 410) |
| | Min. wind speed in mph | Sn | S | (Channel 430) |
| | Max. wind speed in mph | Sx | S | (Channel 450) |
| | Avg. wind speed in mph | Sg | S | (Channel 470) |
| | Vct. wind speed in mph | Sv | S | (Channel 490) |
| | Act. wind direction in ° | Da | D | (Channel 500) |
| | Min. wind direction in ° | Dn | D | (Channel 520) |
| | Max. wind direction in ° | Dx | D | (Channel 540) |
| | Vectorial wind direction in ° | Dv | D | (Channel 580) |
| `E4<CR>` | Act. Compass heading in ° | Ca | D | (Channel 510) |
| | Act. Global Radiation in W/m² | Ga | W | (Channel 900) |
| | Min. Global Radiation in W/m² | Gn | W | (Channel 920) |
| | Max. Global Radiation in W/m² | Gx | W | (Channel 940) |
| | Avg. Global Radiation in W/m² | Gg | W | (Channel 960) |
| | Act. Specific Enthalpy in KJ/Kg | Ea | J | (Channel 215) |
| | Act. Wet Bulb Temperature in °C | Ba | C | (Channel 114) |
| | Act. Wet Bulb Temperature in °F | Ba | F | (Channel 119) |
| | Act. Air Density in kg/m³ | Ad | G | (Channel 310) |
| `E5<CR>` | act. Leaf Wetness mV | La | X | (Channel 710) |
| | act. Leaf Wetness State | Lb | X | (Channel 711) |
| | external temperature (act) °C | Te | C | (Channel 101) |
| | external temperature (act) °F | Te | F | (Channel 106) |
| | Reserve | Xx | X | |
| | Reserve | Xx | X | |
| | Reserve | Xx | X | |
| | Reserve | Xx | X | |
| | Reserve | Xx | X | |
| `Mx<CR>` | Displays the same values as `Ex<CR>`, but without additional information such as the measurement variable and unit | | | |
| `I0<CR>` | Serial number; date of manufacture; project number; parts list version; SPLAN version; hardware version; firmware version; E2 version; device version | | | |
| `I1<CR>` | Outputs the device description | | | |

| | |
|---|---|
| `R0<CR>` | Executes a device reset |
| `R1<CR>` | Resets the accumulated rain quantity and executes a device reset |
| `X0<CR>` | Temporarily switches to UMB binary protocol |

**Examples:**

```
E0<CR>     E0;Ta+024.9C;Tp+012.2C;Tw+026.8C;Hr+045.0P;Pa+0980.6H;
           Sa+005.1M;Da+156.6D;Ra+00042.24M;Rt+060N;Ri+002.6M;
M0<CR>     M0;+024.9;+012.2;+026.8;+045.0;+0980.6;
           +005.1;+156.6;+00042.24;+060;+002.6;
E2<CR>     E2;Sa+005.1M;Sn+001.1M;Sx+007.1M;Sg+005.1M;Sv+005.0M;
           Da+156.6D;Dn+166.6D;Dx+176.6D;Dv+156.6D;
M2<CR>     M2;+005.1;+001.1;+007.1;+005.1;+005.0;
           +156.6;+166.6;+176.6;+156.6;
I0<CR>     I0;001;0109;0701;004;005;001;016;011;00002;<CR><LF>
R0<CR>     R0;OK;<CR><LF>
```

### 19.6 Communication in SDI-12 Mode

The communication in the SDI-12 mode of the WSxxx-UMB is conforming to the standard defined in ‚SDI-12 A Serial-Digital Interface Standard for Microprocessor-Based Sensors Version 1.3 January 12, 2009‘ . The station may be operated in bus mode together with other SDI-12 sensors, connected to one SDI master (logger).

#### 19.6.1 Preconditions for SDI-12 Operation

As the interface settings defined in the SDI-12 standard are significantly different from the UMB default settings the related parameters have to be set properly by the UMB Config Tool (latest version!).

The protocol mode of the station has to be set to “SDI-12”. This will automatically set the baud rate to 1200.

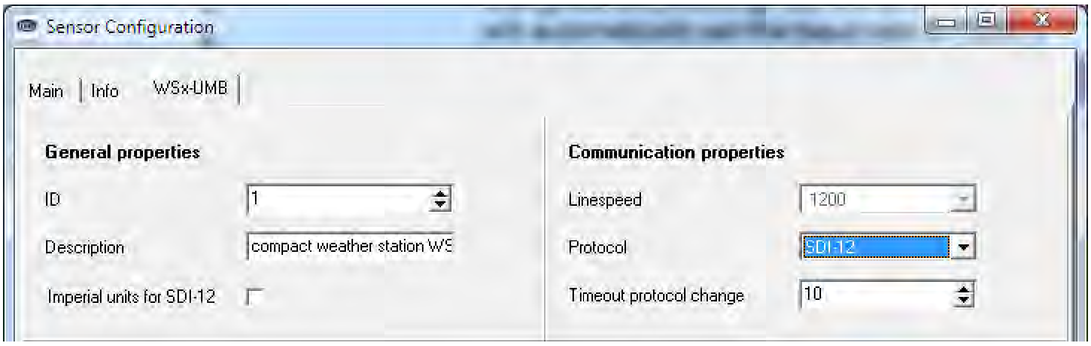
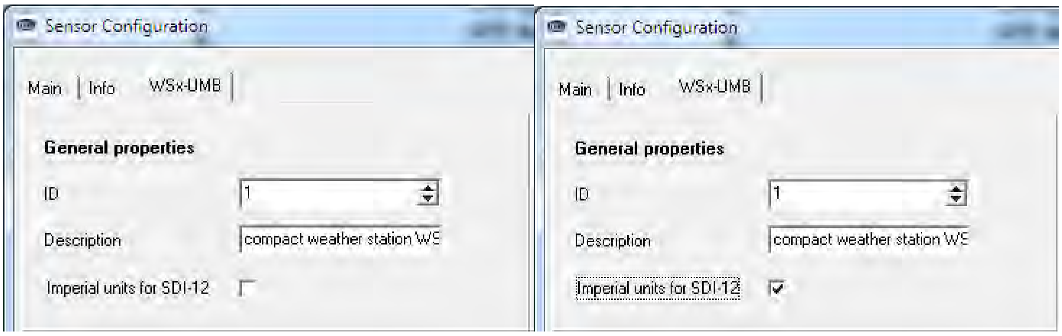



Figure 34: Sensor Configuration SDI-12

Measurement data can be transmitted alternatively in metric or US units. The selection is done by the UMB Config Tool.




Metric units US units

Figure 35: Sensor Configuration SDI-12 Units

When operating the device in SDI-12 mode it is basically no more possible to access the device with the UMB Config Tool, due to the different interface parameter settings. To enable configuration access nevertheless the interface is operated in standard UMB mode (19200 8N1) for the first 5 seconds after reset / power on. During this time the UMB device ID, if unequal 1, is set to 200, so access will be possible even if the device ID is unknown. If a valid UMB telegram is received within this 5 sec, the device will stay in UMB mode for the configured time out (several minutes) so that the configuration can be modified.

- Connect the PC to the WSxxx-UMB through an RS-485 converter
- Start the UMB Config Tool and create a WSxxx-UMB with the address (1 or 200) of the actual device and activate at least one sensor. Start the measurement (will report connection error at first)
- Reset the device (Power off / on)
- When measurement values are received the measurement can be terminated, the interface is now open for configuration.

### 19.6.2 Command Set

For details of the SDI-12 protocol please refer to the above mentioned standard document.
Following commands are available for devices of the WS family:

**Note**: The examples in the following sections use italics to print the requests from the logger (*0V!*)

| Command | Function |
|---|---|
| ?! | Address search (Wildcard request, one device only on bus!) |
| a! | Request device active? |
| aI! | Request device identification |
| aAb! | Address change to b ( 0 … 9, A …Z, a … z) |
| aM! | Measurement basic minimal data set |
| aM1! | Measurement temperatures |
| aM2! | Measurement humidity |
| aM3! | Measurement air pressure |
| aM4! | Measurement wind |
| aM5! | Measurement compass |
| aM6! | Measurement precipitation |
| aM7! | Measurement global radiation |
| aM8! | Measurement external temperature |
| aMC! | Measurement, basic minimal data set, transmit values with CRC |
| aMC1! ... aMC8! | Measurement (assignment of values as for aMn! commands), transmit values with CRC |
| aC! | Concurrent measurement, full basic data set |
| aC1! ... aC8! | Concurrent measurement, assignment of values as for aMn! commands, partly extended data sets |
| aCC! | Concurrent measurement, transmit values with CRC |
| aCC1! ... aCC8! | Concurrent measurement, assignment of values as for aMn! commands, partly extended data sets, transmit values with CRC |
| aD0! | Data request buffer 0 |
| aD1! | Data request buffer 1 |
| aD2! | Data request buffer 2 |
| aD3! | Data request buffer 3 |
| aD4! | Data request buffer 4 |
| aR0! | Data request from continuous measurement, data set 0 |
| aR1! | Data request from continuous measurement, data set 1 |
| aR2! | Data request from continuous measurement, data set 2 |
| aR3! | Data request from continuous measurement, data set 3 |
| aR4! | Data request from continuous measurement, data set 4 |
| aRC0! | Data request from continuous measurement, data set 0 with CRC |
| aRC1! | Data request from continuous measurement, data set 1 with CRC |
| aRC2! | Data request from continuous measurement, data set 2 with CRC |
| aRC3! | Data request from continuous measurement, data set 3 with CRC |
| aRC4! | Data request from continuous measurement, data set 4 with CRC |
| aV! | Command verification: Evaluate sensor status and heating temperatures, data request with aD0!, aD1! |
| aXU<m/u>! | Change the unit system for SDI data |
| aXH+nnnn! | Set local altitude of the device for calculation of rel. air pressure |

| Command | Function |
|---|---|
| aXD+nnn.n! | Set local compass deviation |
| aXL<n/s/w>! | Set power saving mode |
| aXMn! | Set the heating mode of the device |
| aXA<t/p/w>+nn! | Integration time for average and min/max evaluation |
| aXC! | Clear the abs. precipitation amount ( includes a device reset) |
| aXR! | Device reset |

The composition of the minimal and the full basic data set depends on the variant (WS200 ... WS600) of the device in question (see below). The same applies to the availability of the additional measurement commands (aM1!, aC1! etc.)

Due the applied measurement processes the devices of the WS family will, different from other sensors described in the SDI-12 document, in **normal operation mode** always measure continuously. This causes some special properties while in this mode:

- The device does not need a “Wakeup” and does not have a sleep mode. So the reactions to “Break” signals and any related timings are inapplicable. “Break” will be ignored by WS devices.
- Data requested with M- or C- commands are always available immediately. The device will always respond with `a000n` resp. `a000nn`. This means the device will not send any service request and will ignore measurement abort signals. The logger should request the data immediately.
- M- and C- command only differ in the number of values made available in the buffers (in both cases the maximum permitted by the standards of 9 resp. 20).
- We recommend to use the commands for continuous measurement (R-commands) to request the data.
- When in **power saving mode 2** the device will wake up by a „Break“ signal. Other functions of the „Break“ signal are not implemented.
- When in **power saving mode 2**the device responds to M or C commands with `a002n` resp. `a002nn` and holds the data available within 2 seconds. It will not send a service request, signals to abort the measurement are ignored.
- For the reduced data set in power saving mode 2 a unified data buffer structure for all device models has been defined. Depending on the individual model unused channels will be set to the “invalid” marker 999.9.

### 19.6.3 Address Configuration

UMB Device-ID and SDI-12 Address are connected, but the different address ranges and the fact, that UMB ID's are integer numbers, while SDI-12 addresses are ASCII characters, have to be considered.

The SDI-12 address is built from the UMB device ID as follows:

UMB Device ID 1 (default) corresponds to SDI-12 Address '0' (SDI-12 default).

Changing the SDI12 address by SDI12 setting command also modifies the UMB device ID accordingly.

Valid Address Ranges:

| UMB (dec) | | | SDI-12 (ASCII) | | |
|---|---|---|---|---|---|
| 1 | to | 10 | '0' | to | '9' |
| 18 | to | 43 | 'A' | to | 'Z' |
| 50 | to | 75 | 'a' | to | 'z' |

### 19.6.4 Data Messages

In the interest of simplified evaluation the assignment of measurement values to data buffers '0' ... '9' has been defined unified for all measurement commands. For this reason the responses to C-requests have been restricted to 35 characters, not using the 75 characters permitted for these requests

Currently buffers '0' to '4' are in use.

As with M-requests max. 9 values may be transmitted; the base data set of 9 values has been assigned to buffers '0' and '1'. Buffers '2' to '4' contain further measurement values. This definition guaranties the compatibility to loggers designed according to older versions of the SDI-12 standard.

The buffer assignment depends on the device variant (WS200-UMB ... WS600-UMB).

The complete set of measurement values, as defined for the UMB protocol has been made available also in the SDI-12 environment. They can be accessed using the additional M and C commands (aM1! ... aM8!, aMC1! ... aMC8!, aC1! ... aC8!, aCC1! ... aCC8!) (see below).

If the measurement value is not available for some reason, e.g. sensor failure, this is indicated by a value of +999.0. or -999.9 The logger can then evaluate the reason of failure by a aV! Verification request. The following tables show the measurement values in the sequence they are arranged in the telegram (see example).

Depending on the configuration of the device the values will be transmitted in metric or US units.

**Note:** The configured system of units is not indicated in the data messages. The logger may request this setting with the I-command and adjust the evaluation of the data messages accordingly

Example: M Request from a WS600-UMB station

*0M!*

00009<CR><LF> 9 measurement values are available

*0D0!*

0+13.5+85.7+1017.0+2.5+3.7<CR><LF>

Air temperature 13.5°C, rel. humidity 85.7%, rel. air pressure 1017hPa
avg. wind speed 2.5m/s, max wind speed 3.7m/s.

*0D1!*

0+43.7+9.8+60+4.4<CR><LF>

Wind direction 43.7° wet bulb temperature 9.8°C,
type of precipitation 60 (rain), precipitation intensity 4.4mm/h

Example: C Request from a WS600-UMB station

*0M!*

`000020<CR><LF>` 20 measurement values are available

*0D0!*

`0+13.5+85.7+1017+2.5+3.7<CR><LF>`

air temperature 13.5°C, rel. humidity 85.7%, rel. air pressure 1017hPa
avg. wind speed 2.5m/s, max wind speed 3.7m/s.

*0D1!*

`0+43.7+9.8+60+4.4<CR><LF>`

wind direction 43.7° wet bulb temperature 9.8°C,
type of precipitation 60 (rain), precipitation intensity 4.4mm/h

*0D2!*

`0+11.2+10.3+1.10<CR><LF>`

dewpoint 11.2°C, wind chill temperature 10,3°C
diff. precipitation 1.10mm

*0D3!*

`0+3.2+0.0+3.5+100.0<CR><LF>`

act. wind speed 3,2m/s, min. wind speed 0.0 m/s
vect. avg. wind speed 3.5m/s, quality of wind values 100%

*0D4!*

`0+43.7+41.3+45.7+29.3<CR><LF>`

act. wind direction 43,7°, min. wind direction 41,3°,
max. wind direction 45,7°, specific enthalpy29,3kJ/kg

### 19.6.4.1 Buffer assignment Basic Data Set WS600-UMB

Device configured for measurement values in metric units:

| Measurement value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer '0' | | | | |
| Air temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Air Pressure | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (avg) | 460 | 0.0 | 75.0 | m/s |
| Wind Speed (max) | 440 | 0.0 | 75.0 | m/s |
| Buffer '1' | | | | |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |
| Precipitation Type | 700 | 0, 60, 70 | | |
| Precipitation Intensity | 820 | 0.0 | 200.0 | mm/h |
| Buffer '2' | | | | |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Wind chill Temperature (act) | 111 | -60.0 | 70.0 | °C |
| Amount of Precip. difference | 625 | 0.00 | 100000.00 | mm |
| Buffer '3' | | | | |
| Wind Speed (act) | 400 | 0.0 | 75.0 | m/s |
| Wind Speed (min) | 420 | 0.0 | 75.0 | m/s |
| Wind Speed (vct) | 480 | 0.0 | 75.0 | m/s |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Buffer '4' | | | | |
| Wind Direction (act) | 500 | 0.0 | 359.9 | ° |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

Example: Request Buffer '0'

```
0D0!
0+13.5+85.7+2.5+3.7<CR><LF>
```

Air Temperature 13.5°C, rel. Humidity 85.7%, average wind speed 2.5m/s, peak wind speed 3.7m/s

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Air Pressure | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (avg) | 470 | 0.0 | 167.8 | mph |
| Wind Speed (max) | 450 | 0.0 | 167.8 | mph |
| Buffer ‘1’ | | | | |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Precipitation Type | 700 | 0, 60, 70 | | |
| Precipitation Intensity | 840 | 0.000 | 7.874 | in/h |
| Buffer ‘2’ | | | | |
| Dew Point (act) | 115 | -58.0 | 140.0 | °F |
| Wind chill Temperature (act) | 116 | -76.0 | 158.0 | °F |
| Amount of Precip. difference | 645 | 0.0000 | 3937.0000 | in |
| Buffer ‘3’ | | | | |
| Wind Speed (act) | 410 | 0.0 | 167.8 | mph |
| Wind Speed (min) | 430 | 0.0 | 167.8 | mph |
| Wind Speed (vct) | 490 | 0.0 | 167.8 | mph |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Puffer ‘4’ | | | | |
| Wind Direction(act) | 500 | 0.0 | 359.9 | ° |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

#### 19.6.4.2 Buffer Assignment Basic Data Set WS500-UMB

Device configured for measurement values in metric units:

| Measurement value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Air Pressure | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (avg) | 460 | 0.0 | 75.0 | m/s |
| Wind Speed (max) | 440 | 0.0 | 75.0 | m/s |
| Buffer ‘1’ | | | | |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Wet Bulb Temperature (act) | 114 | 0.0 | 359.9 | °C |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Wind chill Temperature (act) | 111 | -60.0 | 70.0 | °C |
| Buffer ‘2’ | | | | |
| Wind Speed (act) | 400 | 0.0 | 75.0 | m/s |
| Wind Speed (min) | 420 | 0.0 | 75.0 | m/s |
| Wind Speed (vct) | 480 | 0.0 | 75.0 | m/s |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Buffer ‘3’ | | | | |
| Wind Direction (act) | 500 | 0.0 | 359.9 | ° |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

Example: Request Buffer ‘0’

```
0D0!
0+13.5+85.7+2.5+3.7<CR><LF>
```

Air Temperature 13.5°C, rel. Humidity 85.7%, average wind speed 2.5m/s, peak wind speed 3.7m/s

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Air Pressure | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (avg) | 470 | 0.0 | 167.8 | mph |
| Wind Speed (max) | 450 | 0.0 | 167.8 | mph |
| Buffer ‘1’ | | | | |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Dew Point (act) | 115 | -58.0 | 140.0 | °F |
| Wind chill Temperature (act) | 116 | -76.0 | 158.0 | °F |
| Buffer ‘2’ | | | | |
| Wind Speed (act) | 410 | 0.0 | 167.8 | mph |
| Wind Speed (min) | 430 | 0.0 | 167.8 | mph |
| Wind Speed (vct) | 490 | 0.0 | 167.8 | mph |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Puffer ‘3’ | | | | |
| Wind Direction(act) | 500 | 0.0 | 359.9 | ° |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

#### 19.6.4.3 Buffer Assignment Basic Data Set WS400-UMB

Device configured for measurement in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer '0' | | | | |
| Air Temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100,0 | % |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Abs. Air Pressure(act) | 300 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Buffer '1' | | | | |
| Precipitation Type | 700 | 0, 60, 70 | | |
| Precipitation Intensity | 820 | 0.0 | 200.0 | mm/h |
| Amount of Precip. Difference | 625 | 0.00 | 100000.00 | mm |
| Amount of Precip. Absolute | 620 | 0.0 | 100000.0 | mm |
| Buffer '2' | | | | |
| Air Temperature (min) | 120 | -50.0 | 60.0 | °C |
| Air Temperature (max) | 140 | -50.0 | 60.0 | °C |
| Air Temperature (avg) | 160 | -50.0 | 60.0 | °C |
| Rel. Humidity (min) | 220 | 0.0 | 100.0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100.0 | % |
| Buffer '3' | | | | |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Rel. Air Pressure(min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Rel. Humidity (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Rel. Humidity (avg) | 365 | 300.0 | 1200.0 | hPa |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

Example: Request Buffer '0'

*0D0!*

`0+13.5+85.7+11.2+1017.0+1001.0`

Air temperature 13.5°C, rel. humidity 85.7%, dew point 11.2°C, rel. air pressure 1017.0hPa, abs. pressure 1001.0hPa

Device configured for measurement in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Dew Point (act) | 115 | -58.0 | 14.0 | °F |
| Abs. Air Pressure(act) | 300 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Buffer ‘1’ | | | | |
| Precipitation Type | 700 | 0, 60, 70 | | |
| Precipitation Intensity | 840 | 0.000 | 7.874 | in/h |
| Amount of Precip. Difference | 645 | 0.0000 | 3937.0000 | in |
| Amount of Precip. Absolute | 640 | 0.000 | 3937.000 | in |
| Buffer ‘2’ | | | | |
| Air Temperature (min) | 125 | -58.0 | 140.0 | °F |
| Air Temperature (max) | 145 | -58.0 | 140.0 | °F |
| Air Temperature (avg) | 165 | -58.0 | 140.0 | °F |
| Rel. Humidity (min) | 220 | 0.0 | 100.0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100.0 | % |
| Buffer ‘3’ | | | | |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Rel. Air Pressure(min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Rel. Humidity (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Rel. Humidity (avg) | 365 | 300.0 | 1200.0 | hPa |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Specific Enthalpy | 215 | -100.0 | 1000.0 | kJ/kg |

#### 19.6.4.4 Buffer Assignment Basic Data Set WS300-UMB

Device configured for measurement in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Puffer '0' | | | | |
| Air Temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Abs. Air Pressure(act) | 300 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Puffer '1' | | | | |
| Air Temperature (min) | 120 | -50.0 | 60.0 | °C |
| Air Temperature (max) | 140 | -50.0 | 60.0 | °C |
| Air Temperature (avg) | 160 | -50.0 | 60.0 | °C |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Puffer '2' | | | | |
| Rel. Humidity (min) | 220 | 0.0 | 100,0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100,0 | % |
| Rel. Air Pressure (min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (avg) | 365 | 300.0 | 1200.0 | hPa |
| Puffer '3' | | | | |
| Abs. Humidity (min) | 225 | 0.0 | 1000.0 | g/m³ |
| Abs. Humidity (max) | 245 | 0.0 | 1000.0 | g/m³ |
| Abs. Humidity (avg) | 265 | 0.0 | 1000.0 | g/m³ |
| Puffer '4' | | | | |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

Example: Request buffer '0'

*0D0!*

`0+13.5+85.7+11.2+1017.0+1001.0`

Air temperature 13.5°C, rel. humidity 85.7%, dew point 11.2°C, rel. air pressure 1017.0hPa, abs. pressure 1001.0hPa

Device configured for measurement in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Dew Point (act) | 115 | -58.0 | 140.0 | °F |
| Abs. Air Pressure(act) | 300 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Buffer ‘1’ | | | | |
| Air Temperature (min) | 125 | -58.0 | 140.0 | °F |
| Air Temperature (max) | 145 | -58.0 | 140.0 | °F |
| Air Temperature (avg) | 165 | -58.0 | 140.0 | °F |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Buffer ‘2’ | | | | |
| Rel. Humidity (min) | 220 | 0.0 | 100,0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100,0 | % |
| Rel. Air Pressure (min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (avg) | 365 | 300.0 | 1200.0 | hPa |
| Buffer ‘3’ | | | | |
| Abs. Humidity (min) | 225 | 0.0 | 1000.0 | g/m³ |
| Abs. Humidity (max) | 245 | 0.0 | 1000.0 | g/m³ |
| Abs. Humidity (avg) | 265 | 0.0 | 1000.0 | g/m³ |
| Buffer ‘4’ | | | | |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

#### 19.6.4.5 Buffer Assignment Basic Data Set WS200-UMB

Device configured for measurement values in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Wind Speed (avg) | 460 | 0.0 | 75.0 | m/s |
| Wind Speed (max) | 440 | 0.0 | 75.0 | m/s |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Wind Direction (act) | 500 | 0.0 | 359.9 | ° |
| Compass Heading(act) | 510 | 0.0 | 359.0 | ° |
| Buffer ‘1’ | | | | |
| Wind Speed (act) | 400 | 0.0 | 75.0 | m/s |
| Wind Speed (min) | 420 | 0.0 | 75.0 | m/s |
| Wind Speed (vct) | 480 | 0.0 | 75.0 | m/s |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Buffer ‘2’ | | | | |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Wind Direction corr. (act) | 502 | 0.0 | 359.9 | ° |

Example: Request Buffer ‘0’

*0D0!*

`0+2.5+3.7+45.5+37.8+10.3<CR><LF>`

Avg. wind speed 2.5m/s, peak wind speed 3.7m/s, avg wind direction (vect.) 45.5°, wind direction (act.) 37.8°, compass heading 10.3°

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Wind Speed (avg) | 470 | 0.0 | 167.8 | mph |
| Wind Speed (max) | 450 | 0.0 | 167.8 | mph |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Wind Direction (act) | 500 | 0.0 | 359.9 | ° |
| Compass Heading(act) | 510 | 0.0 | 359.0 | ° |
| Buffer ‘1’ | | | | |
| Wind Speed (act) | 410 | 0.0 | 167.8 | mph |
| Wind Speed (min) | 430 | 0.0 | 167.8 | mph |
| Wind Speed (vct) | 490 | 0.0 | 167.8 | mph |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Buffer ‘2’ | | | | |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Wind Direction corr. (act) | 502 | 0.0 | 359.9 | ° |

#### 19.6.4.6 Buffer Assignment Basic Data Set WS501-UMB, WS502-UMB, WS503-UMB, WS504-UMB

Device configured for measurement values in metric units:

| Measurement value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer '0' | | | | |
| Air temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Air Pressure | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (avg) | 460 | 0.0 | 75.0 | m/s |
| Wind Speed (max) | 440 | 0.0 | 75.0 | m/s |
| Buffer '1' | | | | |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Global Radiation (act) | 900 | 0.0 | 1400.0 | W/m² |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Wind Chill Temperature (act) | 111 | -60.0 | 70.0 | °C |
| Buffer '2' | | | | |
| Wind Speed (act) | 400 | 0.0 | 75.0 | m/s |
| Wind Speed (min) | 420 | 0.0 | 75.0 | m/s |
| Wind Speed (vct) | 480 | 0.0 | 75.0 | m/s |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Buffer '3' | | | | |
| Wind Direction (act) | 500 | 0.0 | 359.9 | ° |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |
| Buffer '4' | | | | |
| Global Radiation (min) | 920 | 0.0 | 1400.0 | W/m² |
| Global Radiation (max) | 940 | 0.0 | 1400.0 | W/m² |
| Global Radiation (avg) | 960 | 0.0 | 1400.0 | W/m² |

Example: Request Buffer '0'

*0D0!*

`0+13.5+85.7+2.5+3.7<CR><LF>`

Air Temperature 13.5°C, rel. Humidity 85.7%, average wind speed 2.5m/s, peak wind speed 3.7m/s

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Air Pressure | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (avg) | 470 | 0.0 | 167.8 | mph |
| Wind Speed (max) | 450 | 0.0 | 167.8 | mph |
| Buffer ‘1’ | | | | |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Global Radiation (act) | 900 | 0.0 | 1400.0 | W/m² |
| Dew Point (act) | 115 | -58.0 | 140.0 | °F |
| Windchill Temperature (act) | 116 | -76.0 | 158.0 | °F |
| Buffer ‘2’ | | | | |
| Wind Speed (act) | 410 | 0.0 | 167.8 | mph |
| Wind Speed (min) | 430 | 0.0 | 167.8 | mph |
| Wind Speed (vct) | 490 | 0.0 | 167.8 | mph |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Puffer ‘3’ | | | | |
| Wind Direction(act) | 500 | 0.0 | 359.9 | ° |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |
| Buffer ‘4’ | | | | |
| Global Radiation (min) | 920 | 0.0 | 1400.0 | W/m² |
| Global Radiation (max) | 940 | 0.0 | 1400.0 | W/m² |
| Global Radiation (avg) | 960 | 0.0 | 1400.0 | W/m² |

#### 19.6.4.7 Buffer Assignment Basic Data Set WS301-UMB, WS302-UMB, WS303-UMB, WS304-UMB

Device configured for measurement in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Puffer ‘0’ | | | | |
| Air Temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Global Radiation(act) | 900 | 0.0 | 1400.0 | W/m² |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Puffer ‘1’ | | | | |
| Air Temperature (min) | 120 | -50.0 | 60.0 | °C |
| Air Temperature (max) | 140 | -50.0 | 60.0 | °C |
| Air Temperature (avg) | 160 | -50.0 | 60.0 | °C |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Puffer ‘2’ | | | | |
| Rel. Humidity (min) | 220 | 0.0 | 100,0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100,0 | % |
| Rel. Air Pressure (min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (avg) | 365 | 300.0 | 1200.0 | hPa |
| Puffer ‘3’ | | | | |
| Abs. Humidity (act) | 205 | 0.0 | 1000.0 | g/m³ |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |
| Puffer ‘4’ | | | | |
| Global Radiation (min) | 920 | 0.0 | 1400.0 | W/m² |
| Global Radiation (max) | 940 | 0.0 | 1400.0 | W/m² |
| Global Radiation (avg) | 960 | 0.0 | 1400.0 | W/m² |

Example: Request buffer ‘0’

*0D0!*

`0+13.5+85.7+11.2+1017.0+780.0`

Air temperature 13.5°C, rel. humidity 85.7%, dew point 11.2°C, rel. air pressure 1017.0hPa, global radiation 780.0W/m²

Device configured for measurement in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Dew Point (act) | 115 | -58.0 | 140.0 | °F |
| Global Radiation(act) | 900 | 0.0 | 1400.0 | W/m² |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Buffer ‘1’ | | | | |
| Air Temperature (min) | 125 | -58.0 | 140.0 | °F |
| Air Temperature (max) | 145 | -58.0 | 140.0 | °F |
| Air Temperature (avg) | 165 | -58.0 | 140.0 | °F |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Buffer ‘2’ | | | | |
| Rel. Humidity (min) | 220 | 0.0 | 100,0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100,0 | % |
| Rel. Air Pressure (min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (avg) | 365 | 300.0 | 1200.0 | hPa |
| Buffer ‘3’ | | | | |
| Abs. Humidity (act) | 205 | 0.0 | 1000.0 | g/m³ |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |
| Buffer ‘4’ | | | | |
| Global Radiation (min) | 920 | 0.0 | 1400.0 | W/m² |
| Global Radiation (max) | 940 | 0.0 | 1400.0 | W/m² |
| Global Radiation (avg) | 960 | 0.0 | 1400.0 | W/m² |

#### 19.6.4.8 Buffer assignment Basic Data Set WS601-UMB

Device configured for measurement values in metric units:

| Measurement value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Air Pressure | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (avg) | 460 | 0.0 | 75.0 | m/s |
| Wind Speed (max) | 440 | 0.0 | 75.0 | m/s |
| Buffer ‘1’ | | | | |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Leaf Wetness State (act) | 711 | 0 / 1 | | |
| Precipitation Type | 700 | 0, 40 | | |
| Precipitation Intensity | 820 | 0.0 | 200.0 | mm/h |
| Buffer ‘2’ | | | | |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Wind chill Temperature (act) | 111 | -60.0 | 70.0 | °C |
| Amount of Precip. difference | 625 | 0.00 | 100000.00 | mm |
| Buffer ‘3’ | | | | |
| Wind Speed (act) | 400 | 0.0 | 75.0 | m/s |
| Wind Speed (min) | 420 | 0.0 | 75.0 | m/s |
| Wind Speed (vct) | 480 | 0.0 | 75.0 | m/s |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |
| Buffer ‘4’ | | | | |
| Wind Direction (act) | 500 | 0.0 | 359.9 | ° |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

Example: Request Buffer ‘0’

*0D0!*

`0+13.5+85.7+2.5+3.7<CR><LF>`

Air Temperature 13.5°C, rel. Humidity 85.7%, average wind speed 2.5m/s, peak wind speed 3.7m/s

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Air Pressure | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (avg) | 470 | 0.0 | 167.8 | mph |
| Wind Speed (max) | 450 | 0.0 | 167.8 | mph |
| Buffer ‘1’ | | | | |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Leaf Wetness State (act) | 711 | 0 / 1 | | |
| Precipitation Type | 700 | 0, 60, 70 | | |
| Precipitation Intensity | 840 | 0.000 | 7.874 | in/h |
| Buffer ‘2’ | | | | |
| Dew Point (act) | 115 | -58.0 | 140.0 | °F |
| Wind chill Temperature (act) | 116 | -76.0 | 158.0 | °F |
| Amount of Precip. difference | 645 | 0.0000 | 3937.0000 | in |
| Buffer ‘3’ | | | | |
| Wind Speed (act) | 410 | 0.0 | 167.8 | mph |
| Wind Speed (min) | 430 | 0.0 | 167.8 | mph |
| Wind Speed (vct) | 490 | 0.0 | 167.8 | mph |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Puffer ‘4’ | | | | |
| Wind Direction(act) | 500 | 0.0 | 359.9 | ° |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

#### 19.6.4.9 Buffer Assignment Basic Data Set WS401-UMB

Device configured for measurement in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer '0' | | | | |
| Air Temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100,0 | % |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Leaf Wetness State (act) | 711 | 0 / 1 | | |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Buffer '1' | | | | |
| Precipitation Type | 700 | 0, 40 | | |
| Precipitation Intensity | 820 | 0.0 | 200.0 | mm/h |
| Amount of Precip. Difference | 625 | 0.00 | 100000.00 | mm |
| Amount of Precip. Absolute | 620 | 0.0 | 100000.0 | mm |
| Buffer '2' | | | | |
| Air Temperature (min) | 120 | -50.0 | 60.0 | °C |
| Air Temperature (max) | 140 | -50.0 | 60.0 | °C |
| Air Temperature (avg) | 160 | -50.0 | 60.0 | °C |
| Rel. Humidity (min) | 220 | 0.0 | 100.0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100.0 | % |
| Buffer '3' | | | | |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Rel. Air Pressure(min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Rel. Humidity (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Rel. Humidity (avg) | 365 | 300.0 | 1200.0 | hPa |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |

Example: Request Buffer '0'

*0D0!*

`0+13.5+85.7+11.2+1017.0+1001.0`

Air temperature 13.5°C, rel. humidity 85.7%, dew point 11.2°C, rel. air pressure 1017.0hPa, abs. pressure 1001.0hPa

Device configured for measurement in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Dew Point (act) | 115 | -58.0 | 14.0 | °F |
| Leaf Wetness State (act) | 711 | 0 / 1 | | |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Buffer ‘1’ | | | | |
| Precipitation Type | 700 | 0, 40 | | |
| Precipitation Intensity | 840 | 0.000 | 7.874 | in/h |
| Amount of Precip. Difference | 645 | 0.0000 | 3937.0000 | in |
| Amount of Precip. Absolute | 640 | 0.000 | 3937.000 | in |
| Buffer ‘2’ | | | | |
| Air Temperature (min) | 125 | -58.0 | 140.0 | °F |
| Air Temperature (max) | 145 | -58.0 | 140.0 | °F |
| Air Temperature (avg) | 165 | -58.0 | 140.0 | °F |
| Rel. Humidity (min) | 220 | 0.0 | 100.0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100.0 | % |
| Buffer ‘3’ | | | | |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Rel. Air Pressure(min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Rel. Humidity (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Rel. Humidity (avg) | 365 | 300.0 | 1200.0 | hPa |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Specific Enthalpy | 215 | -100.0 | 1000.0 | kJ/kg |

### 19.6.4.10 Buffer Assignment Basic Data Set Power Saving Mode 2 (all Models)

Device configured for measurement in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer '0' | | | | |
| Air Temperature (act) | 100 | -50.0 | 60.0 | °C |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Amount of Precip. Difference | 625 | 0.00 | 100000.00 | mm |
| Rel. Air Pressure(act) | 305 | 300.0 | 1200.0 | hPa |
| Wind Speed (act) | 400 | 0.0 | 75.0 | m/s |
| Buffer '1' | | | | |
| Wind Direction(act) | 500 | 0.0 | 359.9 | ° |
| Global Radiation | 900 | 0.0 | 1400.0 | W/m$^2$ |
| Leaf Wetness State (act) | 711 | 0 / 1 | | |
| External Temperature | 101 | -20.0 | 80.0 | °C |
| Buffer '2' | | | | |
| Amount of Precip. Absolute | 620 | 0.0 | 100000.0 | mm |
| Dew point (act) | 110 | -50.0 | 60.0 | °C |
| Abs. Humidity (act) | 205 | 0.0 | 1000.0 | g/m³ |
| Mixing Ratio(act) | 210 | 0.0 | 1000.0 | g/kg |
| Abs. Air Pressure(act) | 300 | 300.0 | 1200.0 | hPa |
| Buffer '3' | | | | |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |
| Air Density | 310 | 0.000 | 3.000 | kg/m3 |
| Compass (act) | 510 | 0.0 | 359.0 | ° |

Example: Request Buffer '0'

*0D0!*

`0+13.5+85.7+0.2+1017.0+1.8`

Air temperature 13.5°C, rel. humidity 85.7%, precipitation 0.2°C, rel. air pressure 1017.0hPa, wind speed1.8m/s

Device configured for measurement in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer '0' | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Amount of Precip. Difference | 645 | 0.0000 | 3937.0000 | in |
| Rel. Air Pressure(act) | 305 | 300.0 | 12000 | hPa |
| Wind Speed (act) | 410 | 0.0 | 167.8 | mph |
| Buffer '1' | | | | |
| Wind Direction(act) | 500 | 0.0 | 359.9 | ° |
| Global Radiation | 900 | 0.0 | 1400.0 | $W/m^2$ |
| Leaf Wetness State (act) | 711 | 0 / 1 | | |
| External Temperature | 106 | -4.0 | 176.0 | °F |
| Buffer '2' | | | | |
| Amount of Precip. Absolute | 640 | 0.000 | 3937.000 | in |
| Dew point (act) | 115 | -58.0 | 140.0 | °F |
| Abs. Humidity (act) | 205 | 0.0 | 1000.0 | $g/m^3$ |
| Mixing Ratio(act) | 210 | 0.0 | 1000.0 | g/kg |
| Abs. Air Pressure(act) | 300 | 300.0 | 1200.0 | hPa |
| Buffer '3' | | | | |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |
| Air Density | 310 | 0.000 | 3.000 | kg/m3 |
| Compass (act) | 510 | 0.0 | 359.0 | ° |

### 19.6.5 Additional Measurement Commands

With the additional measurement commands

aM1! … aM6!

aMC1! … aMC6! (M-Command, data transmission with CRC)

aC1! … aC6!

aCC1! … aCC6! (C- Command, data transmission with CRC)

The complete data sets of the compact weather station, as defined for the UMB protocol are available in a SDI-12 environment as well.

The measurement values are ordered according to sensor types.

Equally to the base data sets max. 9 values can be requested with an additional M command, while an additional C request allows for up to 20 values.

The buffer assignment as documented in the following paragraphs has consequently been structured in a way that with each M command the buffers D0 and D1 are used. If the respective sensor type has more values available the buffers D2 up to D4 will be occupied if required.

| | | | |
|---|---|---|---|
| M1 / C1 | Temperature | M: 8 Values | C: 8 Values |
| M2 / C2 | Humidity | M: 8 Values | C: 12 Values |
| M3 / C3 | Air Pressure | M: 8 Values | C: 8 Values |
| M4 / C4 | Wind | M: 9 Values | C: 12 Values |
| M5 / C5 | Compass | M: 1 Values | C: 1 Values |
| M6 / C6: | Precipitation, Leaf Wetness | M: 9 Values | C: 9 Values |
| M7 / C7 | Global Radiation | M: 4 Values | C: 4 Values |

If the sensor type requested with the measurement command is not available with the actual variant of the compact weather station (WS200-UMB ... WS600-UMB) the station will respond with

`a0000<CR><LF>` resp.

`a00000<CR><LF>`

#### 19.6.5.1 Buffer Assignment Additional Measurement Commands M1 / C1: Temperature

Device configured for measurement values in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 100 | -50.0 | 60.0 | °C |
| Air Temperature (min) | 120 | -50.0 | 60.0 | °C |
| Air Temperature (max) | 140 | -50.0 | 60.0 | °C |
| Air Temperature (avg) | 160 | -50.0 | 60.0 | °C |
| Dew Point (act) | 110 | -50.0 | 60.0 | °C |
| Buffer ‘1’ | | | | |
| Dew Point (min) | 130 | -50.0 | 60.0 | °C |
| Dew Point (max) | 150 | -50.0 | 60.0 | °C |
| Dew Point (avg) | 170 | -50.0 | 60.0 | °C |
| Wet Bulb Temperature (act) | 114 | -50.0 | 60.0 | °C |

Example: Request with M command

```
0M1!
00008<CR><LF>
0D0!
0+12.5+10.7+13.5+11.8+5.3<CR><LF>
0D1!
0+4.2+5.9+5.6+9.8<CR><LF>
```

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Air Temperature (act) | 105 | -58.0 | 140.0 | °F |
| Air Temperature (min) | 125 | -58.0 | 140.0 | °F |
| Air Temperature (max) | 145 | -58.0 | 140.0 | °F |
| Air Temperature (avg) | 165 | -58.0 | 140.0 | °F |
| Dew Point (act) | 115 | -58.0 | 140.0 | °F |
| Buffer ‘1’ | | | | |
| Dew Point (min) | 135 | -58.0 | 140.0 | °F |
| Dew Point (max) | 155 | -58.0 | 140.0 | °F |
| Dew Point (avg) | 175 | -58.0 | 140.0 | °F |
| Wet Bulb Temperature (act) | 119 | -58.0 | 140.0 | °F |

#### 19.6.5.2 Buffer Assignment Additional Measurement Commands M2 / C2: Humidity

Device configured for measurement values in metric or US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Rel. Humidity (act) | 200 | 0.0 | 100.0 | % |
| Rel. Humidity (min) | 220 | 0.0 | 100.0 | % |
| Rel. Humidity (max) | 240 | 0.0 | 100.0 | % |
| Rel. Humidity (avg) | 260 | 0.0 | 100.0 | % |
| Puffer ‘1’ | | | | |
| Abs. Humidity (act) | 205 | 0.0 | 1000.0 | g/m³ |
| Abs. Humidity (min) | 225 | 0.0 | 1000.0 | g/m³ |
| Abs. Humidity (max) | 245 | 0.0 | 1000.0 | g/m³ |
| Abs. Humidity (avg) | 265 | 0.0 | 1000.0 | g/m³ |
| Specific Enthalpy (act) | 215 | -100.0 | 1000.0 | kJ/kg |
| Puffer ‘2’ | | | | |
| Mixing Ratio(act) | 210 | 0.0 | 1000.0 | g/kg |
| Mixing Ratio (min) | 230 | 0.0 | 1000.0 | g/kg |
| Mixing Ratio (max) | 250 | 0.0 | 1000.0 | g/kg |
| Mixing Ratio (avg) | 270 | 0.0 | 1000.0 | g/kg |

Example: Request with M command

```
0M2!
00008<CR><LF>
0D0!
0+48.5+48.2+48.8+48.5<CR><LF>
0D1!
0+5.7+5.5+5.9+5.7+29.3<CR><LF>
```

Example: Request with C command

```
0C2!
000012<CR><LF>
0D0!
0+48.5+48.2+48.8+48.5<CR><LF>
0D1!
0+5.7+5.5+5.9+5.7+29.3<CR><LF>
0D2!
0+4.6+4.4+5.0+4.6<CR><LF>
```

#### 19.6.5.3 Buffer Assignment Additional Measurement Commands M3 / C3: Air Pressure

Device configured for measurement values in metric or US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Abs. Air Pressure(act) | 300 | 300.0 | 1200.0 | hPa |
| Abs. Air Pressure (min) | 320 | 300.0 | 1200.0 | hPa |
| Abs. Air Pressure (max) | 340 | 300.0 | 1200.0 | hPa |
| Abs. Air Pressure (avg) | 360 | 300.0 | 1200.0 | hPa |
| Air Density (act) | 310 | 0.000 | 3.000 | kg/m3 |
| Puffer ‘1’ | | | | |
| Rel. Air Pressure (act) | 305 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (min) | 325 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (max) | 345 | 300.0 | 1200.0 | hPa |
| Rel. Air Pressure (avg) | 365 | 300.0 | 1200.0 | hPa |

Example: Request with M command

```
0M3!
00009<CR><LF>
0D0!
0+1001.0+1000.0+1002.0+1001.0+1.119<CR><LF>
0D1!
0+1017.0+1016.0+1018.0+1017.0<CR><LF>
```

Example: Request with C command

```
0C3!
000009<CR><LF>
0D0!
0+1001.0+1000.0+1002.0+1001.0+1.119<CR><LF>
0D1!
0+1017.0+1016.0+1018.0+1017.0<CR><LF>
```

#### 19.6.5.4 Buffer Assignment Additional Measurement Commands M4 / C4: Wind

Device configured for measurement values in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer '0' | | | | |
| Wind Speed (act) | 400 | 0.0 | 75.0 | m/s |
| Wind Speed (min) | 420 | 0.0 | 75.0 | m/s |
| Wind Speed (max) | 440 | 0.0 | 75.0 | m/s |
| Wind Speed (avg) | 460 | 0.0 | 75.0 | m/s |
| Wind Speed (vct) | 480 | 0.0 | 75.0 | m/s |
| Puffer '1' | | | | |
| Wind Direction (act) | 500 | 0.0 | 359.9 | ° |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Puffer '2' | | | | |
| Wind Direction corr. (act) | 502 | 0.0 | 359.9 | ° |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Wind Chill Temperature (act) | 111 | -60.0 | 70.0 | °C |
| Wind Speed Standard Dev. | 403 | 0.0 | 60.0 | m/s |
| Wind Direction Standard Dev. | 503 | 0.0 | 359.9 | ° |

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer '0' | | | | |
| Wind Speed (act) | 410 | 0.0 | 167.8 | mph |
| Wind Speed (min) | 430 | 0.0 | 167.8 | mph |
| Wind Speed (max) | 450 | 0.0 | 167.8 | mph |
| Wind Speed (avg) | 470 | 0.0 | 167.8 | mph |
| Wind Speed (vct) | 490 | 0.0 | 167.8 | mph |
| Puffer '1' | | | | |
| Wind Direction (act) | 500 | 0.0 | 359.9 | ° |
| Wind Direction (min) | 520 | 0.0 | 359.9 | ° |
| Wind Direction (max) | 540 | 0.0 | 359.9 | ° |
| Wind Direction (vct) | 580 | 0.0 | 359.9 | ° |
| Puffer '2' | | | | |
| Wind Direction corr. (act) | 502 | 0.0 | 359.9 | ° |
| Wind Quality | 805 | 0.0 | 100.0 | % |
| Wind chill Temperature (act) | 116 | -76.0 | 158.0 | °F |
| Wind Speed Standard Dev. | 413 | 0.0 | 167.8 | mph |
| Wind Direction Standard Dev. | 503 | 0.0 | 359.9 | ° |

#### 19.6.5.5 Buffer Assignment Additional Measurement Commands M5 / C5: Compass

Device configured for measurement values in metric or US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Compass (act) | 510 | 0.0 | 359.0 | ° |

Example: Request with M command

*0M5!*

`00001<CR><LF>`

*0D0!*

`0+348.0<CR><LF>`

Example: Request with C command

*0C5!*

`000001<CR><LF>`

*0D0!*

`0+348.0<CR><LF>`

#### 19.6.5.6 Buffer Assignment Additional Measurement Commands M6 / C6: Precipitation and Leaf Wetness

Device configured for measurement values in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Precip. Amount absolute | 620 | 0.0 | 100000.0 | mm |
| Precip. Amount difference | 625 | 0.00 | 100000.00 | mm |
| Precipitation Intensity | 820 | 0.0 | 200.0 | mm/h |
| Precipitation Type | 700 | 0, 40, 60, 70 | | |
| Buffer ‘1’ | | | | |
| Leaf Wetness mV (act) | 710 | 0,0 | 1500,0 | mV |
| Leaf Wetness mV (min) | 730 | 0,0 | 1500,0 | mV |
| Leaf Wetness mV (max) | 750 | 0,0 | 1500,0 | mV |
| Leaf Wetness mV (avg) | 770 | 0,0 | 1500,0 | mV |
| Leaf Wetness State | 711 | 0 / 1 | | |

Example: Request with M command

```
0M6!
00009<CR><LF>
0D0!
0+1324.5+1.10+4.4+60<CR><LF>
0D1!
0+603.5+562.4+847.4+623.8+1<CR><LF>
```

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Precip. Amount absolute | 640 | 0.000 | 3937.000 | In |
| Precip. Amount difference | 645 | 0.0000 | 3937.0000 | In |
| Precipitation Intensity | 840 | 0.000 | 7.874 | in/h |
| Precipitation Type | 700 | 0, 60, 70 | | |
| Buffer ‘1’ | | | | |
| Leaf Wetness mV (act) | 710 | 0,0 | 1500,0 | mV |
| Leaf Wetness mV (min) | 730 | 0,0 | 1500,0 | mV |
| Leaf Wetness mV (max) | 750 | 0,0 | 1500,0 | mV |
| Leaf Wetness mV (avg) | 770 | 0,0 | 1500,0 | mV |
| Leaf Wetness State | 711 | 0 / 1 | | |

### 19.6.5.7 Buffer Assignment Additional Measurement Commands M7 / C7: Global Radiation

Device configured for measurement values in metric or US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| Global Radiation (act) | 900 | 0.0 | 1400.0 | W/m² |
| Global Radiation (min) | 920 | 0.0 | 1400.0 | W/m² |
| Global Radiation (max) | 940 | 0.0 | 1400.0 | W/m² |
| Global Radiation (avg) | 960 | 0.0 | 1400.0 | W/m² |

Example: Request with M Command

```
0M7!
00004<CR><LF>
0D0!
0+780.0+135.0+920.0+530.0<CR><LF>
```

### 19.6.5.8 Buffer Assignment Additional Measurement Commands M8 / C8: External Temperature

Device configured for measurement values in metric units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| External Temperature (act) | 101 | -40.0 | 80.0 | °C |

Example: Request with M Command

```
0M8!
00001<CR><LF>
0D0!
0+13.5<CR><LF>
```

Device configured for measurement values in US units:

| Measurement Value | UMB Channel | Min | Max | Unit |
|---|---|---|---|---|
| Buffer ‘0’ | | | | |
| External Temperature (act) | 106 | -40.0 | 176.0 | °F |

### 19.6.6 Message Device Identification

The device responds to the identification request with following message (example for SDI-12 device address '0':

*0I!*

013Lufft.deWSx00ynnn

x: device type (4, 5, 6, 2, 3 )

y: Metric / US units ( m = metric, u = US )

nnn: Software version

i.e. for a WS600-UMB, configured for US units:

*0I!*

013Lufft.deWS600u022

### 19.6.7 Message Verification

The command verification aV! is used to evaluate status information of the device. The device responds with

a0005<CR<LF>

to the request, i.e. 5 values are available in the buffers.

The first 3 "measurement values", transmitted in buffer '0' contain the status information of the measurement channels.

The status data of the channels are assembled to form "fake measurement values", where each digit represents one status. See below for the coding of states. Generally each sensor has two status values, one for the direct value and another for the measurement value buffer used for the evaluation of the average, min, and max values.

The last two values, transmitted in buffer '1', show the heating temperatures of wind and precipitation sensor.

| Buffer '0' | | | | |
|---|---|---|---|---|
| Status group1: +nnnn | Air temperature, air temperature buffer, dew point, dew point buffer | | | |
| Status group1: +nnnnnn (WS401 / WS601 only) | Air temperature, air temperature buffer, dew point, dew point buffer, leaf wetness status, leaf wetness buffer status | | | |
| Status group 2: +nnnnnn | Rel. Humidity, rel. Humidity buffer, abs. Humidity, abs humidity buffer, mixing ration, mixing ration buffer | | | |
| Status group 3: +nnnnnn | Air pressure, air pressure buffer, wind, wind buffer, compass, precipitation (WS301/501 transmits the global radiation status instead of the precipitation status) | | | |
| Buffer '1', device configured for metric units | | | | |
| Measurement value | UMB Channel | min | max | Unit |
| Heating temp. Wind sensor | 112 | -50 | +150 | °C |
| Heating temp. Precip. sensor | 113 | -50 | +150 | °C |
| Puffer '1', device configured for US units | | | | |
| Heating temp. Wind sensor | 117 | -58 | +302 | °F |
| Heating temp. Precip. sensor | 118 | -58 | +302 | °F |

Sensor status codes:

| Sensor status | Code |
|---|---|
| OK | 0 |
| UNGLTG_KANAL | 1 |
| E2_CAL_ERROR<br>E2_CRC_KAL_ERR<br>FLASH_CRC_ERR<br>FLASH_WRITE_ERR<br>FLASH_FLOAT_ERR | 2 |
| MEAS_ERROR | 3 |
| MEAS_UNABLE | 4 |
| INIT_ERROR | 5 |
| VALUE_OVERFLOW<br>CHANNEL_OVERRANGE | 6 |
| VALUE_UNDERFLOW<br>CHANNEL_UNDERRANGE | 7 |
| BUSY | 8 |
| other sensor status | 9 |

Example (WS600-UMB, SDI-12 Address ‘0’, no error):

```
0V!
00005<CR><LF>
0D0!
0+0000+000000+00000<CR><LF>
0D1!
0+73.0+65.3<CR><LF>
```

Example (WS600-UMB, SDI-12 Address ‘0’, compass failure):

```
0V!
00005<CR><LF>
0D0!
0+0000+000000+000030<CR><LF>
0D1!
0+73.0+65.3<CR><LF>
```

### 19.6.8 Message Change of Unit System

The command is used to change the unit system used for the SDI12 data between metric and US units. It is implemented as manufacturer specific X command.

Command: `aXU<u/m>!`

Response: `aU<u/m><CR><LF>`

u : US units

m: metric units

Example: change to metric units, SDI-12 address '0'

`0XUm!`

`0Um<CR><LF>`

### 19.6.9 Message: Setting of the Averaging Interval Length

The avg, min, max and vct values of the measurement values are evaluated over a floating interval with a length of 1 to 10 min. The length of this interval can be adjusted separately for the groups temperature / humidity, air pressure and wind. (The averaging algorithm is not applied to precipitation and compass).

Command: `aXA<t/p/w/r>+nn!`

t : Temperature and Humidity

p: Air pressure

w: Wind

r: Global radiation

nn: Interval in minutes, valid range: 1 bis 10

Response: `aXA<t/p/w/r>+nn<CR><LF>`

The response to the attempt of setting of an invalid interval length is

`aXAf<CR><LF>`

Example: Setting the interval for temperature and humidity to 5 minutes

*`0XAt+5!`*

`0XAt+5<CR><LF>`

### 19.6.10 Message: Setting of the Local Altitude

For the calculation of the relative air pressure the local altitude of the device is required.

Command: `aXH+nnnn!`

nnnn: local altitude of the sensor in m

Response: `aXH+nnnn<CR><LF>`

The response to the attempt of setting of an invalid altitude (-100 < altitude < 5000) is

`aXHf<CR><LF>`

Example: The altitude of the installation location is 135m above sea level

*`0XH+135!`*

`0XH+135<CR><LF>`

### 19.6.11 Setting of the Local Magnetic Declination

For exact compass heading the local magnetic declination must be set.

Command: aXD+nnn.n!

nnn.n: local magnetic declination at installation site in ° *)

Response: aXD+nnn.n<CR><LF>

The response to the attempt of setting of an invalid altitude (-180.0<declination<+180.0) is aXDf<CR><LF>

Example: The declination at the installation location is -5.3°

*0XD-5.3!*

0XD-5.3<CR><LF>

*) The magnetic declination is available from various web sites, e.g. http://www.ngdc.noaa.gov/geomag-web/#declination

### 19.6.12 Message: Activation / Deactivation of Compass Correction

The correction of the wind direction by the compass bearing can be activated or deactivated.

Command: aXW<c/u>!

c: wind direction is corrected by the compass bearing

u: wind direction is not corrected

Response: aXW<c/u><CR><LF>

The response to the attempt of setting an invalid option is aXWf<CR><LF>

Example: Compass correction of wind direction is activated

*0XWc!*

0XWc<CR><LF>

### 19.6.13 Message: Setting the Power Saving Mode

For installations with limited power supply the compact weather station may be operated in power saving mode (see Chap. 35).

**Note:** Operation in power saving mode has some functional restrictions!

Command: aXL<n/s/w>!

n: Normal Operation

s: Power saving mode 1 (Heating/Fan off)

w: Power saving mode 2 (Sleep mode)

Response: aXL<n/s/w><CR><LF>

The response is followed by the station reset, i.e. the station will be offline for a few seconds.

The response to the selection of an invalid option or of an invalid combination of mode and device model is aXLf<CR><LF>

Example: The station shall be set to power saving mode 2

*0XLw!*

0XLw<CR><LF>

### 19.6.14 Message: Setting the Heating Mode

The heating of the precipitation and the wind sensors can be configured in different operation modes (see chapter 10.4). Depending on the actual variant of the compact weather station (WS200 ...WS600) only certain combinations of operating modes are available. The station evaluates the valid combinations from the station heating mode requested in the command automatically.

Command: `aXMn!`

n: Heating Operating Mode (0: Automatic, 1: Mode 1, 2: Off, 3: Eco Mode 1)

Response: `aXMnm<CR><LF>`

n: Selected Heating Mode Wind Sensor

m: Selected Heating Mode Precipitation Sensor

The response to the attempt of setting an invalid operation mode is

`aXMf<CR><LF>`

Example: A WS400-UMB shall be set to Mode 1

*`0XM1!`*

`0XM21<CR><LF>`

As the WS400-UMB does not have a wind sensor the heating mode wind is automatically set to 2 (= off).

### 19.6.15 Message: Setting of the Leaf Wetness Threshold

The parameter to be set defines the voltage threshold for the leaf wetness sensor (WS401-UMB and WS601-UMB only, see p. 58), where the leaf wetness state changes between 0 and 1. With SDI12 operation, the voltage value required for the evaluation of the correct threshold setting is retrieved with the aM6! command (see p.105).

Command: `aXB+nnn.n!`

nnn.n: threshold for leaf wetness state in mV

Response: `aXB+nnn.n<CR><LF>`

The response to the attempt of setting of an invalid threshold (200.0<=threshold<=1200.0) is

`aXBf<CR><LF>`

Example: The leaf wetness voltage measured in dry condition is 613mV. The recommended setting of the threshold is 633mV

*`0XB+633.0!`*

`0XD+633.0<CR><LF>`

#### 19.6.16 Message: Setting of the Rain Gauge Resolution

The resolution of the tipping bucket rain gauge of WS401-UMB and WS601-UMB, as well as the resolution of an optional external rain gauge connected to a model without internal precipitation measurement can be mechanically adjusted (see p. 31). The mechanical resolution must be set in the sensor configuration.

Command: `aXK+n!`

n: resolution of the rain gauge in 1/10mm, valid settings 1, 2, 5, 10 (0.1mm, 0.2mm, 0.5mm, 1.0mm)

Response: `aXK+n<CR><LF>`

The response to the attempt of setting of an invalid resolution is

`aXKf<CR><LF>`

Example: The mechanical resolution of the rain gauge is 0.2mm

*`0XK+2!`*

`0XK+2<CR><LF>`

#### 19.6.17 Message: Clearing the Absolute Precipitation Amount

The command clears the accumulated absolute precipitation amount to 0.0mm. At the same time a station reset is applied.

Command: `aXC!`

Response: `aXCok<CR><LF>`

The response is followed by the station reset, i.e. the station will be offline for a few seconds.

Example:

*`0XC!`*

`0XCok<CR><LF>`

#### 19.6.18 Message: Station Reset

The command initiates a station reset.

Command: `aXR!`

Response: `aXRok<CR><LF>`

The response is followed by the station reset, i.e. the station will be offline for a few seconds.

Example:

*`0XR!`*

`0XRok<CR><LF>`

## 19.7 Communication in Modbus Mode

For a simpler integration of WS family Compact Weather Stations into a PLC environment the Modbus communication protocol has been made available.

Measurement values are mapped to Modbus Input Registers. The range of values available is basically the same as for the UMB protocol, including different unit systems.

In the interest of simple and safe integration the use of register pairs for floating point values or 32 bit integers, which is not part of the Modbus standard, has not been applied. All measurement values are mapped to 16bit integers using suitable scaling factors.

### 19.7.1 Modbus Communication Parameters

The WSxxx-UMB can be configured for MODBUS-RTU or for MODBUS-ASCII.

The base configuration has to be done using the UMB Config Tool.

When selecting MODBUS RTU or MODBUS-ASCII with the UMB Config Tool, communication parameters 19200 Bd, even parity, will be preselected.

| | |
|---|---|
| Modbus operating modes: | MODBUS-RTU, MODBUS-ASCII |
| Baud rate: | 19200 (9600, 4800 or lower) |
| Interface Setting | 8E1, 8N1 |

**NOTE:** The Modbus communication has been tested for a poll rate of 1 sec. The proper function of the Compact Weather Station with higher Modbus poll rates has not been tested.

We suggest to set the poll rate to 10 sec or slower, as, with the exception of the channels „wind speed / wind directions fast“, which are provided for special purposes, the update rate of the data is >= 10sec. Anyway for most of the weather data significant changes have tob e expected more in the range of minutes.

### 19.7.2 Addressing

The Modbus address is deducted from the the UMB device ID (see Chap. 19.3.2).

A device with UMB device ID 1 also has the UMB address 1, etc..

The valid address range of Modbus from 1 to 247 is smaller than that of the UMB device IDs. If a UMB device ID > 247 has been selected, the Modbus address will be set to 247.

### 19.7.3 Modbus Functions

The functions of conformance class 0 and 1 have been implemented as far as they are applicable for WSxxx-UMB, i.e. all functions operating on register level.

| | | |
|---|---|---|
| | **Conformance Class 0** | |
| 0x03 | Read Holding Registers | Selected configuration settings |
| 0x16 | Write Multiple Registers | Selected configuration settings |
| | **Conformance Class 1** | |
| 0x04 | Read Input Registers | Measurement values and status information |
| 0x06 | Write Single Register | Selected configuration settings |
| 0x07 | Read Exception Status | Currently not used |
| | **Diagnostics** | |
| 0x11 | Report Slave ID | (responds also to broadcast address) |

#### 19.7.3.1 Function 0x03 Read Holding Registers

The Holding Registers are used to make a selected set of adjustable parameters available for Modbus access. As for the measurement values the parameters are mapped to 16bit integers.

| Reg. No. | Reg. Addr | Function | Values | Scale |
|---|---|---|---|---|
| 1 | 0 | Local Altitude | Altitude in m, for calculation of relative air pressure<br>Value range -100 … 5000 | 1.0 |
| 2 | 1 | Deviation | Local deviation for the correction of compass heading.<br>Value range -3599 … 3599<br>(equalling -359.9° … +359.9°) | 10.0 |
| 3 | 2 | Averaging Interval TFF | Interval for averaging and min/max evaluation in minutes<br>Value range 1 … 10 | 1.0 |
| 4 | 3 | Averaging Interval Air Pressure | Interval for averaging and min/max evaluation in minutes<br>Value range 1 … 10 | 1.0 |
| 5 | 4 | Averaging Interval Wind | Interval for averaging and min/max evaluation in minutes<br>Value range 1 … 10 | 1.0 |
| 6 | 5 | Averaging Interval Global Radiation | Interval for averaging and min/max evaluation in minutes<br>Value range 1 … 10 | 1.0 |
| 7 | 6 | Heating Mode | High-Byte: Heating Mode Wind<br>Low-Byte Heating Mode R2S<br>Value range of each byte 0 … 3<br>(Details s. 10.4) | |
| 8 | 7 | Reset abs. Rain | (Function only when writing to the register, reading will give 0 always) | |
| 9 | 8 | Station reset | (Function only when writing to the register, reading will give 0 always) | |

**Heating Modes** (see 10.5):

| | |
|---|---|
| Automatic | 0 |
| Mode 1 | 1 |
| Off | 2 |
| Eco 1 | 3 |

19.7.3.2 Function 0x06 Write Holding Register, 0x10 Write Multiple Registers

By writing into the holding registers selected parameters of the WSxxx-UMB can be adjusted through Modbus.

Register assignment see19.7.3.1

The transmitted values will be checked for plausibility. Illegal values will not be accepted and cause a Modbus exception.

When writing the value 0x3247 (12871d) to register no. 8 (reg. addr. 7) the stored absolute rain amount will be set to 0. Subsequently a station reset will be initiated.

When writing the value 0x3247 (12871d) to register no. 9 (reg. addr. 8) a station reset will be initiated.

#### 19.7.3.3 Function 0x04 Read Input Registers

The input registers are containing the measurement values of the compact weather station and the related status information.

The measurement values are mapped to the 16bit registers using scaling factors (0 … max. 65530 for unsigned values, -32762 … 32762 for signed values).

Values 65535 (0xffff) resp. 32767 are used for the indication of erroneous or not available measurement values. A more detailed specification of the error can be evaluated from the status registers.

The assignment of values to the available register addresses (0 … 124) has been arranged in a way so that the user can read the most frequently used data with few (ideally only one) register block requests

Following blocks have been defined:

- Status information
- Frequently used values which are independent of the unit system (met./ imp.) in use
- Frequently used values in metric units
- Frequently used values in imperial units
- Other measurement values

When using the metric unit system the first three blocks can the supply all data usually required with one request.

There is no difference in the register assignment between the sub types of the WS family. If, dependent on the type, some value is not available, this will be indicated by setting the register to the error value.

For detailed information about measurement ranges, units etc. please refer to the related description of the UMB channels (Chapter 6 and 19.1)

| Reg. No. | Reg. Addr. | Value (UMB Channel) | Range | Scaling Factor, Remarks |
|---|---|---|---|---|
| | | **Status Information** | | |
| 1 | 0 | Identification | High Byte: WS-Type (2,3,4,5,6)<br>Low Byte: Software Version | |
| 2 | 1 | Device Status | | |
| 3 | 2 | Sensor Status 1 | Air temperature buffer, air temperature, dew point buffer, dew point(high byte -> low byte, see table below) | Coding 4 bit per status, see below |
| 4 | 3 | Sensor Status 2 | Rel. humidity buffer, rel. humidity, abs. humidity buffer, abs. humidity(high byte -> low byte, see table below) | Coding 4 bit per status, see below |
| 5 | 4 | Sensor Status 3 | Mixing ratio buffer, mixing ration, air press. buffer, air press. (high byte -> low byte, see table below) | Coding 4 bit per status, see below |
| 6 | 5 | Sensor Status 4 | Wind, wind buffer, precipitation, compass(high byte -> low byte, see table below) | Coding 4 bit per status, see below |
| 7 | 6 | Sensor Status 5 | Global radiation buffer, global radiation, leaf wetness buffer, leaf wetness (high byte -> low byte, see table below) | Coding 4 bit per status, see below |
| 8 | 7 | Sensor Status 6 | External temperature (see table below) | |
| 9 | 8 | Reserve | | |
| 10 | 9 | | Diagnostic: run time in 10sec steps | |

| Reg. No. | Reg. Addr. | Value (UMB Channel) | Range | Scaling Factor, signed/unsigned, Remarks |
|---|---|---|---|---|
| | | **Values Independent of the Unit System** | | |
| 11 | 10 | 200 | Relative Humidity (act.) | Factor 10, s |
| 12 | 11 | 220 | Relative Humidity (min.) | Factor 10, s |
| 13 | 12 | 240 | Relative Humidity (max.) | Factor 10, s |
| 14 | 13 | 260 | Relative Humidity (avg.) | Factor 10, s |
| 15 | 14 | 305 | Rel. Air Pressure (act.) | Factor 10, s |
| 16 | 15 | 325 | Rel. Air Pressure (min.) | Factor 10, s |
| 17 | 16 | 345 | Rel. Air Pressure (max.) | Factor 10, s |
| 18 | 17 | 365 | Rel. Air Pressure (avg.) | Factor 10, s |
| 19 | 18 | 500 | Wind Direction (act.) | Factor 10, s |
| 20 | 19 | 520 | Wind Direction (min.) | Factor 10, s |
| 21 | 20 | 540 | Wind Direction (max.) | Factor 10, s |
| 22 | 21 | 580 | Wind Direction (vct.) | Factor 10, s |
| 23 | 22 | 501 | Wind Direction fast | Factor 10, s |
| 24 | 23 | 502 | Wind Direction compass corr. | Factor 10, s |
| 25 | 24 | 510 | Compass | Factor 10, s |
| 26 | 25 | 805 | Precipitation Type | Factor 1, s |
| 27 | 26 | 700 | Wind Measurement Quality | Factor 1, u |
| 28 | 27 | 900 | Global Radiation | Factor 10, s |
| 29 | 28 | 920 | Global Radiation | Factor 10, s |
| 30 | 29 | 940 | Global Radiation | Factor 10, s |
| 31 | 30 | 960 | Global Radiation | Factor 10, s |

| Reg. No. | Reg. Addr. | Value (UMB Channel) | Range | Scaling Factor, signed/unsigned Remarks |
|---|---|---|---|---|
| | | **Values in Metric Units** | | |
| 32 | 31 | 100 | Air Temperature °C (act.) | Factor 10, s |
| 33 | 32 | 120 | Air Temperature °C (min.) | Factor 10, s |
| 34 | 33 | 140 | Air Temperature °C (max.) | Factor 10, s |
| 35 | 34 | 160 | Air Temperature °C (avg.) | Factor 10, s |
| 36 | 35 | 110 | Dew Point °C (akt.) | Factor 10, s |
| 37 | 36 | 130 | Dew Point °C (min.) | Factor 10, s |
| 38 | 37 | 150 | Dew Point °C (max.) | Factor 10, s |
| 39 | 38 | 170 | Dew Point °C (avg.) | Factor 10, s |
| 40 | 39 | 111 | Wind Chill-Temperature °C | Factor 10, s |
| 41 | 40 | 112 | Heating Temperature Wind °C | Factor 10, s |
| 42 | 41 | 113 | Heating Temperature R2S °C | Factor 10, s |
| 43 | 42 | 400 | Wind Speed m/s (akt.) | Factor 10, s |
| 44 | 43 | 420 | Wind Speed m/s (min.) | Factor 10, s |
| 45 | 44 | 440 | Wind Speed m/s (max.) | Factor 10, s |
| 46 | 45 | 460 | Wind Speed m/s (avg.) | Factor 10, s |
| 47 | 46 | 480 | Wind Speed m/s (vct.) | Factor 10, s |
| 48 | 47 | 401 | Wind Speed fast m/s | Factor 10, s |
| 49 | 48 | 620 | Precipitation abs. mm | Factor 100, u, limited to 655.34mm |
| 50 | 49 | 620 | Precipitation diff. mm | Factor 100, u, limited to 100.00mm |
| 51 | 50 | 820 | Precipitation intens. mm/h | Factor 100, u, limited to 200.00mm/h |

| Reg. No. | Reg. Addr. | Value (UMB Channel) | Range | Scaling Factor, signed/unsigned Remarks |
|---|---|---|---|---|
| | | **Values in US Units** | | |
| 52 | 51 | 105 | Air Temperature °F (act.) | Factor 10, s |
| 53 | 52 | 125 | Air Temperature °F (min.) | Factor 10, s |
| 54 | 53 | 145 | Air Temperature °F (max.) | Factor 10, s |
| 55 | 54 | 165 | Air Temperature °F (avg.) | Factor 10, s |
| 56 | 55 | 115 | Dew Point °F (act.) | Factor 10, s |
| 57 | 56 | 135 | Dew Point °F (min.) | Factor 10, s |
| 58 | 57 | 155 | Dew Point °F (max.) | Factor 10, s |
| 59 | 58 | 175 | Dew Point °F (avg.) | Factor 10, s |
| 60 | 59 | 116 | Wind Chill-Temperature °F | Factor 10, s |
| 61 | 60 | 117 | Heating Temperature Wind °F | Factor 10, s |
| 62 | 61 | 118 | Heating Temperature R2S °F | Factor 10, s |
| 63 | 62 | 410 | Wind Speed mph (act.) | Factor 10, s |
| 64 | 63 | 430 | Wind Speed mph (min.) | Factor 10, s |
| 65 | 64 | 450 | Wind Speed mph (max.) | Factor 10, s |
| 66 | 65 | 470 | Wind Speed mph (avg.) | Factor 10, s |
| 67 | 66 | 490 | Wind Speed mph (vct.) | Factor 10, s |
| 68 | 67 | 411 | Wind Speed fast mph | Factor 10, s |
| 69 | 68 | 640 | Precipitation abs. In | Factor 1000, u, limited to 25.800 in |
| 70 | 69 | 640 | Precipitation diff. in | Factor 10000, u, limited to 3.9370in |
| 71 | 70 | 840 | Precipitation Intens. in/h | Factor 10000, u, limited to 6.5534 in |

| **Reg. No.** | **Reg. Addr.** | **Value (UMB Channel)** | **Range** | **Scaling Factor, signed/unsigned, Remarks** |
|---|---|---|---|---|
| | | **Further Values** | | |
| | 71 | 205 | Absolute Humidity (act.) | Factor 10, s |
| 73 | 72 | 225 | Absolute Humidity (min.) | Factor 10, s |
| 74 | 73 | 245 | Absolute Humidity (max.) | Factor 10, s |
| 75 | 74 | 265 | Absolute Humidity (avg.) | Factor 10, s |
| 76 | 75 | 210 | Mixing Ratio (act.) | Factor 10, s |
| 77 | 76 | 230 | Mixing Ratio (min.) | Factor 10, s |
| 78 | 77 | 250 | Mixing Ratio (max.) | Factor 10, s |
| 79 | 78 | 270 | Mixing Ratio (avg.) | Factor 10, s |
| 80 | 79 | 300 | Abs. Air Pressure (act.) | Factor 10, s |
| 81 | 80 | 320 | Abs. Air Pressure (min.) | Factor 10, s |
| 82 | 81 | 340 | Abs. Air Pressure (max.) | Factor 10, s |
| 83 | 82 | 360 | Abs. Air Pressure (avg.) | Factor 10, s |
| 84 | 83 | 405 | Wind Speed km/h (act.) | Factor 10, s |
| 85 | 84 | 425 | Wind Speed km/h (min.) | Factor 10, s |
| 86 | 85 | 445 | Wind Speed km/h (max.) | Factor 10, s |
| 87 | 86 | 465 | Wind Speed km/h (avg.) | Factor 10, s |
| 88 | 87 | 485 | Wind Speed km/h (vct.) | Factor 10, s |
| 89 | 88 | 415 | Wind Speed kts (act.) | Factor 10, s |
| 90 | 89 | 435 | Wind Speed kts (min.) | Factor 10, s |
| 91 | 90 | 455 | Wind Speed kts (max.) | Factor 10 , s |
| 92 | 91 | 475 | Wind Speed kts (avg.) | Factor 10, s |
| 93 | 92 | 495 | Wind Speed kts (vct.) | Factor 10, s |
| 94 | 93 | 406 | Wind Speed fast km/h | Factor 10, s |
| 95 | 94 | 416 | Wind Speed fast kts | Factor 10, s |
| 96 | 95 | 403 | Wind Speed Std. Dev. m/s | Factor 100, s |
| 97 | 96 | 413 | Wind Speed Std. Dev. mph | Factor 100, s |
| 98 | 97 | 503 | Wind Dir. Standard Dev. | Factor 100, s |
| 99 | 98 | 114 | Wet Bulb Temp. °C (act) | Factor 10, s |
| 100 | 99 | 119 | Wet Bulb Temp. °F (act) | Factor 10, s |
| 101 | 100 | 215 | Specific Enthalpy (act) | Factor 10, s |
| 102 | 101 | 310 | Air Density (act) | Factor 1000, s |
| 103 | 102 | 710 | Leaf Wetness mV (act) | Factor 1, s |
| 104 | 103 | 730 | Leaf Wetness mV (min) | Factor 1, s |
| 105 | 104 | 750 | Leaf Wetness mV (max) | Factor 1, s |
| 106 | 105 | 770 | Leaf Wetness mV (avg) | Factor 1, s |
| 107 | 106 | 711 | Leaf Wetness State (act) | Factor 1, s |
| 108 | 107 | 101 | External Temperature °C (act) | Factor 10, s |
| 109 | 108 | 109 | External Temperature °F (act) | Factor 10, s |
| | | Reserved | | |

**Sensor Status:**

Each register holds 4 sensor status coded with 4 bits per status, so that together they build one 16bit number. The sequence defined in the table above is to understand as from most significant half byte to least significant half byte. Most of the sensors have two status values, one for the sensor itself and the current measurement value, another one for the buffer, from which average, min. And max values are evaluated.

Assignment of Status Information to Status Register

| Register | Byte | Half-Byte | Status |
|---|---|---|---|
| Sensor Status 1 | High | High | Temperature Buffer |
| | | Low | Temperature |
| | Low | High | Dewpoint Buffer |
| | | Low | Dewpoint |
| Sensor Status 2 | High | High | Rel. Humidity Buffer |
| | | Low | Rel. Humidity |
| | Low | High | Abs. Humidity Buffer |
| | | Low | Abs. Humidity |
| Sensor Status 3 | High | High | Mixing Ratio Buffer |
| | | Low | Mixing Ratio |
| | Low | High | Air Pressure Buffer |
| | | Low | Air Pressure |
| Sensor Status 4 | High | High | Wind Buffer |
| | | Low | Wind |
| | Low | High | Precipitation |
| | | Low | Compass |
| Sensor Status 5 | High | High | Global Radiation Buffer |
| | | Low | Global Radiation |
| | Low | High | Leaf Wetness Buffer |
| | | Low | Leaf Wetness |
| Sensor Status 6 | High | High | |
| | | Low | External Temperature |
| | Low | High | |
| | | Low | |

**Example Sensor Status 1**:

Temperature buffer status, temperature status, dewpoint buffer status, dewpoint status

| High Byte | | Low Byte | |
|---|---|---|---|
| High | Low | High | Low |
| Temperature-Buffer | Temperature | Dew point-Buffer | Dew point |
| 5 | 3 | 0 | 7 |

The example values above (for illustration only, the given combination will not occur in reality) are combined to the register value 0x5307 = 21255.

The single status are retrieved from the register as integer part of

Status 1 = register / 4096

Status 2 = (register / 256) AND 0x000F

Status 3 = (register / 16) AND 0x000F

Status 4 = register AND 0x000F

Following table shows the status coding:

Coding of Sensor Status:

| Sensor State | Code |
|---|---|
| OK | 0 |
| UNGLTG_KANAL | 1 |
| E2_CAL_ERROR<br>E2_CRC_KAL_ERR<br>FLASH_CRC_ERR<br>FLASH_WRITE_ERR<br>FLASH_FLOAT_ERR | 2 |
| MEAS_ERROR,<br>MEAS_UNABLE | 3 |
| INIT_ERROR | 4 |
| VALUE_OVERFLOW<br>CHANNEL_OVERRANGE<br>VALUE_UNDERFLOW<br>CHANNEL_UNDERRANGE | 5 |
| BUSY | 6 |
| Other Sensor State | 7 |

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**TÜV RHEINLAND ENERGY GMBH**

# ADDENDUM

Addendum to TÜV test report no. 936/21227195/C dated 12 October 2016 on performance testing of the Fidas® 200 S, Fidas® 200 and Fidas® 200 E for suspended particulate matter $PM_{2.5}$ and $PM_{10}$ manufactured by PALAS GmbH

TÜV report: 936/21239834/B
Cologne, 7 September 2018

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**TÜV Rheinland Energy GmbH and its Ambient Air Quality department in particular** is accredited for the following activities:

- Determination of emissions and ambient air quality affected by air pollutants and odorous substances
- Inspection of correct installation, functionality and calibration of continuous emission monitoring systems including systems for data evaluation and remote monitoring of emissions,
- Measurements in combustion chambers;
- Performance testing of measuring systems for continuous monitoring of emissions and air quality as well as electronic data evaluation and remote monitoring systems for emissions
- Determination of the stack height and air quality forecasts for hazardous and odorous substances;
- Determination of emissions and ambient air quality affected by noise and vibration, determination of
- sound power levels and noise measurements at wind turbines;

**according to EN ISO/IEC 17025.**

The accreditation will expire on 10-12-2022. DAkkS registration number: D-PL-11120-02-00.



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# 1. Summary Overview

TÜV Rheinland Energy GmbH was commissioned by PALAS GmbH to carry out performance testing for the Fidas® 200 S, Fidas® 200 and Fidas® 200 E ambient air monitors for suspended particulate matter $PM_{2.5}$ and $PM_{10}$.

- VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated September 2010 or June 2002 respectively.
- VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated September 2010 or August 2004 respectively.
- EN 12341 "Air Quality - Determination of the $PM_{10}$ fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341 dated 1998
- European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005
- Guideline "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated January 2010

Based on the requirements for testing stated above, the Fidas® 200 S, Fidas® 200 and Fidas® 200 E for $PM_{10}$ and $PM_{2.5}$ suspended particulate matter have already been performance tested and publically announced as such as follows:

- Fidas® 200 S for suspended particulate matter $PM_{10}$ and $PM_{2.5}$, UBA announcement dated 27 February 2014 (BAnz AT 01.04.2014 B12, chapter IV number 5.1) – original announcement
- Fidas® 200 S and Fidas® 200 for suspended particulate matter $PM_{10}$ and $PM_{2.5}$, UBA announcement dated 25 February 2015 (BAnz AT 02.04.2015 B5, chapter IV 14th notification) – notification regarding the new instrument version Fidas® 200, communication of design changes, new form of presentation for the software and new software version.

- Fidas® 200 S and Fidas® 200 for suspended particulate matter $PM_{10}$ and $PM_{2.5}$, UBA announcement dated 22 July 2015 (BAnz AT 26.08.2015 B4, chapter III number 2.1) – supplementary testing (extended equivalence testing, communication of design changes, inclusion of MonoDust 1500 as a test standard).

- Fidas® 200 S, Fidas® 200 and Fidas® 200 E for suspended particulate matter $PM_{10}$ and $PM_{2.5}$, UBA announcement dated 18 February 2016 (BAnz AT 14.03.2016 B7, chapter V 6th notification) – notification regarding the correction of a mistake in the test report and the manual, the approval of an alternative weather station, type WS300-UMB, approval of an alternative, extended IADS, a new instrument version Fidas® 200 E (with external sensor) and a new software version

- Fidas® 200 E, Fidas® 200 and Fidas® 200 S for suspended particulate matter $PM_{10}$ and $PM_{2.5}$ fractions, UBA announcement dated 14 July 2016 (BAnz AT 01.08.2016 B11, chapter V 35th notification) – notification regarding the IADS temperature during sensitivity tests of the particle sensor, communication of design changes, new software version

- Fidas® 200 S, Fidas® 200 and Fidas® 200 E for suspended particulate matter $PM_{10}$ and $PM_{2.5}$, UBA announcement dated 22 February 2017 (BAnz AT 15.03.2017 B6, chapter V 10th notification) – notification regarding the extension of the test interval for the sensitivity of the particle sensor to 3 months instead of 1 month, communication of design changes, correction of a mistake in the test report and new software version

- Fidas® 200 E, Fidas® 200 and Fidas® 200 S for suspended particulate matter $PM_{10}$ and $PM_{2.5}$ fractions, UBA announcement dated 13 July 2017 (BAnz AT 31.07.2017 B12, chapter II 30th notification) – notification regarding a new software version.

Standard EN 16450 "Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter ($PM_{10}$; $PM_{2,5}$)" has been available since July 2017. This standard, for the first time, harmonises requirements for the performance testing of automated measuring systems for the determination of dust concentrations ($PM_{10}$ and $PM_{2.5}$) on a European level and will form the basis for the approval of such AMS in the future.

The present addendum presents an assessment of the Fidas® 200 measuring system (instrument versions Fidas® 200 E, Fidas® 200 and Fidas® 200 S) regarding compliance with the requirements defined in standard EN 16450 (July 2017).

As most of the performance characteristics and performance criteria defined in chapter 7 of standard EN 16450 (July 2017) have been tested and assessed already in the context of the original performance test, the majority of test results can be taken from and/or re-assessed on the basis of the original test report. We were able to re-assess some of the test criteria using data from the original report on performance testing or from tests which have been performed in the context of the controlled development of the AMS in accordance with standard series EN 15267. Entirely new tests were performed only for test items "7.4.8 Dependence of span on supply voltage" and "7.4.9 Dependence of reading on water vapour concentration" in Summer 2017.

With the exception of test items

6.1 7 Dependence of measured value on surrounding temperature (7.4.7).

6.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7) and

6.1 4 Flow rate accuracy (7.4.4).

All tests were performed with instrument version Fidas® 200 S. These criteria were specifically tested for various temperature ranges (-20°C to +50°C for Fidas® 200 S (outdoor version), +5°C to +40°C for Fidas® 200 and Fidas® 200 E (installation in temperature controlled environments).

With the exception of the three test criteria singled out above, all test results obtained as well as the conclusions drawn and statements made fully apply to all three instrument versions.

On its publication, this addendum becomes an integral part of TÜV Rheinland test report no. 936/21227195/C dated 12 October 2016 and will be available at www.qal1.de.

The Fidas® 200 S, Fidas® 200 and Fidas® 200 E measuring systems use scattered light with a combination of a polychromatic LED and 90° scattering detection to determine dust concentrations. A pump sucks in ambient air via a Sigma2 sampling inlet (4.8 l/min @ 25 °C and 1013 hPa). The air is then transported to the measuring system via a sampling tube. A heater for the IADS (Intelligent Aerosol Drying System) is integrated in the sampling tube to prevent condensation effects on particles. The aerosol passes through the aerosol sensor immediately downstream of the sampling tube. This is where both the particle size and the number of particles is measured in real time, simultaneously but separately relying on the scattered-light method.

The tests were performed in the laboratory and in a several-months long field test.

The several-months long field test was performed at the sites listed in Table 1.

Table 1: Description of the test sites

| | Cologne Parking lot, Summer | Cologne Parking lot, Winter | Bonn, Crossroads, Winter | Bornheim, Motorway parking area Summer |
|---|---|---|---|---|
| Period | 05/2012–09/2012 | 11/2012–02/2013 | 02/2013–05/2013 | 05/2013–07/2013 |
| Number of measurement pairs: Candidates | 101 | 66 | 60 | 58 |
| Description | Urban background | Urban background | Affected by traffic | Rural area + motorway |
| Classification of ambient air pollution | low to average | average to high | average to high | Low |

Additional equivalence tests were performed in the context of two comparison campaigns in the UK as listed in Table 2:

Table 2: Description of the test sites (UK)

| | Teddington, Winter | Teddington, Summer |
|---|---|---|
| Period | 02/2014–04/2014 | 04/2014–06/2014 |
| Number of measurement pairs: Candidates | 45 | 45 |
| Description | Urban background | Urban background |
| Classification of ambient air pollution | average | average |

The following table provides an overview of the equivalence tests performed.

Table 3: Results of equivalent testing (raw data)

| Comparison campaigns | Evaluation algorithm | $PM_x$ | Slope | Axis intercept | All Data sets $W_{CM}$<25 % Raw data | Calibration yes/no | All Data sets $W_{CM}$<25% cal. Data |
|---|---|---|---|---|---|---|---|
| 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 |

* Given the significance of the slope or the axis intercept, a calibration became necessary.

## 1.1 Summary report on test results

### Summary of test results in accordance with standard EN 16450 (July 2017)

| Performance criterion | Requirement | Test result | satis-fied | Page |
|---|---|---|---|---|
| 1 Measuring ranges | 0 µg/m³ to 1000 µg/m³ as a 24-hour average value<br>0 µg/m³ to 10,000 µg/m³ as a 1-hour average value, if applicable | The instrument's upper limit of measurement is at ~4 000 particles/cm³ (at a coincidence error of 10%) which roughly corresponds to a maximum concentration of 0–10 000 µg/m³ (measured against SAE Fine standardised dust). | yes | 64 |
| 2 negative signals | Shall not be suppressed | While the AMS is able to display negative readings directly and via the various outputs, they should not be expected given instrument design and the measurement principle applied. | yes | 65 |
| Zero level and detection limit | Zero level: ≤ 2.0 µg/m³<br>Detection limit: ≤ 2.0 µg/m³ | The zero level and the detection limit resulted from the tests of both instruments both for PM10 and PM2.5 and were < 0.1 µg/m³. | yes | 66 |
| 4 Flow rate accuracy (7.4.4) | ≤ 2.0% | The relative difference determined for the mean of the measuring results at flow rates at -20°C and at +50°C did not exceed -1.99% (Fidas® 200 S) and 1.08% at flow rates at +5°C to +40°C (Fidas® 200/Fidas® 200 E). | yes | 68 |
| Constancy of sample flow rate (7.4.5) | ≤ 2.0% sampling flow (averaged flow)<br>≤ 5% rated flow (instantaneous flow) | The 24h-averages deviate from their rated values by less then ± 2.0%, all instantaneous values deviate by less than ± 5%. | yes | 70 |
| 6 Leak tightness of the sampling system (7.4.6) | ≤ 2.0% of sample flow rate | The criterion for passing the leak test as specified by the AMS manufacturer – maximum flow rate of 0 ± 0.1 l/min when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness. The maximum leak rate determined at 0.04 l/min did not exceed 2.0% of the nominal sample flow rate of 4.8 l/min. | yes | 73 |

| Performance criterion | Requirement | Test result | satis-fied | Page |
|---|---|---|---|---|
| 7 Dependence of measured value on surrounding temperature (7.4.7) | ≤ 2.0 µg/m³ | The ambient air temperature range tested at the site of installation was -20°C to +50°C (Fidas® 200 S) and +5°C to +40°C (Fidas® 200/Fidas® 200 E). Taking into account the readings provided by the instrument, the maximum effect of the surrounding temperature on the zero point for all three instrument versions did not exceed 0.1 µg/m³ both for PM10 and PM2.5. | yes | 75 |
| 8 Dependence of measured value (span) on surrounding temperature (7.4.7) | ≤ 5% from the value at the nominal test temperature | The ambient air temperature range tested at the site of installation was -20°C to +50°C (Fidas® 200 S) and +5°C to +40°C (Fidas® 200/Fidas® 200 E). Deviations at the reference point did not exceed 4.9% for PM2.5 and 4.5% for PM10 (Fidas® 200 S) as well as -1.9% for PM2.5 and -1.9% for PM10 (Fidas® 200) and -4.8% for PM2.5 and -4.6% for PM10 (Fidas® 200 E). | yes | 80 |
| 9 Dependence of span on supply voltage (7.4.8) | ≤ 5% from the value at the nominal test voltage | Voltage variations did not cause deviations exceeding -0.4% for PM2.5 and -0.3% for PM10 as a percentage of the initial voltage of 230V. | yes | 85 |
| 10 Effect of failure of mains voltage | Instrument parameters shall be secured against loss. On return of main voltage the instrument shall automatically resume functioning. | Buffering protects all instrument parameters against loss. On return of mains voltage the instrument returns to operating mode and automatically resumes measuring once it has reached the status “device ready”. | yes | 87 |

| Performance criterion | Requirement | Test result | satis-fied | Page |
|---|---|---|---|---|
| 11 Dependence of reading on water vapour concentration (**7.4.9)** | ≤ 2.0 µg/m³ in zero air | Differences between readings determined at relative humidifies of 40% and 90% did not exceed 0.1 µg/m³. Various water vapour concentrations were not observed to cause any effect on zero readings. | yes | 88 |
| 12 Zero checks (7.5.3) | Absolute value ≤ 3.0 µg/m³ | The maximum absolute measured value at zero was determined at 0.1 µg/m³ for PM2.5 and PM10. | yes | 90 |
| 13 Recording of operational parameters (7.5.4) | Measuring systems shall be able to provide data of operational states for telemetric transmission of – at minimum – the following parameters:<br>Flow rate<br>pressure drop over sample filter (if relevant)<br>Sampling time<br>Sampling volume (if relevant);<br>Mass concentration of relevant PM fraction(s)<br>Ambient temperature<br>Exterior air pressure<br>Air temperature in measuring section<br>temperature of sampling inlet if heated inlet is used | The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232). The instrument provides operating statuses and all relevant parameters. | yes | 95 |
| 14 Daily averages (7.5.5) | The AMS shall allow for the formation of daily averages or values. | It is possible to form valid daily averages. | yes | 97 |

| Performance criterion | Requirement | Test result | satis-fied | Page |
|---|---|---|---|---|
| 15 Availability (7.5.6) | At least 90%. | The availability for SN 0111 was 99.4%, for SN 0112 it was 99.1%. | yes | 98 |
| 16 Between-AMS uncertainty ubs,AMS (7.5.8.4) | ≤ 2.5 µg/m³ | At no more than 0.85 µg/m³ for $PM_{2.5}$ and no more than 1.19 µg/m³ for $PM_{10}$, the uncertainty between the candidate $u_{bs}$ remains well below the permissible maximum of 2.5 µg/m³. | yes | 101 |
| 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8) | ≤ 25% at the level of the relevant limit value related to 24-hour average results (if required, after calibration) | Without the need for any correction factors, the expanded uncertainties WAMS were below the expanded, relative uncertainty Wdqo defined for fine dust at 25% for PM2.5 and PM10 for all data sets observed. The uncertainties WAMS determined for PM2.5 remained below the expanded, relative uncertainty Wdqo specified for fine dust at 25% for all data sets observed with the exception of Bornheim, summer. Correction factors shall be applied in accordance with item 6.1 17 Use of correction factors/terms . | no | 113 |
| 17 Use of correction factors/terms (7.5.8.5–7.5.8.8) | After the calibration:<br>≤ 25% at the level of the relevant limit value related to the 24-hour average results | After the use of correction factors, the candidate systems met the requirements for data quality of air quality monitors for all data sets, both for $PM_{2.5}$ and for $PM_{10}$. Requirements for $PM_{10}$ have been met without the need for a correction factor. The correction of the slope and the axis intercept however, have led to a further (slight) improvement of the expanded uncertainty. | yes | 140 |

| Performance criterion | Requirement | Test result | satis-fied | Page |
|---|---|---|---|---|
| 18 Maintenance interval (7.5.7) | At least 14 d | The maintenance interval is defined by the need for regular inspections of the particle sensor using CalDust 1100 or MonoDust 1500 and is at three months. | yes | 148 |
| 19 Automatic diagnostic check (7.5.4) | Shall be possible for the AMS | All instrument functions described in the operation manual are available and can be activated. The current operating status is continuously monitored and any issues will be flagged via a series of different warning messages. Data on monitored parameters incl. automated calibration checks are collected during data recording. | yes | 152 |
| 20 Checks of temperature sensors, pressure and/or humidity sensors | Shall be checked for the AMS to be within the following criteria<br>± 2°C<br>± 1kPa<br>± 5 % RH | It is easy to check and adjust the sensors for determining ambient temperature, ambient pressure and relative humidity on-site. It is also possible to check the temperature sensor of the IADS (humidity compensation). This, however, requires exposition of the entire IADS system in a controlled temperature environment and is therefore usually not possible on-site without disassembly of the sampling system. | yes | 153 |

# 2. Task Definition

## 2.1 Nature of the test

PALAS GmbH commissioned TÜV Rheinland Energy GmbH to carry out performance and supplementary testing of the Fidas® 200 S, Fidas® 200 and Fidas® 200 E measuring systems.

The Fidas® 200 S, Fidas® 200 and Fidas® 200 E for $PM_{10}$ and $PM_{2.5}$ suspended particulate matter have already been performance tested and publically announced as such.

The present addendum presents an assessment of the Fidas® 200 S, Fidas® 200 and Fidas® 200 E measuring systems regarding compliance with the requirements for automated measuring systems defined in the new standard EN 16450 (July 2017).

## 2.2 Objectives

The measuring systems are designed to determine the $PM_{10}$ and $PM_{2.5}$ fractions of dust concentrations in the range between 0–10 000 µg/m³ (4 000 P/cm³ for a 10% coincidence error).

The existing performance test had been performed in respect of the requirements applicable at the time of testing while at the same time taking into account the latest developments.

The test was performed on the basis of the following standards:

- VDI Guideline 4202, Part 1 – “Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants,” dated September 2010 or June 2002 respectively. [1]
- VDI Guideline 4203, part 3 – “Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants”, dated September 2010 or August 2004 respectively. [2]
- [3] EN 12341 “Air Quality - Determination of the $PM_{10}$ fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods“, German version EN 12341: 1998, [3]
- European standard EN 14907, “Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter”, German version EN 14907: 2005 [4]
- Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version dated January 2010 [5]

Since July 2017, the European Standard

- Standard EN 16450 “Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter ($PM_{10}$; $PM_{2,5}$), German version EN 16450:2017 [9]

has been available. This standard, for the first time, harmonises requirements for the performance testing of automated measuring systems for the determination of dust concentrations ($PM_{10}$ and $PM_{2.5}$) on a European level and will form the basis for the approval of such AMS in the future.

The present addendum presents an assessment of the Fidas® 200 measuring system (instrument versions Fidas® 200 E, Fidas® 200 and Fidas® 200 S) regarding compliance with the requirements defined in standard EN 16450 (July 2017).

As most of the performance characteristics and performance criteria defined in chapter 7 of standard EN 16450 (July 2017) have been tested and assessed already in the context of the original performance test, the majority of test results can be taken from and/or re-assessed on the basis of the original test report. We were able to re-assess some of the test criteria using data from the original report on performance testing or from tests which have been performed in the context of the controlled development of the AMS in accordance with standard series EN 15267. Entirely new tests were performed only for test items “7.4.8 Dependence of span on supply voltage” and “7.4.9 Dependence of reading on water vapour concentration” in Summer 2017.

All tests except for 6.1 7 Dependence of measured value on surrounding temperature (7.4.7), 6.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7) and 6.1 4 Flow rate accuracy (7.4.4) were performed with instrument version Fidas® 200 S. These criteria were specifically tested for various temperature ranges (-20°C to +50°C for Fidas® 200 S (outdoor version), +5°C to +40°C for Fidas® 200 and Fidas® 200 E (installation in temperature controlled environments).

With the exception of the three test criteria singled out above, all test results obtained as well as the conclusions drawn and statements made fully apply to all three instrument versions.

On its publication, this addendum becomes an integral part of TÜV Rheinland test report no. 936/21227195/C dated 12 October 2016 and will be available at www.qal1.de.

# 3. Description of the AMS tested

## 3.1 Measuring principle

The Fidas® 200 S, Fidas® 200 and Fidas® 200 E are optical aerosol sensors which determine the particle size using scattered light on single particles in accordance with Lorenz-Mie.

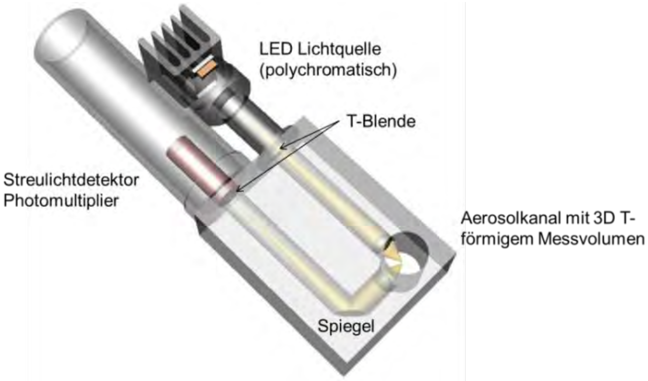



Figure 1: Set-up of the Fidas® measuring system's sensor

Particles move separately through a measurement volume which is optically separated and homogeneously illuminated by polychromatic light.

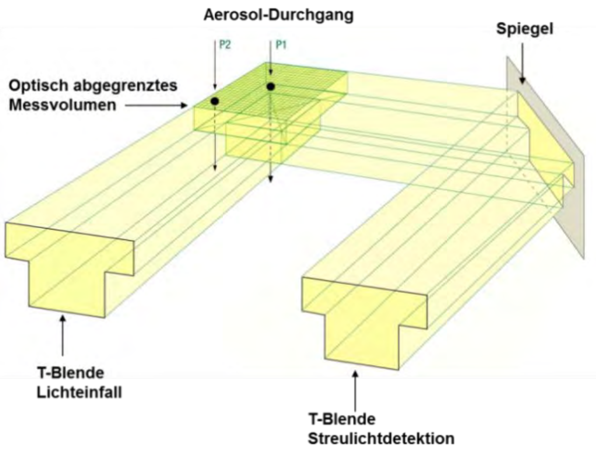



Figure 2: Illustration of the T-aperture

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.

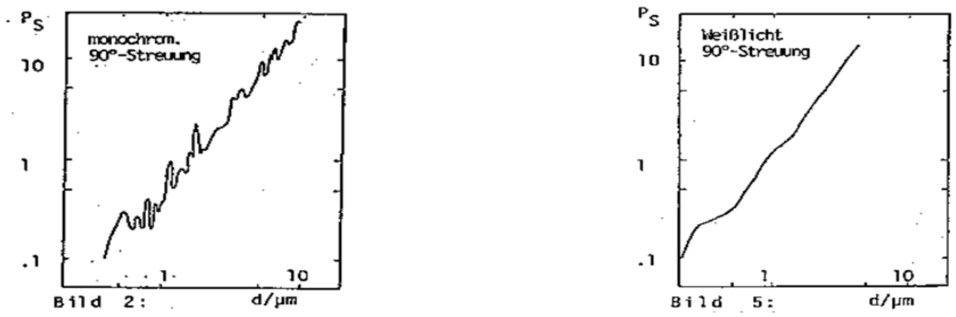



Figure 3: Calibration curve for 90° scattered light detection with monochromatic light source (left) and polychromatic light source (right)

Each particle generates a scattered light impulse, detected at an angle of 85° to 95° degrees. The number concentration is deducted from the number of scattered light impulses. The amplitude (height) of the scattered light impulse is a measure for the particle size diameter. Furthermore, the signal length is measured.

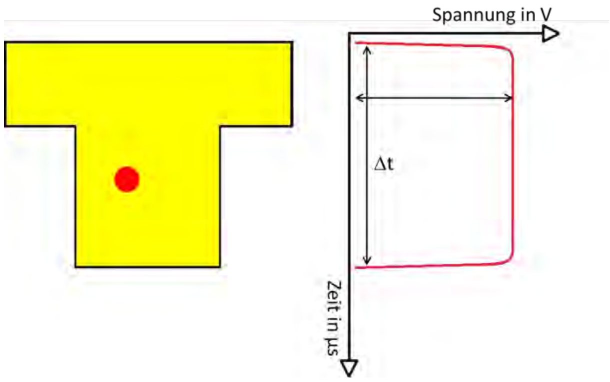



Figure 4: Measurement of scattered light impulse at the single particle Amplitude and signal length are measured

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 5, 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® (see Figure 5, blue curve).

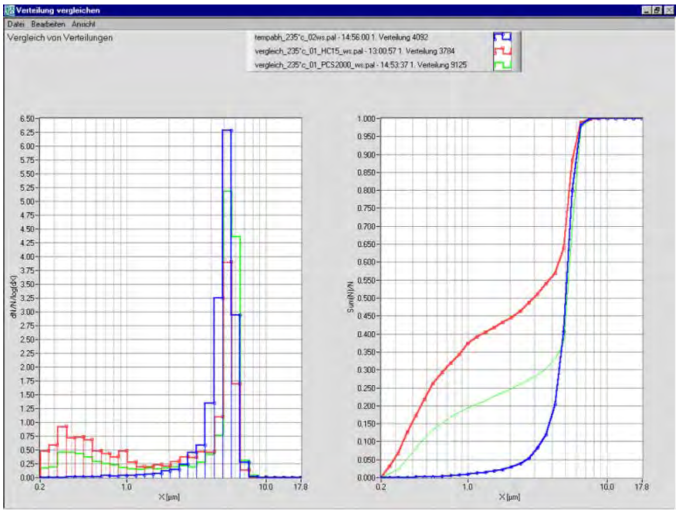



Figure 5: Comparison of an optical scattered light spectrometer with simple rectangular aperture (HC15, red) with an optical scattered light spectrometer with T-aperture (welas®, blue) by using monodisperse particles in the size of 5 µm.

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 air quality 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. This way, smaller particles, measured roadside in high concentration, can be reproduced better (see Figure 6)

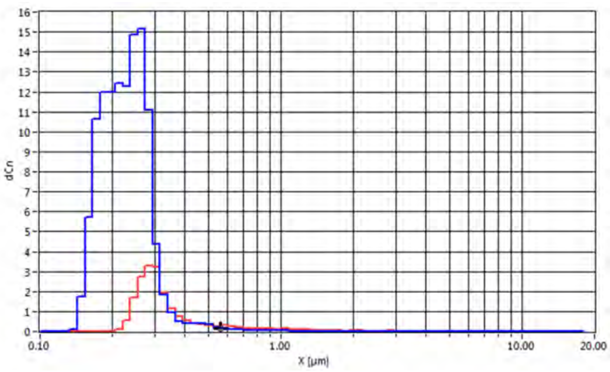



Figure 6: Measurements with the Fidas® roadside (size range from 0.18 µm, blue curve) compared to a different optical measurement system (size range from 0.25 µm, red curve)

The Fidas® 200 S, Fidas® 200 and Fidas® 200 E systems are 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

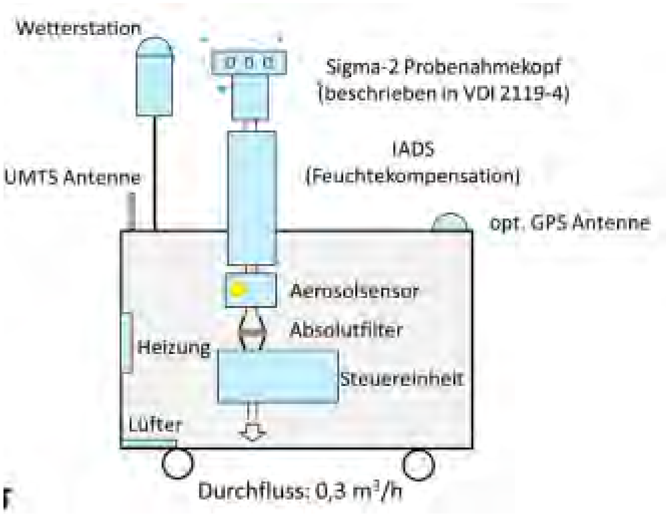
Besides the PM-fractions, which are measured continuously and simultaneously, the measured particle number concentration and particle size distribution with a high time and size resolution (up to 128 size classes) are available.

This additional piece of 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).

## 3.2 Functioning of the measuring system

At a flow rate of 4.8 l/min (at 25°C and 1013hPa), the particle sample passes through the Sigma2 sampling head (as described in VDI 2119, part 4) and reaches the sampling tube which connects the sampling head to the Fidas control unit (or to the external sensor unit in the case of the Fidas® 200 E). In order to avoid water condensation effects especially at high ambient humidity, the IADS humidity compensation module (available as standard or extended version) is used. 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 IADS module is controlled via the Fidas firmware. After passing through the IADS module, the particle sample finally reaches the aerosol sensor which is were the actual measurement takes place. Downstream of the aerosol sensor, the sample passes through an absolute filter which may be used for further analyses of the collected aerosol. The Fidas® 200 S, Fidas® 200 and Fidas® 200 E measuring systems also come with an integrated weather station (type Lufft WS300-UMB for recording parameters such as wind speed, wind direction, precipitation rates, type of precipitation, temperature, humidity and pressure; the alternative is the Lufft WS600-UMB for recording temperature, humidity and pressure). The measuring system's control unit does not only provide the necessary electronics for operating the system, but also 2 sampling pumps, which are connected in parallel. If one pump fails, the other one takes over to ensure smooth operation.

Figure 7 shows the schematic set-up of the Fidas® 200 S, Figure 8 presents the individual stages of measurement in chronological order.




Key

Wetterstation: weatherstation

Sigma-2 Probenahmekopf: Sigma-2 sampling head (described in VDI 2119-4)
UMTS Antenne: UMTS antenna
IADS (Feuchtekompensation): IADS (drying system)
Opt. GPS Antenne: opt. GPS antenna
Aerosolsensor: aerosol sensor
Absolutfilter: absolute filter
Heizung: heating
Steuereinheit: control unit
Lüfter: fan

Figure 7: Schematic set-up of the Fidas® 200 S

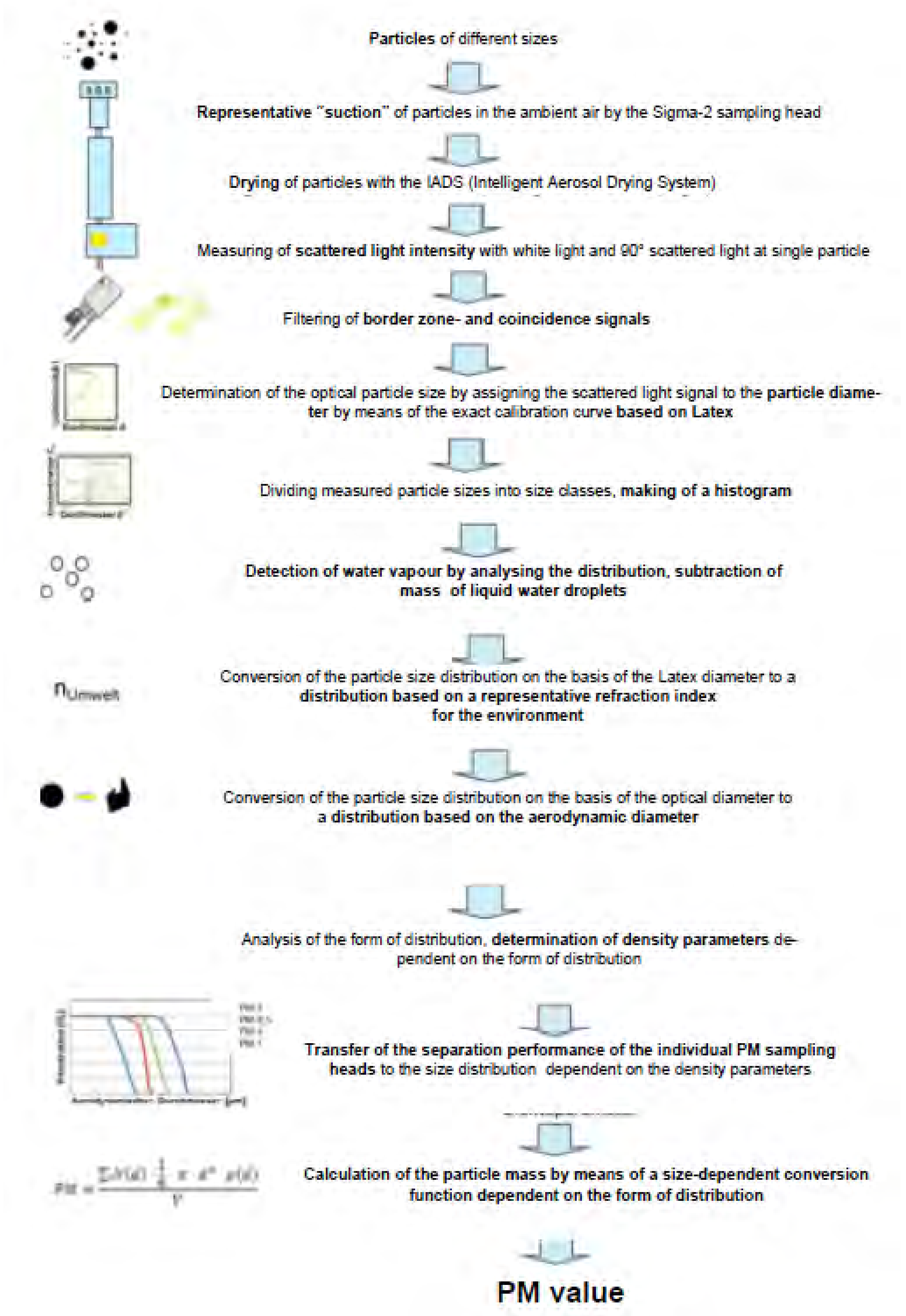



Figure 8: Overview of the individual stages of measurement, Fidas® 200 S and Fidas® 200

The Fidas® 200 S, Fidas® 200 and Fidas® 200 E measuring systems store data as particle size distributions and particle count distribution in the raw-format. To determine mass concentration values, the stored raw data will have to be converted with the help of evaluation algorithm. To this effect, a size-dependent and weighted algorithm converts particle size and counts into mass concentrations. Algorithm PM_ENVIRO_0011 was used for conversion in the context of performance testing.

## 3.3 AMS scope and set-up

The Fidas® 200 S, Fidas® 200 and Fidas® 200 E measuring systems for suspended particulate matter use the scattered light method as their measuring principle.

The measuring system is available as instrument versions Fidas® 200 S (for use outdoors, incl. protective enclosure), Fidas® 200 (for installation at temperature controlled sites such as air-conditioned measurement stations) and as Fidas® 200 E (as Fidas® 200, but with external sensor unit). Figure 9 to Figure 11 present the three instrument versions.

Figure 9: Fidas® 200 S

Figure 10: Fidas® 200

Figure 11: Fidas® 200 E

The tested AMS consists of

- Sigma-2 sampling head
- the sampling tube with IADS humidity compensation (standard or extended version)
- the Fidas® control unit c/w integrated aerosol sensor (Fidas® 200 S and Fidas® 200 E) or with external sensor unit (Fidas® 200 E)
- the compact WS300-UMB or WS600-UMB weather station,
- the UMTS receiver (optional),
- a weather-proof protective enclosure (IP65, Fidas® 200 S only),
- the required connecting tubes and cables,
- a bottle of CalDust 1100 or MonoDust 1500 and
- the operation manuals in German.

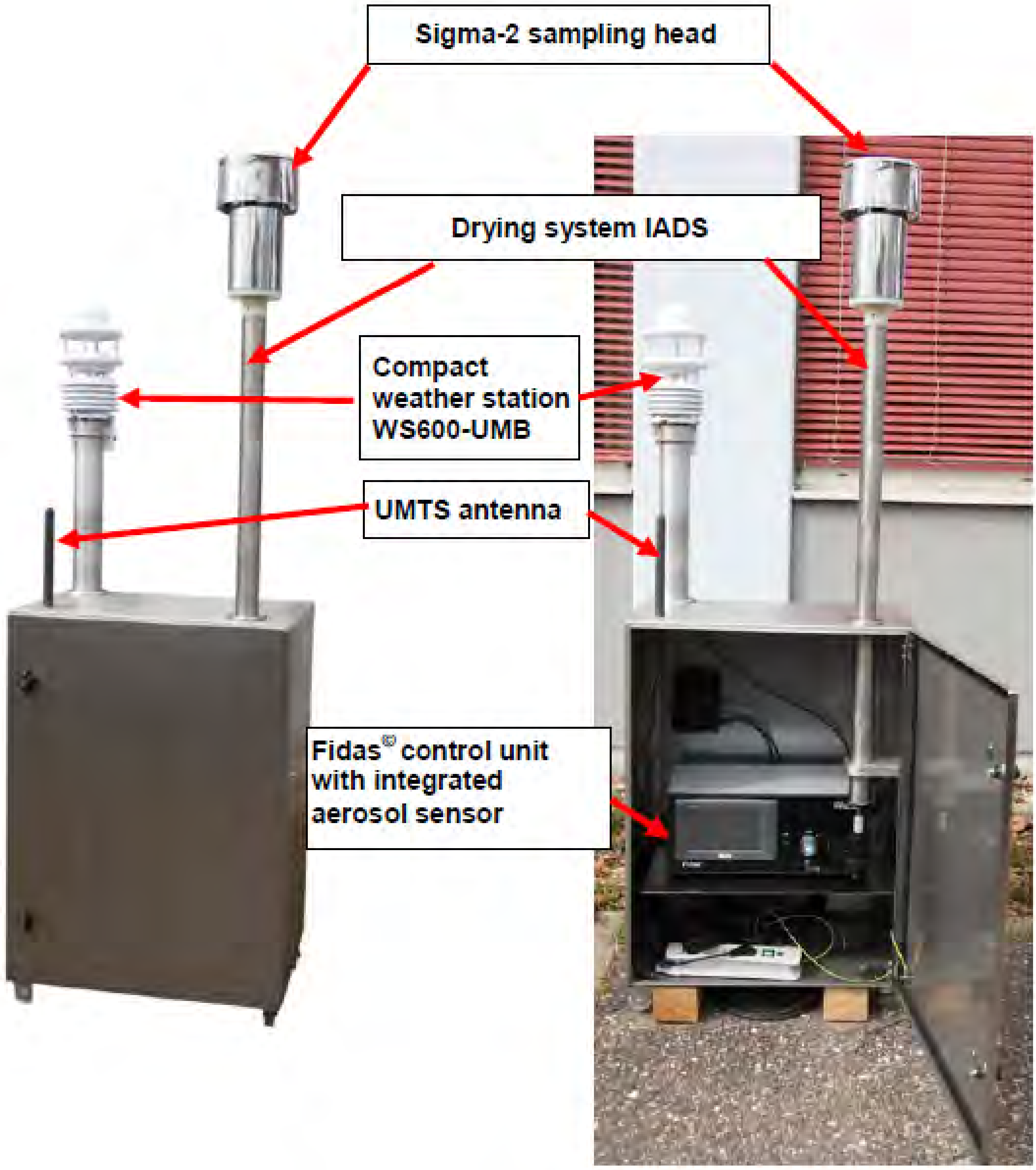



Figure 12: Overview of the entire system based on the Fidas® 200 S version


Figure 13: Sigma2 sampling head


Figure 14: Sampling tube c/w IADS

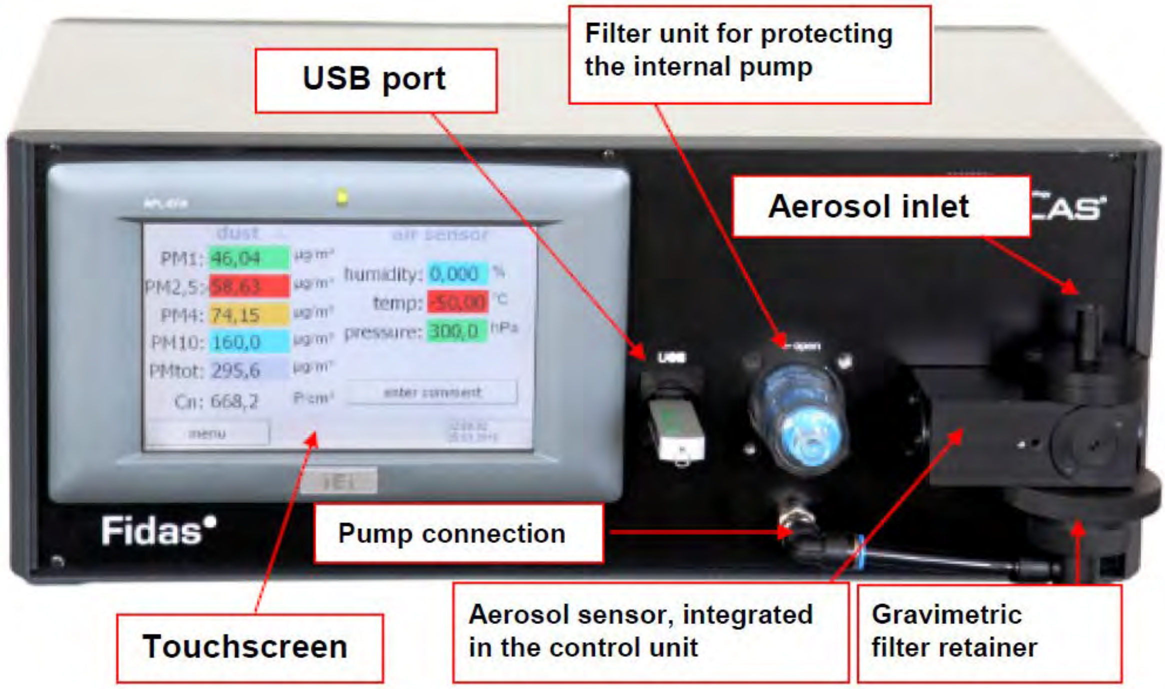



Figure 15: Control unit for Fidas® 200 S and/or Fidas® 200

Figure 16: Weather station (here: Type Lufft WS600-UMB)


Figure 17: Fidas® 200 S measuring system at the measuring station

The measuring system may be operated either directly via the touch screen at the front of the instrument or remotely via an internet connection using a wireless modem using appropriate software (e.g. Teamviewer). The user may retrieve measurement data and system information, change parameters and perform functionality tests of the measuring system.

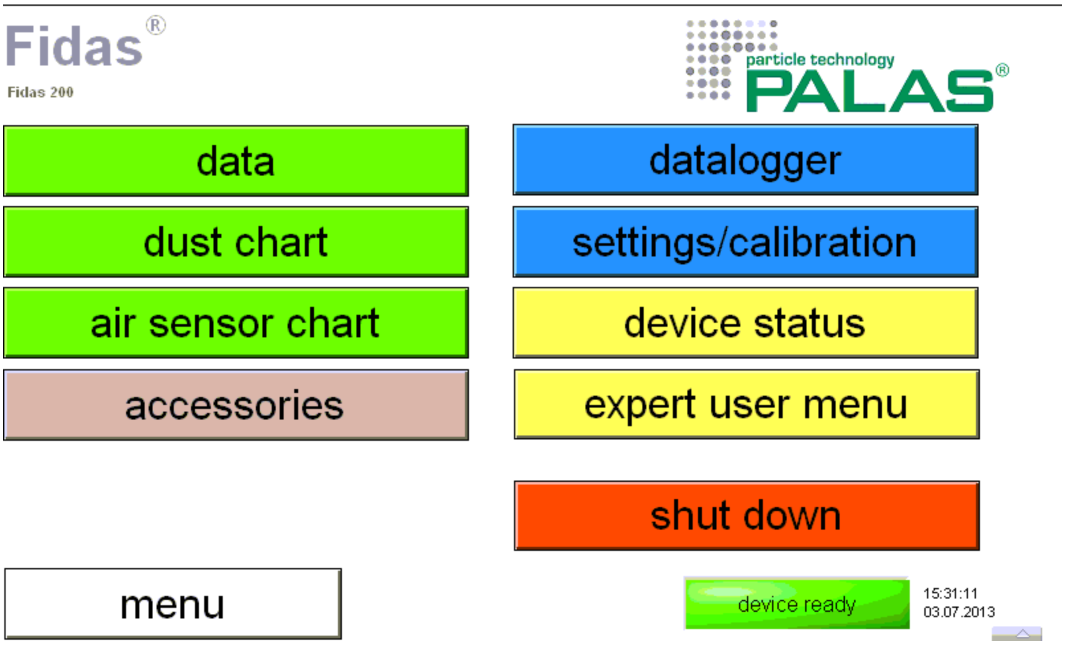



Figure 18: Main menu

The main menu constitutes the top level of the user interface – from here, the user may navigate to the relevant submenus and control operation of the instrument.

| | |
|---|---|
| “Data” menu: | displays measured values |
| “dust chart”: | graphically illustrates PM concentrations and particle count |
| “air sensor chart” menu: | graphically illustrates data provided by the weather station |
| “accessories” menu: | provides information on the IADS, GPS position, weather station, alternative PM values (obtained with different evaluation methods) etc. |
| “data logger” menu: | allows entry of comments stored along with the data set as well as data transfer from internal storage to a flash drive for example |
| “settings/calibration”: | allows checking the calibration for the Fidas® Sensors and a new calibration if possible. also displays a continuous assessment of the calibration and a deviation from the target value |
| “device status”: | displays an overview of critical system parameters, i.e. flow rate, coincidence, pump performance, weather station, IADS, calibration, LED temperature and operating mode |
| “expert user menu”: | allows switching to the expert mode |

Moreover, the instrument status is indicated in the lower right corner – the message "device ready", highlighted in green or a message "check device", highlighted red, is displayed. Selecting the submenu "device status" will show more detailed information about the instrument status.

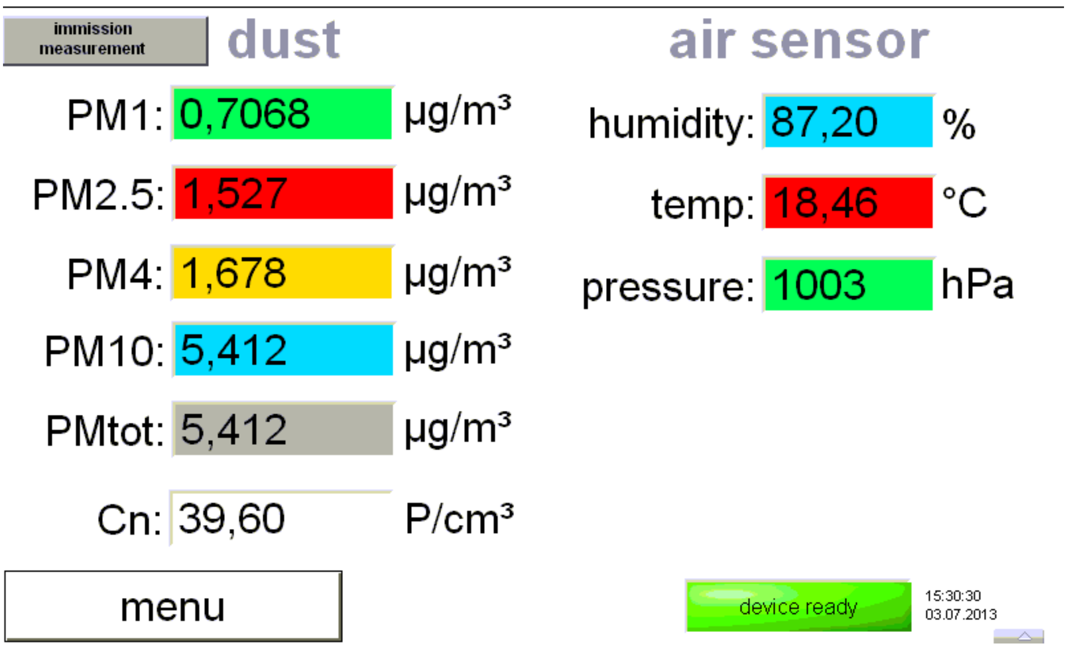



Figure 19: "data" menu

The "data" menu indicates all latest values for the various fractions and the particle count. Moreover, the current ambient temperature, air pressure and humidity are displayed.

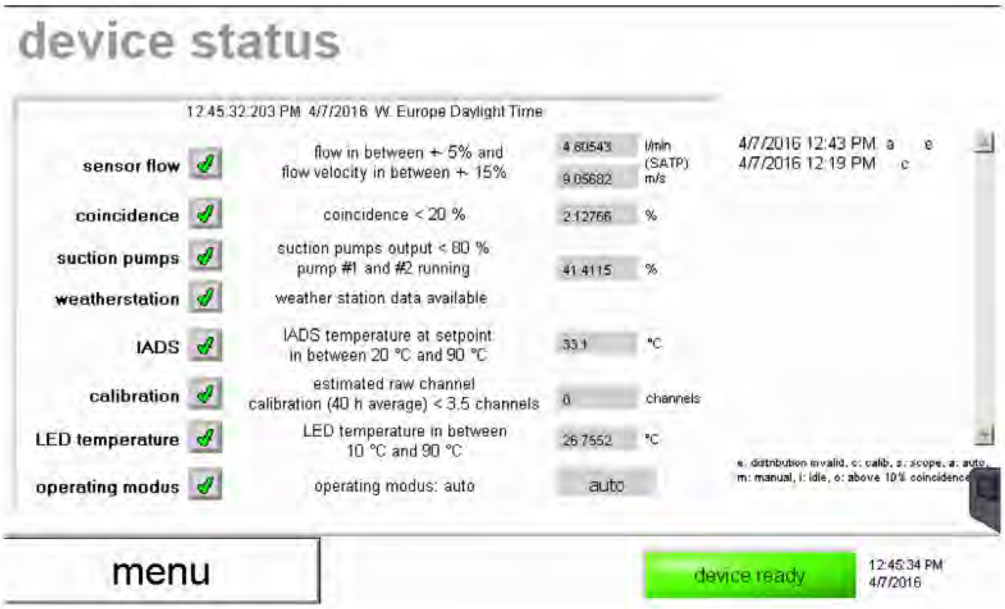



Figure 20: “device status” menu

The user may check various relevant parameters (target and actual values) in the “device status” menu. When one or more parameters experience excessive deviations a “red cross” will appear instead of the “green checkmark”.

The following parameters are continuously being monitored.

| | |
|---|---|
| Sensor flow | With the help of a control system with mass flow meter and taking into account the values measured for temperature and air pressure, the Fidas® 200 controls the flow rate at 4.8 l/min. The flow rate is normalised to “standard atmospheric temperature and pressure” (SATP), i.e. 25°C and 1013hPa.<br><br>The second value indicates particle speed in the optical detection flow.<br><br>An error is flagged when the flow rate deviates from the target rate by more than 15%. The target value is the speed determined as part of the factory calibration taking into account the current IADS temperature and air pressure. |
| Coincidence | Detection of more than one particle in the optical detection flow An error message appears if this occurs in more than 20% of all cases. |

| | |
|---|---|
| Suction pumps | Two pumps, switched in parallel, ensure the volume flow for the Fidas® 200. When one of the pumps fails, the other one takes over. The power consumption increases accordingly which will result in an error message. If the pumps age consistently, an error message appears when exceeding 80%. It is important to note that the instrument will continue to measure and the data will be usable. However, the user will have to replace the pump as soon as possible. |
| Weatherstation | Indicates that the weather station is correctly connected and transmits data. |
| IADS | indicates that the IADS is correctly connected and temperature is controlled correctly. |
| Calibration | monitors the calibration online. A signal is set if the 40h mean deviates by more than 3.5 raw data channels.<br><br>Note: This value may be excessive in some instances which may still mean that the instrument operates correctly. Action (i.e. a field calibration with the help of calibration dust) will only be required if this proves to be a long-term trend (>40 hours). |
| LED temperature | the LED light source is temperature controlled. In the event of any issues with the control system, an error bit starts up. |
| Operating modus | the operating mode should be set to “auto” otherwise data may not be stored correctly or the instrument may not start correctly after a failure in mains voltage. |

In addition to direct communication via the touch screen there are comprehensive options to communicate via RS232 interfaces, USB ports, and Ethernet connections.

The following options are available:

- 1 x RS232 interface for communication via Modbus for remote retrieval of measured values and external control of the measuring system (WebAccess). It is also possible to use the Bayern-Hessen protocol, this was not verified during performance testing, though.
- 1 x Ethernet interface for connecting the instrument to a network or PC, thus allowing data transmission or remote control e.g. via Teamviewer
- 1 x USB port at the instrument front for immediate download of data and processing at an external PC
- 1 x USB port at the instrument back e.g. for connecting a printer, keyboard, mouse or flash drive

A zero filter is mounted to the instrument inlet for the purpose of external zero checks. The use of this filter allows the provision of PM-free air.

Figure 21: Zero filter

Particles of a defined size (CalDust 1100 or MonoDust 1500) are applied to the instrument for testing and, where necessary, adjusting the sensitivity of the particle sensor. The particle size distribution of the dust is monodisperse and the peak resulting in the instrument has

- to be observed at channel 130 ± 1.5 in the case of CalDust 1100 (corresponds to a particle size of 0.93 µm).
- According to the test certificate delivered with the container for MonoDust 1500, the peak has to be observed at channel 141 ± 1.5 which corresponds to a particle size of 1.25 µm.

If the peak occurs outside of the specified range, the value can be adjusted with the help of the photomultiplier. The comparison with a specified particle size automatically aligns the sensitivity for all particle sizes since the instrument only uses an A/D converter.


Figure 22: MonoDust 1500 for verifying/calibrating the sensitivity

Table 4 lists the most important instrument characteristics of the Fidas® 200 S/Fidas® 200/Fidas® 200 E ambient air monitor.

Table 4: Instrument specifications Fidas® 200 S/Fidas® 200/Fidas® 200 E (manufacturer specifications)

| **Dimension/weight** | **Fidas® 200 S / Fidas® 200 / Fidas® 200 E** |
|---|---|
| Measuring device | 185 x 450 x 310 mm / 10 kg (control unit c/w integrated sensor)<br>1810 x 600 x 400 mm / 48 kg (protective housing with control unit, IADS, Sigma-2 and weather station) |
| Sampling tube | ~ 1.4 m between inlet and connecting adapter IADS at the aerosol sensor<br>IADS standard length: 1.20m<br>IADS extended length:<br>1.20 m to 2.10 m, adjustable |
| Sampling head | Sigma-2 in accordance with VDI 2119 part 4 |
| **Power supply** | 100/115/230 V, 50/60 Hz |
| **Power requirement** | ~200 W |
| **Ambient conditions** | |
| Temperature | -20 to +50 °C (Fidas® 200 S)<br>+5 to +40 °C (Fidas® 200 / Fidas® 200 E) |
| Moisture | Fidas® 200 S:<br>Outdoor installation/degree of protection IP65<br>Fidas® 200/Fidas® 200 E:<br>Indoor installation |
| **Sample flow rate (inlet)** | 4.8 l/min, at 25 °C and 1013 hPa |
| **Parameters IADS (dry section)** | |
| Controlled variable | Ambient temperature and humidity |
| Min. Temperature | 23°C |
| humidity compensation | up to a maximum heating output of 90 watt thanks to dynamic adjustment of the IADS temperature |

| | |
|---|---|
| **Aerosol sensor** | |
| Measuring principle | Scattered light measurement, combination of poly chromatic LED and 90° scattered light detection |
| Measuring range during performance testing (particle size) | 0.18–18µm |
| Resolution capacity | 32 classes per decade |
| Time resolution | moving 15-minute average during performance testing, updated every second, other configurations possible |
| Size of the measuring volume | ~ 262 µm x 262 µm x 164 µm,<br>the actual size of the measuring volume for each system is indicated under settings |
| Maximum concentration<br>(at a 10% coincidence error) | 4 x $10^3$ particle / $cm^3$ |
| **WS300-UMB weather station / WS600-UMB** | |
| Sensor for ambient temperature | Measuring range -50 to +60 °C |
| Sensor for rel. humidity | Measuring range 0measuring range 0–100% |
| Sensor for air pressure | Measuring range 300–1200 hPa |
| Sensor for wind direction<br>(WS600-UMB only) | Measuring range 0–359.9° |
| Sensor for wind speed<br>(WS600-UMB only) | Measuring range 0–60 m/s |
| Sensor for precipitation range<br>(WS600-UMB only) | Measuring range 0.3–5 mm drop size |
| **Date storage capacity (internal)** | 1 GB (sufficient for about 100 days at a 60 s saving interval for raw data) |
| **Instrument inputs/outputs** | 1 x RS232 interface for data exchange via Modbus for remote retrieval of measured values and external control of the measuring system (WebAccess)<br>1 x Ethernet interface for connecting the instrument to a network or PC, thus allowing data transmission or remote control e.g. via Teamviewer<br>1 x USB port at the instrument front for immediate download of data and processing at an external PC<br>1 x USB port at the instrument back e.g. for connecting a printer, keyboard, mouse or flash drive |
| **Status signals/error messages** | available (manual chapter 4) |

# 4. Test programme

## 4.1. General

The original performance test [11; 12] in accordance with the requirements of [1; 2; 3; 4; 5] was carried out with two identical Fidas® 200 S instruments, serial numbers 0111 and 0112. This is equally true for the two tests performed at the test sites in the UK which followed the performance test in Germany.

The tests were performed with software version 100327. Raw data sets obtained were converted into concentration values using the PM_ENVIRO_0011 evaluation method.

The original test comprised a laboratory test to determine the performance characteristics as well as a field test over a period of several months at various test sites in Germany and England.

Supplementary testing in the context of approval of instrument version Fidas® 200 was performed with two identical systems, serial numbers 5048 and 5049 [13].

Supplementary testing in the context of approval of instrument version Fidas® 200 E was performed with two identical systems, serial numbers 6623 and 6624 [14].

Additional tests for item 6.1 4 Flow rate accuracy (7.4.4) were performed in the context of qualifying the new flow sensor (type Siargo FS4008-10-O6-CV-A) using two identical systems of instrument version Fidas® 200 S, serial numbers 7146 and 7147 [15].

Supplementary testing for extending the test interval for applying CalDust 1100 or MonoDust 1500 test dust for test item 6.1 18 Maintenance interval (7.5.7) were performed in the context of a one-year measurement campaign with two identical Fidas® 200 S instruments, serial numbers 6230 and 6231 [15].

New tests for items 6.1 9 Dependence of span on supply voltage (7.4.8) and 6.1 11 Dependence of reading on water vapour concentration (7.4.9) were performed with two identical Fidas® 200 S instruments, serial numbers 6486 and 7147.

During supplementary testing, each instrument ran the up-to-date, most recently announced software version. Raw data sets obtained were converted into concentration values using the PM_ENVIRO_0011 evaluation method.

Concentrations are indicated as µg/m³ (operating conditions).

The present addendum presents an assessment of the Fidas® 200 measuring system (instrument versions Fidas® 200 E, Fidas® 200 and Fidas® 200 S) regarding the requirements defined in standard EN 16450 [9].

In this report, the heading for each performance criterion cites the requirements according to [9] including its chapter number and wording.

## 4.2 Laboratory test

A major part of the laboratory test was carried out as part of the existing performance test [11; 12] or in the context of supplementary testing for the purpose of qualifying new instrument versions or design changes [13; 14; 15]. For the present report, test results were either taken from the previous report or re-assessed.

For the following test items, additional tests had to be performed in 2017.

- Influence of mains voltage on measured signal
- Effect of humidity on measured value

The following devices were used to determine the performance characteristics during the laboratory tests.

- Climatic chamber (temperature range –20°C to +50°C, accuracy better than 1°C).
- Isolating transformer,
- 1 mass flow meter Model 4043 (manufacturer: TSI)
- 1 reference flow meter, type BIOS Met Lab 500 (manufacturer: Mesa Lab)
- Zero filter for external zero checks
- CalDust 1100 or MonoDust 1500

Measured values at zero point were recorded internally by the system. Raw data were read either via USB or remotely (using Teamviewer software) and converted into concentration values by PDAnalyze Fidas software using the PM_ENVIRO_0011 method.

Sensitivity tests were performed with monodisperse dust (CalDust 1100 or MonoDust 1500). When applying CalDust 1100 test dust, a peak in the size distribution should generally be expected at channel 130 (this corresponds to a particle size of 0.93 µm); when applying MonoDust 1500 test dust—depending on the test certificate—this is expected at channel 141.1 which corresponds to a particle size of 1.28 µm. To allow for quantification of deviations from the classification, data sets from the field test served as basis for calculating the potential effect of peak shifts of up to ±3 channels on measured values for PM.

In the event of a peak shift in the target channel, there will be a shift in all other channels by the same number of raw data channels. This is linked to the use of an A/D converter which possesses a logarithmic characteristic. If, hypothetically speaking, the entire raw data distribution is shifted by +3 channels and PM values are recalculated accordingly, this will allow to determine the effect on PM measured values. To this effect, the actual measured values and newly calculated PM values based on the hypothetical shift were plotted in an XY diagramme and a linear regression line is calculated from the scatter plot. The following matrix presents the results of this calculation.

Table 5: Matrix presenting the effect of peak shifts on mass concentrations (PM_ENVIRO_0011)

| | PM2,5 | | PM10 | |
|---|---|---|---|---|
| channel shift | slope | offset | slope | offset |
| -3 | 1,086 | 0,03889 | 1,0877 | 0,0331 |
| -2 | 1,056 | 0,025 | 1,057 | 0,012 |
| -1 | 1,029 | 0,0122 | 1,028 | 0,048 |
| 0 | 1 | 0 | 1 | 0 |
| 1 | 0,973 | -0,00785 | 0,976 | -0,0047 |
| 2 | 0,945 | -0,0197 | 0,947 | 0,038 |
| 3 | 0,918 | -0,031 | 0,9224 | 0,083 |

If, for instance, the PM_ENVIRO_0011 method results in a shift by -3 channels, the association between the actual and the hypothetical PM values is described as follows:

$PM_{2,5}$_actual=1.086*$PM_{2,5}$_hypothetical+0.03889
$PM_{10}$_actual=1.0877*$PM_{10}$_hypothetical+0.0331.

A shift by -3 channels leads to particle sizes being determined as too small which in turn results in $PM_{2.5}$ values being too small by a factor of 1.086.

For the purpose of evaluation, a hypothetical measured value of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for $PM_{10}$ was assumed for the ideal situation (a peak for CalDust 1100 exactly at channel 130 and exactly at channel 141.1 for MonoDust 1500). The concentration value expected in accordance with the peak shift was then determined in accordance with the following matrix.

Chapter 6 summarizes the results of the laboratory tests.

## 4.3 Field test

The field test was carried out in the context of the existing performance test [11; 12] with 2 identical measuring systems. These were:

instrument 1: SN 0111
instrument 2: SN 0112

For the present report, test results were either taken from the previous report or re-assessed. No further testing was required.

Test item 6.1 18 Maintenance interval (7.5.7) was the only one for which additional tests for the determination of the long-term stability of the span point were taken into consideration.

The following instruments were used during the field test.

- Measurement container provided by TÜV Rheinland, air-conditioned to about 20 °C and DEFRA measurement station in Teddington
- Weather station (WS 500 manufactured by ELV Elektronik AG or MK III Series manufactured by Rainwise (US) in UK) for collecting meteorological data such as temperature, air pressure, humidity, wind speed, wind direction and precipitation.
- 2 reference measuring systems, LVS3 for $PM_{10}$ in accordance with item 5 (Germany) and SEQ47/50 (UK)
- 2 reference measuring systems, LVS3 for $PM_{2.5}$ in accordance with item 5 (Germany) and SEQ47/50 (UK)
- 1 gas meter, dry version
- 1 mass flow meter Model 4043 (manufacturer: TSI)
- Measuring system for power consumption; Metratester 5 (manufacturer: Gossen Metrawatt)
- Zero filter for external zero checks
- CalDust 1100

The following candidate systems were used for additional tests in order to determine the long-term stability of the reference point.

instrument 1: SN 6230
instrument 2: SN 6231

The following test standard was used:

- MonoDust 1500

Two Fidas® 200 S instruments and two reference systems each for $PM_{10}$ and $PM_{2.5}$ were operated simultaneously for 24 hours during the field test. The reference system (Germany) is a discontinuous system: the filter has to be replaced manually after sampling.

Impaction plates of the $PM_{10}$ and $PM_{2.5}$ sampling inlets were cleaned approximately every two weeks during the test period and greased with silicone grease in order to ensure reliable separation of particles. The Sigma2 sampling inlets of the candidate systems were cleaned roughly every three months in line with the manufacturer's instructions. The sampling head generally has to be cleaned following the manufacturer's instruction taking into account local concentrations of suspended particulate matter.

The flow rates of the tested and the reference instruments were checked before and after the field test as well as before and after each re-location using a dry gas meter or a mass flow controller in each case connected to the instrument's air inlet via a hose line.

### Sites of measurement and instrument installation

Measuring systems in the field test were installed in such a way that only the sampling inlets and the virtual impactors were outside the measuring cabinet on its roof. The central units of the tested instruments were positioned inside the air-conditioned measurement cabinet. The reference system (LVS3) was installed outdoors on the roof of the measurement cabinet.

The field test was performed at the following measurement sites:

Table 6: Field test sites

| No. | Measurement site | Period | Description |
|---|---|---|---|
| 1 | Cologne, summer | 05/2012–09/2012 | Urban background |
| 2 | Cologne, Winter | 11/2012–02/2013 | Urban background |
| 3 | Bonn, crossroads, winter | 02/2013–05/2013 | Affected by traffic |
| 4 | Bornheim, Summer | 05/2013–07/2013 | Rural area + traffic |

Table 7: Additional field test sites in the UK

| No. | Measurement site | Period | Description |
|---|---|---|---|
| 1 | Teddington, Winter | 02/2014–04/2014 | Urban background |
| 2 | Teddington, Summer | 04/2014–06/2014 | Urban background |

Figure 23 to Figure 34 show the PM concentrations measured with the reference systems at the field test sites.

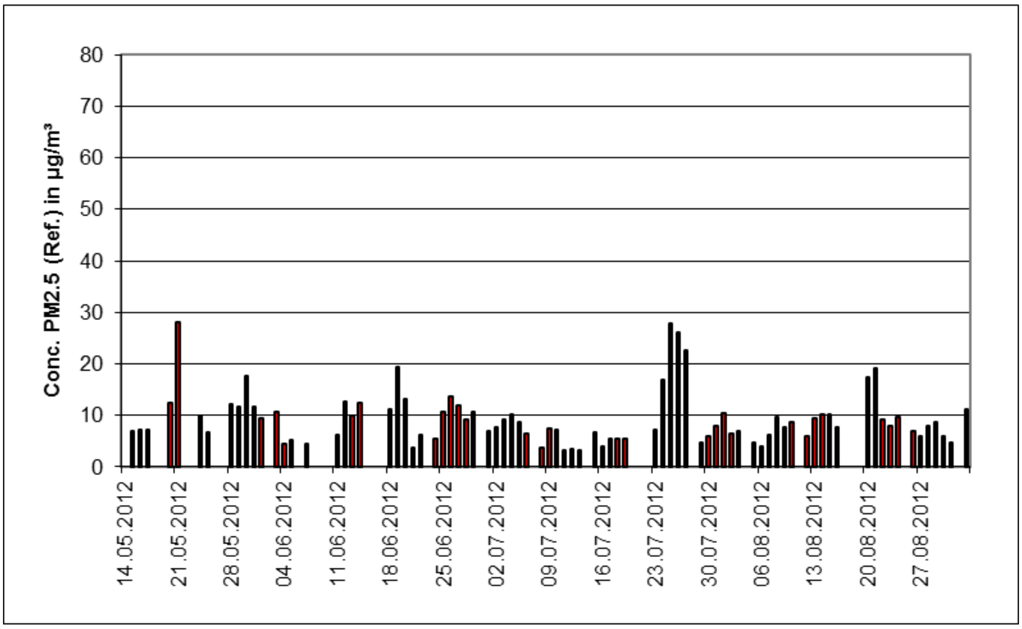



Figure 23: $PM_{2,5}$ concentrations (reference) in Cologne, summer

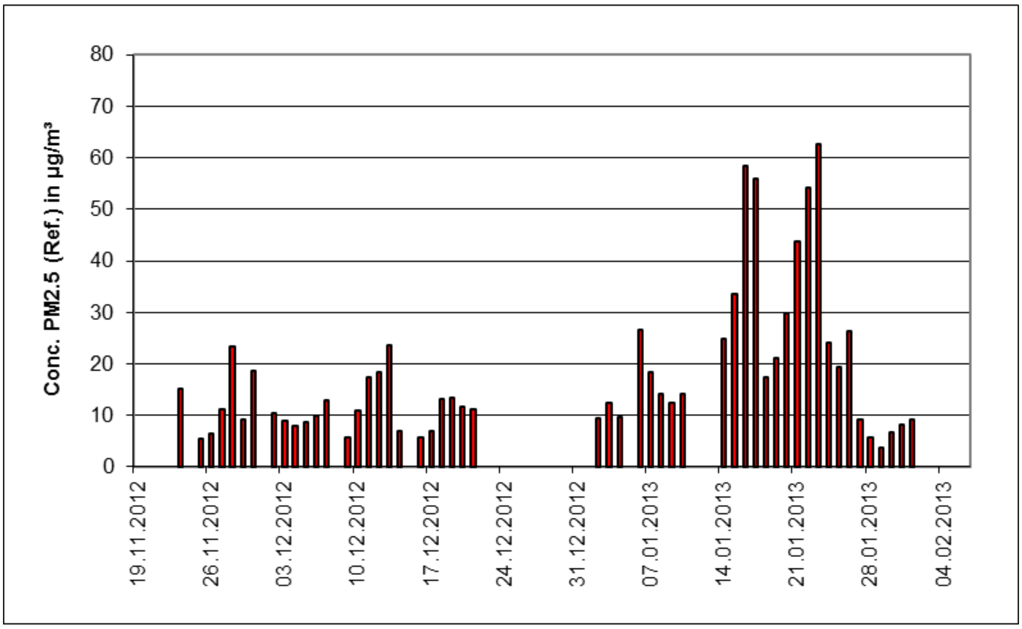



Figure 24: $PM_{2,5}$ concentrations (reference) in Cologne, winter

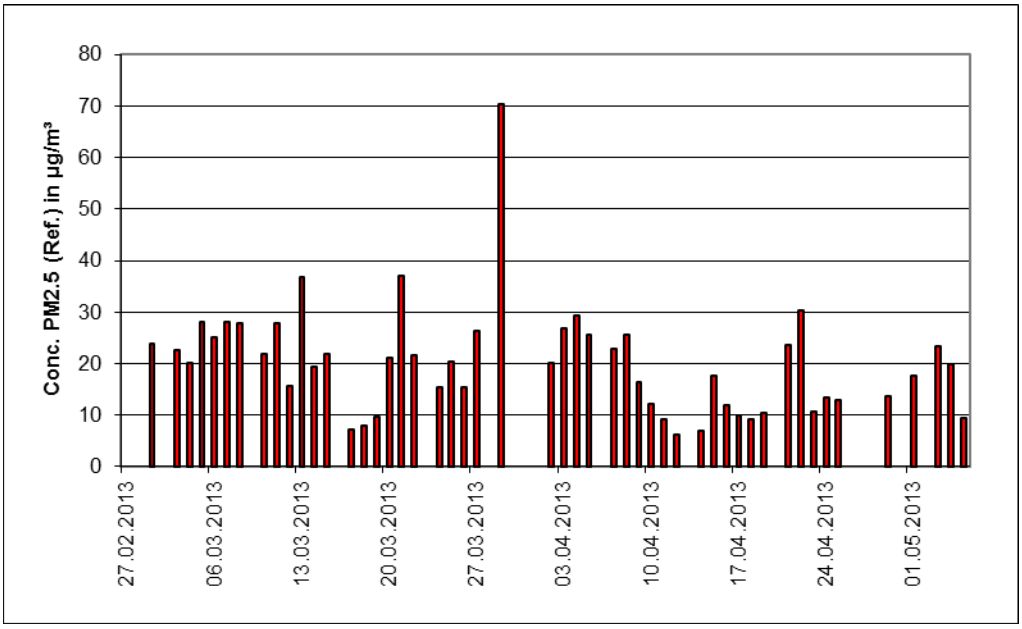



Figure 25: PM$_{2,5}$ concentrations (reference) in Bonn, winter

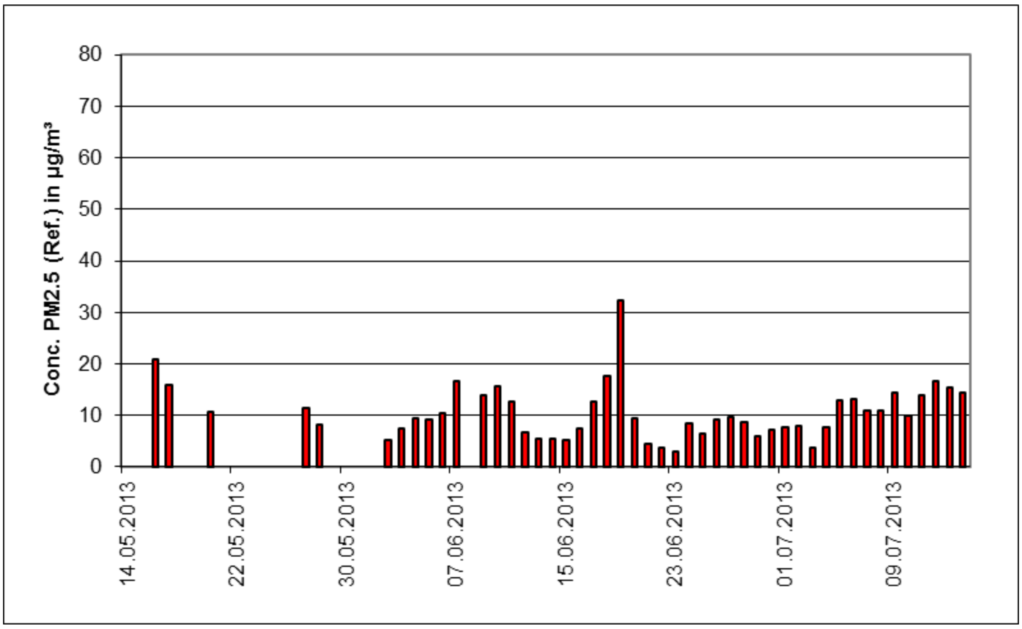



Figure 26: PM$_{2,5}$ concentrations (reference) in Bornheim, summer

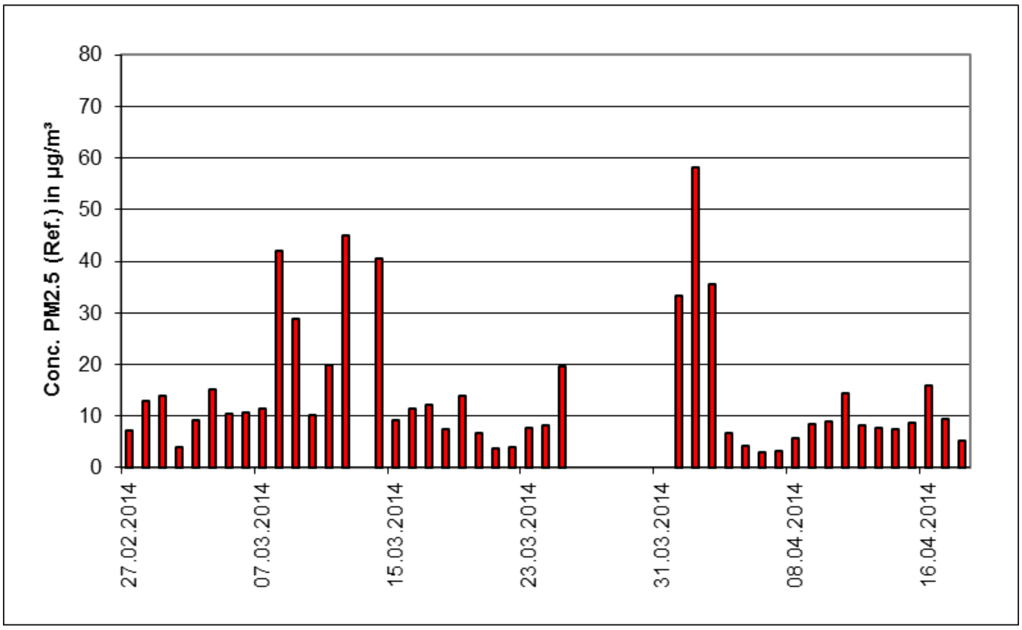



Figure 27: PM$_{2,5}$ concentrations (reference) in Teddington, winter

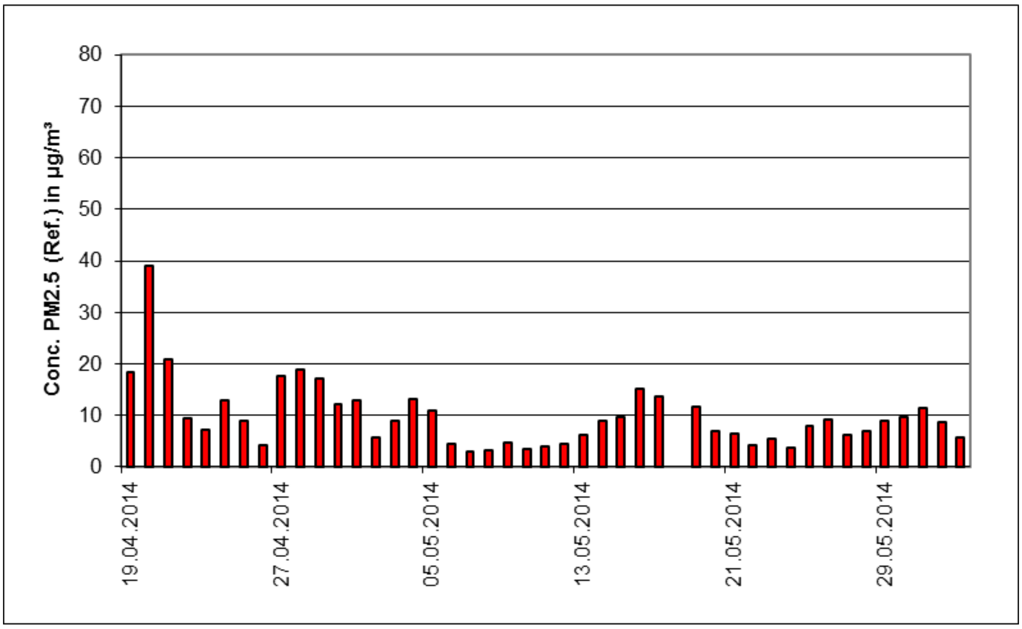



Figure 28: PM$_{2,5}$ concentrations (reference) in Teddington, summer

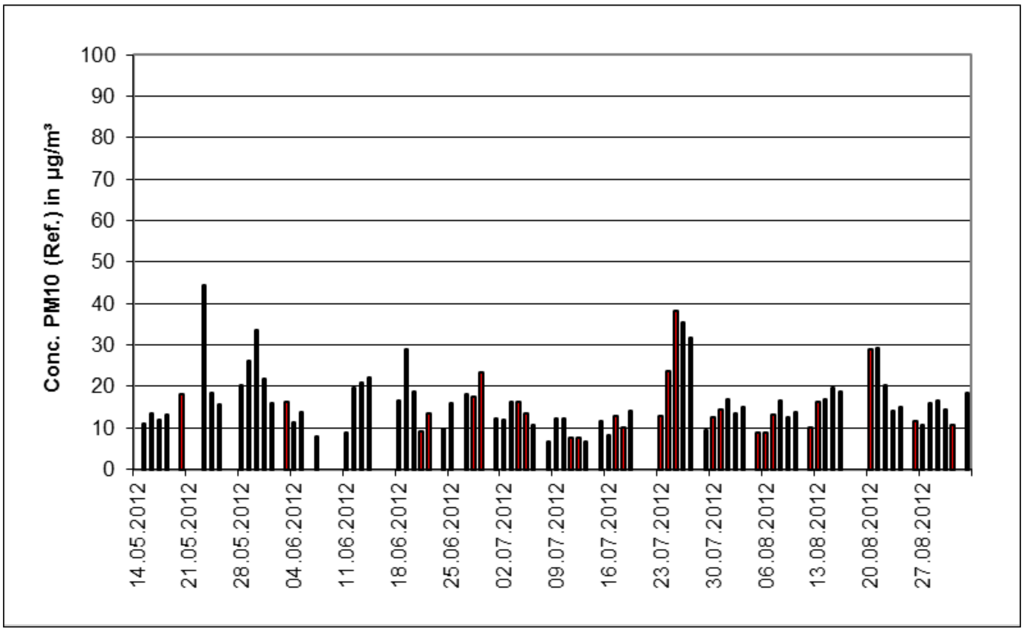



Figure 29: PM$_{10}$ concentrations (reference) in Cologne, summer

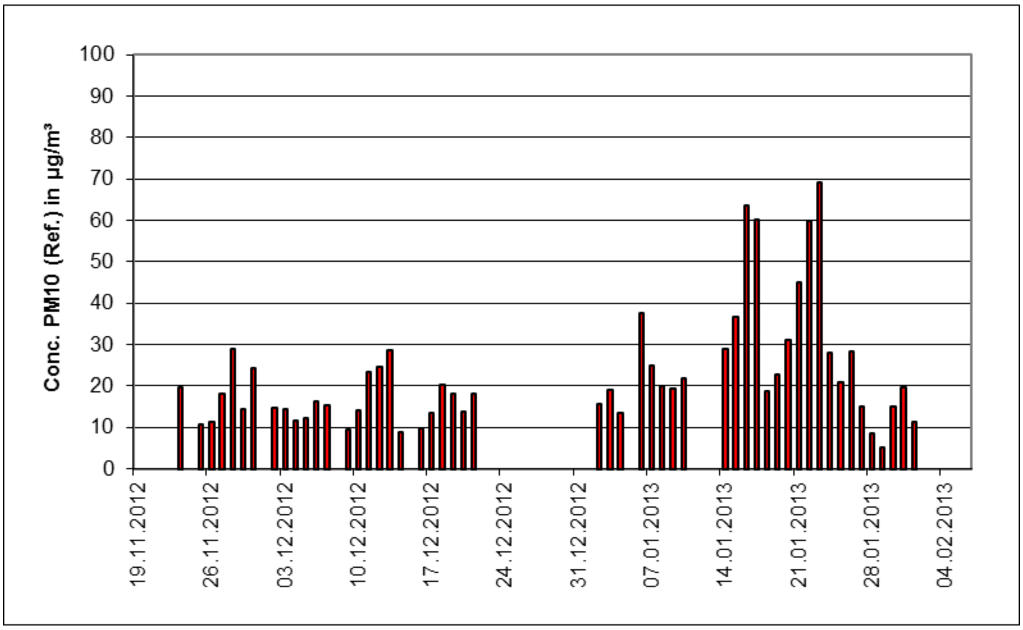



Figure 30: PM$_{10}$ concentrations (reference) in Cologne, winter

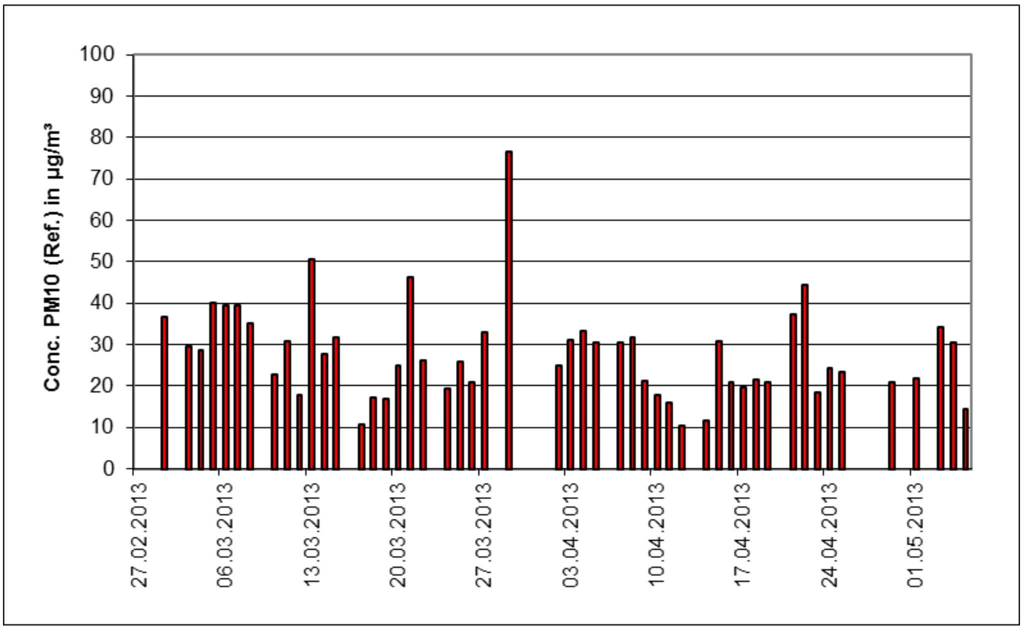



Figure 31: $PM_{10}$ concentrations (reference) in Bonn, winter

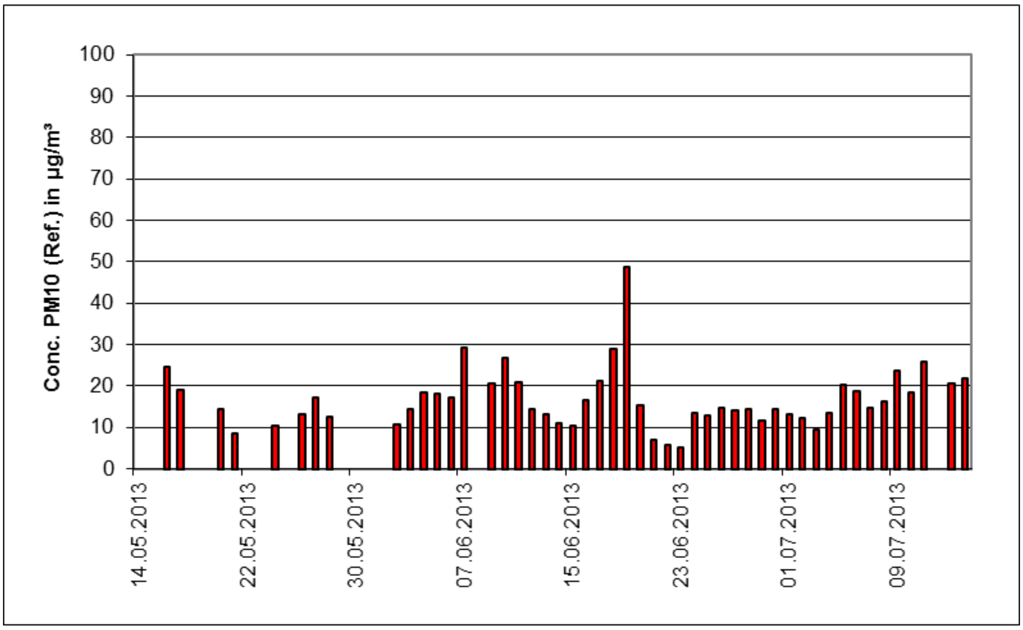



Figure 32: $PM_{10}$ concentrations (reference) in Bornheim, summer

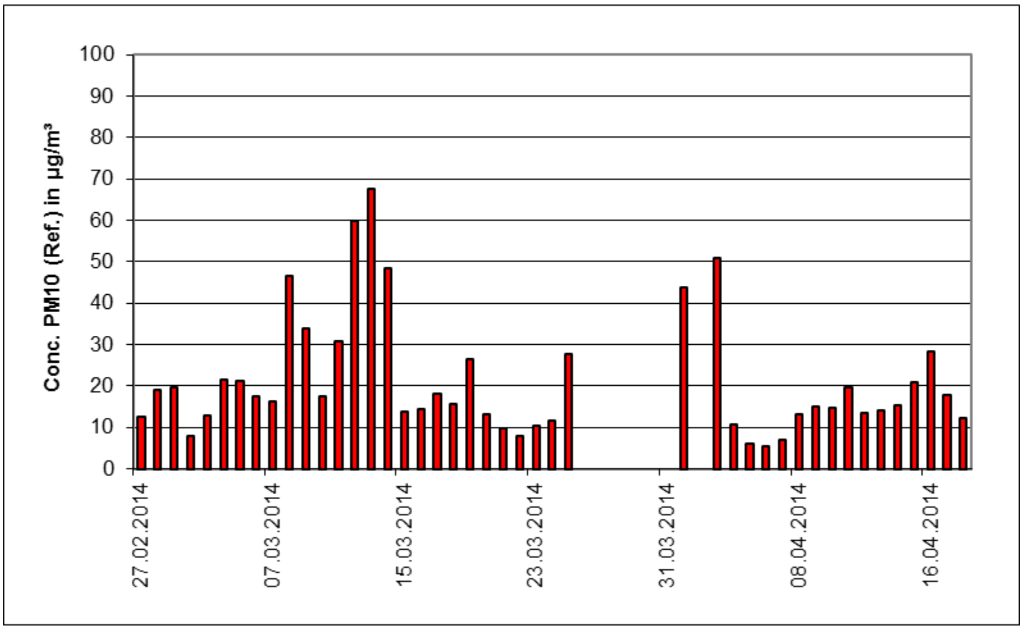



Figure 33: PM$_{10}$ concentrations (reference) in Teddington, winter

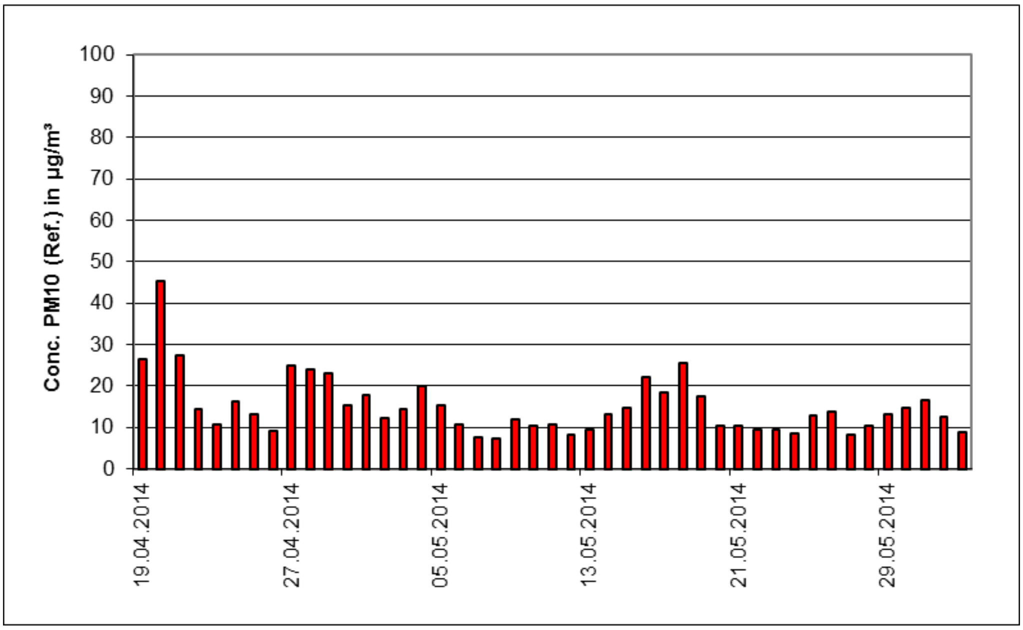



Figure 34: PM$_{10}$ concentrations (reference) in Teddington, summer

The following pictures show the measurement cabinet at the field test sites in Cologne, Bonn and Bornheim as well as in Teddington (UK).

Figure 35: Field test site in Cologne, summer & winter

Figure 36: Field test site in Bonn, winter

Figure 37: Field test site in Bornheim, summer

Figure 38: Field test site in Teddington, UK

In addition to the air quality measuring systems for monitoring suspended particulate matter, a data logger for meteorological data was installed at the container/measurement site. Data on air temperature, pressure, humidity, wind speed, wind direction and precipitation were continually measured. 30-minute mean values were recorded.

The following dimensions describe the design of the measurement cabinet as well as the position of the sampling probes.

Germany

| | |
|---|---|
| • Height of cabinet roof. | 2.50m |
| • Height of the sampling system for test/ | 1.70m/0.51m above cabinet roof |
| • Reference system | 4.20/3.01m/ over ground level |
| • Height of the wind vane: | 4.5 m above ground level |

UK

| | |
|---|---|
| • Height of cabinet roof. | 2.50m |
| • Height of the sampling system for test/ | 1.70m/0.70m or 1.00m above cabinet roof |
| • Reference system level | 4.20/3.20 or 3.50m over ground |
| • Height of the wind vane: | 4.00m above ground level |

In addition to an overview of the meteorological conditions determined during measurements at the 4 field test sites, the following Table 8 therefore provides information on the concentrations of suspended particulate matter. All individual values are presented in annexes 5 and 6.

The essential meteorological data from the comparison campaigns in England are summarised in Table 9 and detailed in annexes 5 and 6.

Table 8: Ambient condition at the field test sites (Germany) as daily averages

| | Cologne Summer | Cologne Winter | Bonn, Winter | Bornheim, Summer |
|---|---|---|---|---|
| number of measurements $PM_{10}$ reference | 82 | 52 | 50 | 49 |
| number of measurements $PM_{2.5}$ reference | 82 | 52 | 50 | 47 |
| **Ratio of $PM_{2.5}$ to $PM_{10}$ [%]** | | | | |
| Range | 38.2–73.7 | 41.6–97.2 | 42.2–96.5 | 39.1–84.6 |
| Average | 55.8 | 73.8 | 70.6 | 60.0 |
| **Air temperature [°C]** | | | | |
| Range | 8.9–30.7 | -3.3–11.9 | -3.4–20.0 | 6.4–27.2 |
| Average | 19.1 | 4.6 | 7.8 | 16.6 |
| **Air pressure [hPa]** | | | | |
| Range | 993–1021 | 988–1027 | 985–1021 | 989–1020 |
| Average | 1008 | 1004 | 1004 | 1007 |
| **Rel. Humidity [%]** | | | | |
| Range | 39.9–87.2 | 70.0–91.2 | 42.8–85.8 | 52.6–89.1 |
| Average | 67.0 | 81.2 | 63.4 | 70.1 |
| **Wind speed [m/s]** | | | | |
| Range | 0.1–2.7 | 0.0–3.3 | 0.4–4.2 | 0.2–4.7 |
| Average | 0.7 | 0.9 | 1.6 | 1.5 |
| **Precipitation rate [mm/d]** | | | | |
| Range | 0.0–29.5 | 0.0–25.7 | 0.0–13.2 | 0.0–34.6 |
| Average | 2.9 | 2.9 | 0.9 | 3.5 |

Table 9: Ambient condition at the field test sites (UK) as daily averages

| | Teddington, Winter | Teddington, Summer |
|---|---|---|
| number of measurements $PM_{10}$ reference | 44 | 45 |
| number of measurements $PM_{2.5}$ reference | 44 | 44 |
| **Ratio of $PM_{2.5}$ to $PM_{10}$ [%]** | | |
| Range | 37.0–90.0 | 34.3–86.3 |
| Average | 61.9 | 62.9 |
| **Air temperature [°C]** | | |
| Range | -1.9–21.1 | 1.7–26.5 |
| Average | 9.9 | 13.6 |
| **Air pressure [hPa]** | | |
| Range | 965–1016 | 981–1017 |
| Average | 997 | 995 |
| **Rel. Humidity [%]** | | |
| Range | 25.1–100 | 29.3–99.9 |
| Average | 74 | 73.3 |
| **Wind speed [m/s]** | | |
| Range | 0.0–4.8 | 0.0–5.4 |
| Average | 0.6 | 0.7 |
| **Precipitation rate [mm/d]** | | |
| Range | 0.0–10.2 | 0.0–22.9 |
| Average | 0.9 | 2.6 |

## Sampling duration

Standard EN 12341 [3] fixes the sampling time at 24h. However, longer sampling times are permissible for low concentrations as are shorter times for higher concentrations.

Standard EN 14907 [4] fixes the sampling time at 24 h ± 1 h.

During the entire field test, all instruments were set to a sampling time of 24 h (from 10:00 to 10:00 o'clock (Cologne, Teddington) and from 7:00 to 7:00 o'clock (Bonn, Bornheim)).

## Data handling

Prior to their assessment for each field test site, measured value pairs determined from reference values during the field test were submitted to a statistical Grubb's test for outliers (99%) in order to prevent distortions of the measured results from data, which evidently is implausible. Measured values pairs detected as significant outliers may be expunged from the pool of values as long as the test statistic remains above the critical value. The January 2010 version of the guideline [5] requires that no more than 2.5% of the data pairs be detected and removed as outliers.

In principle, no measured value pairs are expunged for the tested AMS, unless there are justifiable technical reasons for implausible values. During the entire test, no measured values were expunged for the tested AMS.

Table 10 and Table 11 present an overview of the measured value pairs which have been detected and expunged as significant outliers (reference).

Table 10: Results of the Grubb's test for outliers – reference $PM_{10}$

| Graph Number | Site | Sampler | Number of data-pairs | Maximum Number that can be deleted | Number Identified | Number Deleted | Number of data-pairs remaining |
|---|---|---|---|---|---|---|---|
| A | Cologne Summer | $PM_{10}$ Reference | 83 | 2 | 1 | 1 | 82 |
| B | Cologne Winter | $PM_{10}$ Reference | 52 | 0 | 1 | 0 | 52 |
| C | Bonn Winter | $PM_{10}$ Reference | 50 | 1 | 0 | 0 | 50 |
| D | Bornheim Summer | $PM_{10}$ Reference | 50 | 1 | 2 | 1 | 49 |
| E | Teddington Winter | $PM_{10}$ Reference | 45 | 1 | 1 | 1 | 44 |
| F | Teddington Summer | $PM_{10}$ Reference | 45 | 1 | 0 | 0 | 45 |

Table 11: Results of the Grubb's test for outliers – 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 have been discarded:

Table 12: Value pairs (reference $PM_{10}$) discarded from the data set following Grubb's test

| Location | Date | Reference 1 [µg/m³] | Reference 2 [µg/m³] |
|---|---|---|---|
| Cologne, summer | 21.05.2012 | 45.7 | 41.6 |
| Bornheim, Summer | 12.07.2013 | 28.7 | 33.5 |
| Teddington, Winter | 02.04.2014 | 84.92 | 82.04 |

Table 13: Value pairs (reference $PM_{2.5}$) discarded from the data set following Grubb's test

| Location | Date | Reference 1 [µg/m³] | Reference 2 [µg/m³] |
|---|---|---|---|
| Cologne, summer | 18.05.2012 | 7.1 | 16.0 |
| Cologne, summer | 23.05.2012 | 27.3 | 35.0 |
| Teddington, Winter | 13.03.2014 | 54.93 | 56.97 |
| Teddington, Summer | 18.05.2014 | 18.90 | 17.66 |

**Filter handling – Mass measurement**

The following filters were used during performance testing:

Table 14: Filter materials used

| **Measuring device** | **Filter material, type** | **Manufacturer** |
|---|---|---|
| Reference devices LVS3 or SEQ47/50 (UK only) | Emfab™, ∅ 47 mm | Pall |

Filter handling was performed in compliance with EN 14907.

The methods used for processing and weighing filters and for weighing are described in detail in appendix 2 to this report.

# 5. Reference Measurement Method

The following instruments were used in compliance with EN 12341 and EN 14907 in the context of the field test in 2012–2014:

1. as $PM_{10}$ reference system: Low Volume Sampler LVS3
Manufacturer: Engineering office Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
$PM_{10}$ sampling head

2. as $PM_{2.5}$ reference system: Low Volume Sampler LVS3
Manufacturer: Engineering office Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
$PM_{2.5}$ sampling inlet

For the additional comparison campaigns performed in the UK, two sequential samplers each, type SEQ47/50, were used for $PM_{2.5}$ and $PM_{10}$ respectively. Technically speaking, the sequential sampler is based on the LVS3 low volume sampler. The filter replacement mechanism combined with the filter cartridge and unloader system facilitates continuous 24-hour sampling for a period of up to 15 days. The entire sampling system is cooled by an air jacket – this is why the actual intake pipe is installed in an aluminium cladding tube.

During the tests, two reference systems each for $PM_{2.5}$ and $PM_{10}$ were operated in parallel with the flow controlled at 2.3 m³/h. Under normal conditions the accuracy of flow control is < 1% of the nominal flow rate.

For the LVS3 and the SEQ47/50 low volume sampler, the rotary vane vacuum pump takes in sample air via the sampling inlet. The volumetric flow is measured between the filter and the vacuum pump with the help of a measuring orifice. The air taken in flows from the pump via a separator for the abrasion of the rotary vane to the air outlet.

After sampling has been completed, the electronics display the sample air volume in standard and operating m³.

The $PM_{10}$ and $PM_{2.5}$ concentrations were determined by dividing the quantity of suspended particulate matter on each filter determined in the laboratory with a gravimetric method by the corresponding throughput of sample air flow as operating m³.

# 6. Test results

## 6.1 1 Measuring ranges

*The measuring ranges should meet the following requirements:*
*0 µg/m³ to 1000 µg/m³ as a 24-hour average value*
*0 µg/m³ to 10,000 µg/m³ as a 1-hour average value, if applicable*

## 6.2 Equipment

The test of this criterion did not require any further equipment.

## 6.3 Testing

It was tested whether the measuring system's upper limit of measurement meets the requirements .

## 6.4 Evaluation

The instrument allows for an upper limit of measurement of 4 000 particles/cm³ (at a coincidence error of 10%) which roughly corresponds to a maximum concentration of 0–10 000 µg/m³ (measured against SAE Fine standardised dust).

Measuring range: 0 –10,000 µg/m³

## 6.5 Assessment

The instrument's upper limit of measurement is at ~4 000 particles/cm³ (at a coincidence error of 10%) which roughly corresponds to a maximum concentration of 0–10 000 µg/m³ (measured against SAE Fine standardised dust).

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Not required for this performance criterion.

## 6.1 2 negative signals

*Negative signals shall not be suppressed.*

## 6.2 Equipment

The test of this criterion did not require any further equipment.

## 6.3 Testing

The possibility of displaying negative signals was tested both in the laboratory and in the field test.

## 6.4 Evaluation

The measuring system is able to output negative signals both via its display and its data outputs, however, negative measured values did not occur during the test. Given the measuring principle and design of the instrument, negative values should not be expected.

## 6.5 Assessment

While the AMS is able to display negative readings directly and via the various outputs, they should not be expected given instrument design and the measurement principle applied.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Not required for this performance criterion.

## 6.1 Zero level and detection limit

*Zero level: ≤ 2.0 µg/m³*
*Detection limit: ≤ 2.0 µg/m³*

## 6.2 Equipment

Zero filter for zero checks

## 6.3 Testing

The zero level and detection limit of the AMS shall be determined by measurement of 15 24-hour average readings obtained by sampling from zero air (no rolling or overlapped averages are permitted). The mean of these 15 24-h averages is used as the zero level. The detection limit is calculated as 3,3 times the standard deviation of the 15 24h-averages.

The zero level and the detection limit were determined with zero filters installed at the AMS inlets of instruments with SN 0111 and SN 0112 during normal operation. Air free of suspended particulate matter is applied over a period of 15 days for a duration of 24h each.

## 6.4 Evaluation

The detection limit X is calculated from the standard deviation $s_{x0}$ of the measured values sucking air free from suspended particulate matter through both candidate. It is equal to the standard deviation of the average $x_0$ of the measured values $x_{0i}$ multiplied by 3.3 for each candidate.

$$X = 3.3 \cdot s_{x0} \qquad \text{where} \cdot s_{x0} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

## 6.5 Assessment

The zero level and the detection limit resulted from the tests of both instruments both for $PM_{10}$ and $PM_{2.5}$ and were < 0.1 µg/m³.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 15: Zero level and detection limit $PM_{10}$

| | | Device SN 0111 | Device SN 0112 |
|---|---|---|---|
| Number of values n | | 15 | 15 |
| Average of the zero values (Zero level) $\overline{x}_0$ | µg/m³ | 0.0001924 | 0.0000002 |
| Standard deviation of the values $s_{x0}$ | µg/m³ | 0.0004064 | 0.0000003 |
| Detection limit x | µg/m³ | **1.34E-03** | **1.01E-06** |

Table 16: Zero level and detection limit $PM_{2.5}$

| | | Device SN 0111 | Device SN 0112 |
|---|---|---|---|
| Number of values n | | 15 | 15 |
| Average of the zero values (Zero level) $\overline{x}_0$ | µg/m³ | 0.0001638 | 0.0000002 |
| Standard deviation of the values $s_{x0}$ | µg/m³ | 0.0004036 | 0.0000003 |
| Detection limit x | µg/m³ | **1.33E-03** | **1.01E-06** |

Annex 1 in the appendix contains the individual measured values for the determination of the zero level and detection limit.

## 6.1 4 Flow rate accuracy (7.4.4)

*The relative difference between the two values determined for the flow rate shall be ≤ 2.0%.*

*The relative difference between the two values determined for the flow rate shall fulfil the following performance requirements:*

*≤ 2.0%*

- *at 5°C and 40°C for installations in an air-conditioned environment by default*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

## 6.2 Equipment

Climatic chamber for the temperature range of -20°C to +50°C; a reference flow meter in accordance with item 4 was provided.

## 6.3 Testing

The Fidas® 200 measuring systems operate at a flow rate of 4.8 l/min @ 25 °C and 1013 hPa.

At a temperature of -20 °C and +50 °C, the flow rate was measured with the help of a reference flow meter for both measuring systems, instrument version Fidas® 200 S, by taking 10 measurements over a period of 1h at the flow rate specified by the manufacturer for operation. The measurements were performed at equal intervals throughout the measurement period.

In addition, the measurement programme was repeated at temperatures of +5°C and +40°C using a Fidas® 200 E with the enclosure door open and the heater/fan switched off in order to perform the tests specifically for the permissible ambient temperatures for instrument version Fidas® 200 and Fidas® 200 E.

## 6.4 Evaluation

Averages were calculated from the 10 measured values determined at each temperature and deviations from the operating flow rate determined.

## 6.5 Assessment

The relative difference determined for the mean of the measuring results at flow rates at -20°C and at +50°C did not exceed -1.99% (Fidas® 200 S) and 1.08% at flow rates at +5°C to +40°C (Fidas® 200/Fidas® 200 E).

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 17 and Table 18 summarise the results of the flow rate measurements.

Table 17: Flow rate accuracy at -20°C and +50°C (Fidas® 200 S)

| | | Device SN 7146 | Device SN 7147 |
|---|---|---|---|
| Nominal value flow rate | l/min | 4.8 | 4.8 |
| | | | |
| Mean value at -20°C | l/min | 4.82 | 4.86 |
| Dev. from nominal value | % | 0.45 | 1.26 |
| | | | |
| Mean value at 50°C | l/min | 4.78 | 4.70 |
| Dev. from nominal value | % | -0.32 | -1.99 |

Table 18: Flow rate accuracy at +5°C and +40°C (Fidas® 200/Fidas® 200 E)

| | | Device SN 7146 | Device SN 7147 |
|---|---|---|---|
| Nominal value flow rate | l/min | 4.8 | 4.8 |
| | | | |
| Mean value at 5°C | l/min | 4.77 | 4.85 |
| Dev. from nominal value | % | -0.56 | 1.08 |
| | | | |
| Mean value at 40°C | l/min | 4.79 | 4.78 |
| Dev. from nominal value | % | -0.17 | -0.49 |

Annex 2 in the appendix contains the individual measured values for the determination of the flow rate accuracy.

## 6.1 Constancy of sample flow rate (7.4.5)

*The instantaneous flow rate and the flow rate averaged over the sampling period shall fulfil the performance requirements below.*

*≤ 2.0% sample flow (instantaneous flow)*

*≤ 5% rated flow (instantaneous flow)*

## 6.2 Equipment

For this test, an additional reference flow meter in accordance with item 4 was provided.

## 6.3 Testing

The Fidas® 200 measuring systems operate at a flow rate of 4.8 l/min ± 0.15 l/min@ 25 °C and 1013 hPa.

The sample flow rate was calibrated before the first field test and the checked with the help of a mass flow controller at every new field test site and re-adjusted when necessary.

To determine the constancy of the sample flow rate, the flow rate was recorded and evaluated with the help of a mass flow meter over a period of 24h.

## 6.4 Evaluation

The average, standard deviation as well as the maximum and minimum values were determined from the measured values for the flow rate.

## 6.5 Assessment

Table 19 presents the results of the flow rate checks performed at every field test site.

Table 19: Results of the flow rate checks

| Flow rate check before: | SN 0111 | | SN 0112 | |
|---|---|---|---|---|
| Field test site: | [l/min] | Dev. from target [%] | [l/min] | Dev. from target [%] |
| 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 charts illustrating the constancy of the sample flow rate demonstrate that all measured values determined during sampling deviate from their respective rated values by less than ±5%. For a total flow rate of 4.8 l/min @ 25 °C and 1013 hPa, the deviation from the 24h-mean for the overall flow rate also remains well below the required maximum of ±2.0% from the target value.

The 24h-averages deviate from their rated values by less then ± 2.0%, all instantaneous values deviate by less than ± 5%.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results for the rated flow

Table Table 20 lists the characteristics determined for the flow rate. Figure 39 to Figure 40 provide a chart of the flow rate measurement for both instruments - SN 111 and SN 112.

Table 20: Characteristics of the overall flow rate measurement (24h mean), SN 0111 and SN 0112

| | | Device SN 0111 | Device SN 0112 |
|---|---|---|---|
| Mean value | l/min | 4.81 | 4.80 |
| Dev. from nominal value | % | 0.29 | 0.00 |
| Standard deviation | l/min | 0.05 | 0.01 |
| Minimum value | l/min | 4.60 | 4.60 |
| Maximum value | l/min | 5.00 | 5.00 |

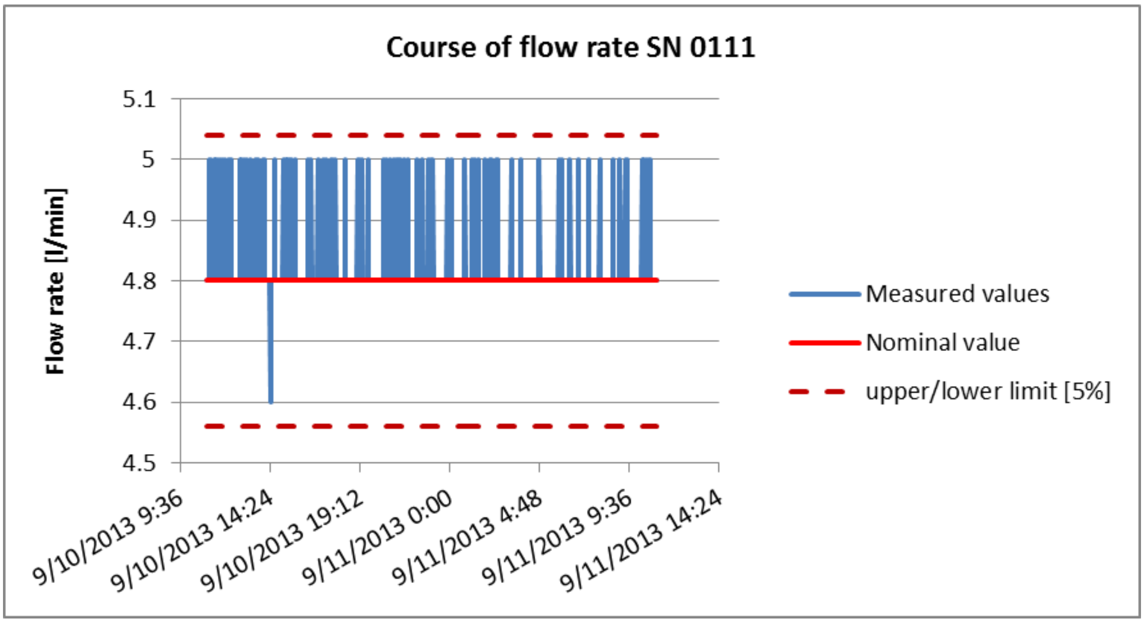



Figure 39: Flow rate of tested instrument SN 0111

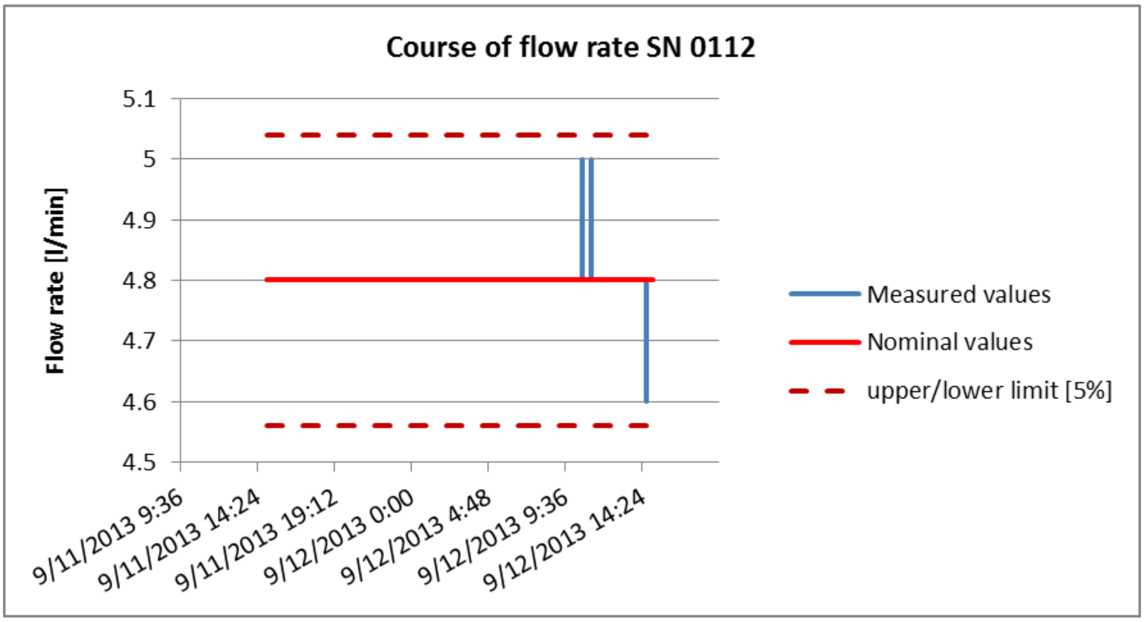



Figure 40: Flow rate of tested instrument SN 0112

## 6.1 6 Leak tightness of the sampling system (7.4.6)

*Leakage shall not exceed 2.0% of the sample flow rate or else meet the AMS manufac turer's specifications in complying with the required data quality objectives (DQO).*

## 6.2 Equipment

Not required for this performance criterion

## 6.3 Testing

The flow sensor of the Fidas® 200 measuring system is located immediately upstream of the pump. For the purpose of determining the instrument's leak rate, it was switched to the calibration mode as described in chapter 4.2 of the operation manual; the inlet was then blocked with the thumb or a plug for example. According to the manufacturer's specifications, the measured flow rate should then drop to 0 ± 0.1 l/min.

This procedure was carried out at the beginning for each field test location.

It is re recommended to test the instrument's leak tightness with the procedure described above every 3 months.

## 6.4 Evaluation

The leak test was carried out at the beginning of the tests at each field test site.

The criterion for passing the leak test as specified by the AMS manufacturer – maximum flow rate of 0 ± 0.1 l/min when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness.

The maximum leak rate determined at 0.04 l/min did not exceed 2.0% of the nominal sample flow rate of 4.8 l/min.

## 6.5 Assessment

The criterion for passing the leak test as specified by the AMS manufacturer – maximum flow rate of 0 ± 0.1 l/min when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness. The maximum leak rate determined at 0.04 l/min did not exceed 2.0% of the nominal sample flow rate of 4.8 l/min.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 21 lists the result from the leak test.

Table 21: Results of the leak test during the field test

| Location | 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 7 Dependence of measured value on surrounding temperature (7.4.7)

*The differences found shall comply with the performance criteria given below.*
*Zero point*
*≤ 2.0 µg/m3*

- *between 5°C and 40°C by default, for installations in an air-conditioned environment.*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

## 6.2 Equipment

Climatic chamber for the temperature range between -20 and +50 °C; zero filter for the zero point check

## 6.3 Testing

The dependence of the zero reading on the surrounding temperature was determined at the following temperatures (within the specifications of the manufacturer):

a) at a nominal temperature $T_{S,n}$ = +20 °C;
b) at a minimum temperature $T_{S,1}$ = -20 °C (Fidas® 200 S) or 5 °C (Fidas® 200/Fidas® 200 E);
c) at a maximum temperature $T_{S,2}$ = 50 °C. or 40 °C (Fidas® 200/Fidas® 200 E).

For the purpose of testing the dependence of the zero point on surrounding temperature, the complete measuring systems were operated inside a climatic chamber (Fidas® 200 S during initial performance testing, Fidas® 200 and Fidas® 200 E in the context of supplementary tests aiming at qualifying each instrument version).

Sample air, free of suspended particles, was supplied to the two candidate systems after fitting two zero filters at the AMS inlet in order to perform zero point checks.

The tests were performed in the temperature sequence $T_{S,n}$ — $T_{S,1}$ — $T_{S,n}$ — $T_{S,2}$ — $T_{S,n}$.

Readings were recorded at zero point after an equilibration period of at least 6h for every temperature step (3 readings each).

## 6.4 Evaluation

Measured values for the concentrations of the individual readings were read and evaluated.

In order to exclude any possible drift due to factors other than temperature, the measurements at $T_{S,n}$ were averaged.

The differences between readings at both extreme temperatures and $T_{S,lab}$ were determined.

## 6.5 Assessment

The ambient air temperature range tested at the site of installation was -20°C to +50°C (Fidas® 200 S) and +5°C to +40°C (Fidas® 200/Fidas® 200 E). Taking into account the readings provided by the instrument, the maximum effect of the surrounding temperature on the zero point for all three instrument versions did not exceed 0.1 µg/m³ both for $PM_{10}$ and $PM_{2.5}$.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 222 :Dependence of the zero point on surrounding temperature, Fidas® 200 S, deviation in µg/m³, mean from three measurements, $PM_{10}$, SN 0111 & SN 0112

| Temperature | SN 0111 | | SN 0112 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | µg/m³ | µg/m³ | µg/m³ | µg/m³ |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| -20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 50 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| Mean value at 20°C | <0,1 | - | <0,1 | - |

Table 23: Dependence of the zero point on surrounding temperature, Fidas® 200 S, Deviation in µg/m³, mean from three measurements, $PM_{2.5}$, SN 0111 & SN 0112

| Temperature | SN 0111 | | SN 0112 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | µg/m³ | µg/m³ | µg/m³ | µg/m³ |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| -20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 50 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| Mean value at 20°C | <0,1 | - | <0,1 | - |

Table 24: Dependence of the zero point on surrounding temperature, Fidas® 200, Deviation in µg/m³, mean from three measurements, $PM_{10}$, SN 5048 & SN 5049

| Temperature | SN 5048 | | SN 5049 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | µg/m³ | µg/m³ | µg/m³ | µg/m³ |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 5 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 40 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| Mean value at 20°C | <0,1 | - | <0,1 | - |

Table 25: Dependence of the zero point on surrounding temperature, Fidas® 200, Deviation in µg/m³, mean from three measurements, $PM_{2.5}$, SN 5048 & SN 5049

| Temperature | SN 5048 | | SN 5049 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | µg/m³ | µg/m³ | µg/m³ | µg/m³ |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 5 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 40 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| Mean value at 20°C | <0,1 | - | <0,1 | - |

Table 26: Dependence of the zero point on surrounding temperature, Fidas® 200 E, deviation in µg/m³, mean from three measurements, $PM_{10}$, SN 6623 & SN 6624

| Temperature | SN 6623 | | SN 6624 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | µg/m³ | µg/m³ | µg/m³ | µg/m³ |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 5 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 40 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| Mean value at 20°C | <0,1 | - | <0,1 | - |

Table 27: Dependence of the zero point on surrounding temperature, Fidas® 200 E, deviation in µg/m³, mean from three measurements, $PM_{2.5}$, SN 6623 & SN 6624

| Temperature | SN 6623 | | SN 6624 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | µg/m³ | µg/m³ | µg/m³ | µg/m³ |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 5 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| 40 | <0,1 | <0,1 | <0,1 | <0,1 |
| 20 | <0,1 | <0,1 | <0,1 | <0,1 |
| Mean value at 20°C | <0,1 | - | <0,1 | - |

Annex 3 in the appendix contains the individual measuring results.

## 6.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7)

*The differences found shall comply with the performance criteria given below.*
*Sensitivity of the measuring system (span):*
*≤ 5% from the value at the nominal test temperature*

- *between 5°C and 40°C by default, for installations in an air-conditioned environment.*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

## 6.2 Equipment

Climatic chamber for the temperature range between -20 and +50 °C; CalDust 1100 and MonoDust 1500 for span checks

## 6.3 Testing

The dependence of AMS sensitivity (span) on the surrounding temperature was determined at the following temperatures (within the specifications of the manufacturer):

a) at a nominal temperature $T_{S,n}$ = +20 °C;
b) at a minimum temperature $T_{S,1}$ = -20 °C (Fidas® 200 S) or 5 °C (Fidas® 200/Fidas® 200 E);
c) at a maximum temperature $T_{S,2}$ = 50 °C (Fidas® 200 S) or 40 °C (Fidas® 200/Fidas® 200 E).

For the purpose of testing the dependence of measured value (span) on surrounding temperature, the complete measuring systems were operated inside a climatic chamber (Fidas® 200 S during initial performance testing, Fidas® 200 and Fidas® 200 E in the context of supplementary tests aiming at qualifying each instrument version).

For the purpose of span checks, the peak position when applying monodisperse test dust CalDust 1100 (Fidas® 200 S/Fidas® 200) or MonoDust 1500 (Fidas® 200 E) was verified and assessed in order to test the instrument's stability of the sensitivity.

When applying CalDust 1100 test dust, a peak in the size distribution should generally be expected at channel 130 (this corresponds to a particle size of 0.93 µm); when applying MonoDust 1500 test dust—depending on the test certificate—this is expected at channel 141.1 which corresponds to a particle size of 1.28 µm. To allow for quantification of deviations from the classification, data sets from the field test served as basis for calculating the potential effect of peak shifts of up to ±3 channels on measured values for PM. For the purpose of evaluation, a hypothetical measured value of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for $PM_{10}$ was assumed for the ideal situation (a peak for CalDust 1100 exactly at channel 130 and exactly at channel 141.1 for MonoDust 1500). The concentration value expected in accordance with the peak shift was then determined in accordance with the matrix presented in chapter 4.2 Laboratory test.

The tests were performed in the temperature sequence $T_{S,n}$ — $T_{S,1}$ — $T_{S,n}$ — $T_{S,2}$ — $T_{S,n}$.

Readings were recorded at zero point after an equilibration period of at least 6h for every temperature step (3 readings each).

## 6.4 Evaluation

Concentration values were determined from individual readings with monodisperse test dust and then evaluated.

In order to exclude any possible drift due to factors other than temperature, the measurements at $T_{S,n}$ were averaged.

The differences between readings at both extreme temperatures and $T_{S,lab}$ were determined.

## 6.5 Assessment

The ambient air temperature range tested at the site of installation was -20°C to +50°C (Fidas® 200 S) and +5°C to +40°C (Fidas® 200/Fidas® 200 E). Deviations at the reference point did not exceed 4.9% for $PM_{2.5}$ and 4.5% for $PM_{10}$ (Fidas® 200 S) as well as -1.9% for $PM_{2.5}$ and -1.9% for $PM_{10}$ (Fidas® 200) and -4.8% for $PM_{2.5}$ and -4.6% for $PM_{10}$ (Fidas® 200 E).

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 28: Dependence of measured value (span) on surrounding temperature, CalDust 1100, Fidas® 200 S, dev. in %, mean from 3 measurements, $PM_{10}$, SN 0111 & SN 0112

| Temperature | SN 0111 | | SN 0112 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | [µg/m³] | % | [µg/m³] | % |
| 20 | 40.0 | 0.0 | 40.0 | -0.1 |
| -20 | 38.2 | -4.4 | 41.8 | 4.5 |
| 20 | 39.9 | -0.2 | 40.0 | 0.0 |
| 50 | 39.5 | -1.2 | 40.0 | 0.0 |
| 20 | 40.0 | 0.1 | 40.1 | 0.1 |
| Mean value at 20°C | 40.0 | - | 40.0 | - |

Table 29: Dependence of measured value (span) on surrounding temperature, CalDust 1100, Fidas® 200 S, dev. in %, mean from 3 measurements, $PM_{2.5}$, SN 0111 & SN 0112

| Temperature | SN 0111 | | SN 0112 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | [µg/m³] | % | [µg/m³] | % |
| 20 | 25.0 | 0.0 | 25.0 | -0.1 |
| -20 | 23.9 | -4.4 | 26.2 | 4.9 |
| 20 | 25.0 | -0.2 | 25.0 | 0.0 |
| 50 | 24.7 | -1.2 | 25.0 | 0.0 |
| 20 | 25.0 | 0.1 | 25.0 | 0.1 |
| Mean value at 20°C | 25.0 | - | 25.0 | - |

Table 30: Dependence of measured value (span) on surrounding temperature, CalDust 1100, Fidas® 200, dev. in %, mean from 3 measurements, $PM_{10}$, SN 5048 & SN 5049

| Temperature | SN 5048 | | SN 5049 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | [µg/m³] | % | [µg/m³] | % |
| 20 | 40.0 | 0.3 | 40.0 | 0.3 |
| 5 | 39.1 | -1.9 | 39.2 | -1.6 |
| 20 | 39.7 | -0.5 | 39.8 | -0.1 |
| 40 | 40.4 | 1.3 | 40.3 | 0.9 |
| 20 | 40.0 | 0.2 | 39.8 | -0.1 |
| Mean value at 20°C | 39.9 | - | 39.9 | - |

Table 31: Dependence of measured value (span) on surrounding temperature, CalDust 1100, Fidas® 200, dev. in %, mean from 3 measurements, $PM_{2.5}$, SN 5048 & SN 5049

| Temperature | SN 5048 | | SN 5049 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | [µg/m³] | % | [µg/m³] | % |
| 20 | 25.0 | 0.3 | 25.0 | 0.3 |
| 5 | 24.4 | -1.9 | 24.5 | -1.6 |
| 20 | 24.8 | -0.6 | 24.9 | -0.2 |
| 40 | 25.3 | 1.4 | 25.2 | 1.1 |
| 20 | 25.0 | 0.2 | 24.9 | -0.2 |
| Mean value at 20°C | 24.9 | - | 24.9 | - |

Table 32: Dependence of measured value (span) on surrounding temperature, MonoDust 1500, Fidas® 200 E, dev. in %, mean from 3 measurements, $PM_{10}$, SN 6623 & SN 6624

| Temperature | SN 6623 | | SN 6624 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | [µg/m³] | % | [µg/m³] | % |
| 20 | 40.7 | 0.7 | 40.5 | 0.7 |
| 5 | 41.0 | 1.4 | 39.8 | -1.1 |
| 20 | 40.3 | -0.3 | 40.1 | -0.2 |
| 40 | 38.5 | -4.6 | 40.4 | 0.5 |
| 20 | 40.3 | -0.3 | 40.0 | -0.5 |
| Mean value at 20°C | 40.4 | - | 40.2 | - |

Table 33: Dependence of measured value (span) on surrounding temperature, MonoDust 1500, Fidas® 200 E, dev. in %, mean from 3 measurements, $PM_{2.5}$, SN 6623 & SN 6624

| Temperature | SN 6623 | | SN 6624 | |
|---|---|---|---|---|
| | Measured value | Deviation to mean value at 20°C | Measured value | Deviation to mean value at 20°C |
| °C | [µg/m³] | % | [µg/m³] | % |
| 20 | 25.5 | 0.7 | 25.3 | 0.8 |
| 5 | 25.7 | 1.6 | 24.9 | -1.1 |
| 20 | 25.2 | -0.4 | 25.1 | -0.3 |
| 40 | 24.1 | -4.8 | 25.3 | 0.5 |
| 20 | 25.2 | -0.4 | 25.0 | -0.5 |
| Mean value at 20°C | 25.3 | - | 25.1 | - |

Annex 3 in the appendix contains the results from 3 individual measurements.

## 6.1 9 Dependence of span on supply voltage (7.4.8)

*The differences found shall comply with the performance criteria given below.*
*Sensitivity of the measuring system (span):*
*≤ 5% from the value at the nominal test voltage*

## 6.2 Equipment

Isolating transformer, MonoDust 1500 for span point checks.

## 6.3 Testing

In order to test the dependence of span on supply voltage, supply voltage was reduced to 195 V starting from 230 V, it was then increased to 253 V via an intermediary step of 230 V.

For the purpose of span checks, the peak position when applying monodisperse test dust MonoDust 1500 to tested instruments SN 6486 and SN 7147 was verified and assessed in order to test the instrument's stability of the sensitivity.

When applying MonoDust 1500 test dust, a peak in the size distribution should, according to the test certificate, generally be expected (during the tests at channel 141.1 which corresponds to a particle size of 1.28 µm). To allow for quantification of deviations from the classification, data sets from the field test served as basis for calculating the potential effect of peak shifts of up to ±3 channels on measured values for PM. For the purpose of evaluation, a hypothetical measured value of 25 µg/m³ for $PM_{2.5}$ and 40 µg/m³ for $PM_{10}$ was assumed for the ideal situation (a peak for MonoDust 1500 exactly at channel 141.1). The concentration value expected in accordance with the peak shift was then determined in accordance with the matrix presented in chapter 4.2Laboratory test.

## 6.4 Evaluation

At span point, the percentage change of the measured value determined for every step related to the starting point at 230 V was considered.

## 6.5 Assessment

Voltage variations did not cause deviations exceeding -0.4% for $PM^{2.5}$ and -0.3% for $PM_{10}$ as a percentage of the initial voltage of 230V.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 35 and Table 34 summarise the test results.

Table 34: Influence of mains voltage on measured value, dev. in %, $PM_{10}$, SN 6486 & SN 7147

| Supply voltage | SN 6486 | | SN 7147 | |
|---|---|---|---|---|
| | Measured value | Deviation to start value at 230 V | Measured value | Deviation to start value at 230 V |
| V | [µg/m³] | % | [µg/m³] | % |
| 230 | 40.00 | - | 39.93 | - |
| 195 | 39.90 | -0.3 | 39.93 | 0.0 |
| 230 | 39.93 | -0.2 | 39.97 | 0.1 |
| 253 | 39.90 | -0.3 | 39.97 | 0.1 |
| 230 | 39.87 | -0.3 | 40.00 | 0.2 |

Table 35: Influence of mains voltage on measured value, dev. in %, $PM_{2.5}$, SN 6486 & SN 7147

| Supply voltage | SN 6486 | | SN 7147 | |
|---|---|---|---|---|
| | Measured value | Deviation to start value at 230 V | Measured value | Deviation to start value at 230 V |
| V | [µg/m³] | % | [µg/m³] | % |
| 230 | 25.00 | - | 24.93 | - |
| 195 | 24.90 | -0.4 | 24.93 | 0.0 |
| 230 | 24.93 | -0.3 | 24.97 | 0.1 |
| 253 | 24.90 | -0.4 | 24.97 | 0.1 |
| 230 | 24.90 | -0.4 | 25.00 | 0.3 |

Annex 4 in the appendix contains the individual results.

## 6.1 10 Effect of failure of mains voltage

*Instrument parameters shall be secured against loss.*
*On return of main voltage the instrument shall automatically resume functioning.*

## 6.2 Equipment

Not required for this performance criterion

## 6.3 Testing

A simulated failure in the mains voltage served to test whether the instrument remained fully functional and reached operation mode on return of the mains voltage.

## 6.4 Evaluation

The measuring system resumes operation after a power failure and the start of the Windows operating system and the Fidas® Start-Up Manager. It is operational after a couple of minutes.

## 6.5 Assessment

Buffering protects all instrument parameters against loss. On return of mains voltage the instrument returns to operating mode and automatically resumes measuring once it has reached the status “device ready”.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 11 Dependence of reading on water vapour concentration (7.4.9)

*The largest difference in readings between 40% and 90% relative humidity shall fulfil the performance criterion stated below: ≤ 2.0 µg/m³ in zero air when cycling relative humidity from 40% to 90% and back.*

.

## 6.2 Equipment

Climatic chamber c/w humidity control for the range between 40% and 90% relative humidity, zero filter for zero checks

## 6.3 Testing

The dependence of reading on water vapour concentration in the sample air was determined by feeding humidified zero air in the range between 40% and 90% relative humidity. To this effect, the Fidas® 200 S measuring system (approved for outdoor installation) was operated in the climatic chamber and the relative humidity of the entire surrounding atmosphere was controlled. Sample air, free of suspended particles was supplied to the instruments SN 6486 and SN 7147 after fitting two zero filters at either AMS inlet in order to perform zero point checks.

After stabilisation of relative humidity and the concentration values, a reading over an 8h-averaging period at 40% relative humidity was recorded. The relative humidity was then raised back to 90% at a rate of 25% per hour. The time needed until an equilibrium was reached (ramp) and the measured value over an averaging time of 8h at 90% relative humidity were recorded. The humidity is then lowered back to 25% at a rate of 40% per h. Again, the time needed until an equilibrium was reached (ramp) and the reading over an averaging time of 8h at 40% relative humidity were recorded.

## 6.4 Evaluation

The measured value for the zero level of 8-hour individual measurements at stable humidity levels were obtained and assessed. The characteristic concerned is the largest difference in µg/m³ between values in the range of 40% to 90% relative humidity.

## 6.5 Assessment

Differences between readings determined at relative humidifies of 40% and 90% did not exceed 0.1 µg/m³. Various water vapour concentrations were not observed to cause any effect on zero readings.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 36: Dependence of reading on water vapour concentration, dev. in µg/m³, $PM_{10}$, SN 6486 & SN 7147

| rel. Humidity | SN 6486 | | SN 7147 | |
|---|---|---|---|---|
| | Measured value | Deviation to previous value | Measured value | Deviation to previous value |
| % | µg/m³ | µg/m³ | µg/m³ | µg/m³ |
| 40 | <0,1 | - | <0,1 | - |
| 90 | <0,1 | <0,1 | <0,1 | <0,1 |
| 40 | <0,1 | <0,1 | <0,1 | <0,1 |
| Maximum deviation | <0,1 | | <0,1 | |
| 40 → 90* | <0,1 | | <0,1 | |
| 90 → 40* | <0,1 | | <0,1 | |

* only informative

Table 37: Dependence of reading on water vapour concentration. dev. in µg/m³. $PM_{2.5}$. SN 6486 & SN 7147

| rel. Humidity | SN 6486 | | SN 7147 | |
|---|---|---|---|---|
| | Measured value | Deviation to previous value | Measured value | Deviation to previous value |
| % | µg/m³ | µg/m³ | µg/m³ | µg/m³ |
| 40 | <0,1 | - | <0,1 | - |
| 90 | <0,1 | <0,1 | <0,1 | <0,1 |
| 40 | <0,1 | <0,1 | <0,1 | <0,1 |
| Maximum deviation | <0,1 | | <0,1 | |
| 40 → 90* | <0,1 | | <0,1 | |
| 90 → 40* | <0,1 | | <0,1 | |

* only informative

## 6.1 12 Zero checks (7.5.3)

*During the tests, the absolute measured value of the AMS shall not exceed the follow ing criterion:*
*Absolute value ≤ 3.0 µg/m³*

## 6.2 Equipment

Zero filter for zero checks

## 6.3 Testing

As part of the field test the checks were performed over a total of 14 months.

As part of regular checks about every month (incl. at the beginning and at the end of the tests at each location), the measuring systems were operated with zero filters fitted to the AMS inlets over a period of at least 24h and zero readings were evaluated.

## 6.4 Evaluation

During the tests, the absolute measured value of the AMS at zero point defined at 3.0 µg/m³ shall not be exceeded.

## 6.5 Assessment

The maximum absolute measured value at zero was determined at 0.1 µg/m³ for $PM_{2.5}$ and $PM_{10}$.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 38 and Table 39 list the measured value obtained for the zero point in µg/m³.

Figure 41 to Figure 44 illustrate the zero drift observed during the test period.

Table 38: Zero point checks SN 0111 & SN 0112, $PM_{10}$, with zero filter

| Date | SN 0111 Measured Value µg/m³ | SN 0111 Measured value (absolute) ≤ 3.0 µg/m³ | Date | SN 0112 Measured Value µg/m³ | SN 0112 Measured value (absolute) ≤ 3.0 µg/m³ |
|---|---|---|---|---|---|
| 5/10/2012 | 0.0 | ok | 5/10/2012 | 0.0 | ok |
| 5/11/2012 | 0.0 | ok | 5/11/2012 | 0.0 | ok |
| 5/12/2012 | 0.0 | ok | 5/12/2012 | 0.0 | ok |
| 5/13/2012 | 0.0 | ok | 5/13/2012 | 0.0 | ok |
| 6/16/2012 | 0.0 | ok | 6/16/2012 | 0.0 | ok |
| 6/17/2012 | 0.0 | ok | 6/17/2012 | 0.0 | ok |
| 7/20/2012 | 0.1 | ok | 7/20/2012 | 0.0 | ok |
| 7/21/2012 | 0.0 | ok | 7/21/2012 | 0.0 | ok |
| 7/22/2012 | 0.0 | ok | 7/22/2012 | 0.0 | ok |
| 8/17/2012 | 0.0 | ok | 8/17/2012 | 0.0 | ok |
| 8/18/2012 | 0.0 | ok | 8/18/2012 | 0.0 | ok |
| 8/19/2012 | 0.0 | ok | 8/19/2012 | 0.0 | ok |
| 11/19/2012 | 0.0 | ok | 11/19/2012 | 0.0 | ok |
| 11/20/2012 | 0.0 | ok | 11/20/2012 | 0.0 | ok |
| 1/11/2013 | 0.0 | ok | 1/11/2013 | 0.0 | ok |
| 1/12/2013 | 0.0 | ok | 1/12/2013 | 0.0 | ok |
| 1/13/2013 | 0.0 | ok | 1/13/2013 | 0.0 | ok |
| 2/5/2013 | 0.0 | ok | 2/5/2013 | 0.0 | ok |
| 2/6/2013 | 0.0 | ok | 2/6/2013 | 0.0 | ok |
| 2/27/2013 | 0.0 | ok | 2/27/2013 | 0.0 | ok |
| 2/28/2013 | 0.1 | ok | 2/28/2013 | 0.1 | ok |
| 3/30/2013 | 0.0 | ok | 3/30/2013 | 0.0 | ok |
| 3/31/2013 | 0.0 | ok | 3/31/2013 | 0.0 | ok |
| 4/1/2013 | 0.0 | ok | 4/1/2013 | 0.0 | ok |
| 4/26/2013 | 0.0 | ok | 4/26/2013 | 0.1 | ok |
| 4/27/2013 | 0.0 | ok | 4/27/2013 | 0.0 | ok |
| 4/28/2013 | 0.0 | ok | 4/28/2013 | 0.0 | ok |
| 5/14/2013 | 0.0 | ok | 5/14/2013 | 0.0 | ok |
| 5/15/2013 | 0.1 | ok | 5/15/2013 | 0.1 | ok |
| 6/22/2013 | 0.0 | ok | 6/22/2013 | 0.0 | ok |
| 6/23/2013 | 0.1 | ok | 6/23/2013 | 0.1 | ok |

Table 39: Zero point checks SN 0111 & SN 0112, $PM_{2.5}$, with zero filter

| Date | SN 0111 | | Date | SN 0112 | |
|---|---|---|---|---|---|
| | Measured Value µg/m³ | Measured value (absolute) ≤ 3.0 µg/m³ | | Measured Value µg/m³ | Measured value (absolute) ≤ 3.0 µg/m³ |
| 5/10/2012 | 0.0 | ok | 5/10/2012 | 0.0 | ok |
| 5/11/2012 | 0.0 | ok | 5/11/2012 | 0.0 | ok |
| 5/12/2012 | 0.0 | ok | 5/12/2012 | 0.0 | ok |
| 5/13/2012 | 0.0 | ok | 5/13/2012 | 0.0 | ok |
| 6/16/2012 | 0.0 | ok | 6/16/2012 | 0.0 | ok |
| 6/17/2012 | 0.0 | ok | 6/17/2012 | 0.0 | ok |
| 7/20/2012 | 0.1 | ok | 7/20/2012 | 0.0 | ok |
| 7/21/2012 | 0.0 | ok | 7/21/2012 | 0.0 | ok |
| 7/22/2012 | 0.0 | ok | 7/22/2012 | 0.0 | ok |
| 8/17/2012 | 0.0 | ok | 8/17/2012 | 0.0 | ok |
| 8/18/2012 | 0.0 | ok | 8/18/2012 | 0.0 | ok |
| 8/19/2012 | 0.0 | ok | 8/19/2012 | 0.0 | ok |
| 11/19/2012 | 0.0 | ok | 11/19/2012 | 0.0 | ok |
| 11/20/2012 | 0.0 | ok | 11/20/2012 | 0.0 | ok |
| 1/11/2013 | 0.0 | ok | 1/11/2013 | 0.0 | ok |
| 1/12/2013 | 0.0 | ok | 1/12/2013 | 0.0 | ok |
| 1/13/2013 | 0.0 | ok | 1/13/2013 | 0.0 | ok |
| 2/5/2013 | 0.0 | ok | 2/5/2013 | 0.0 | ok |
| 2/6/2013 | 0.0 | ok | 2/6/2013 | 0.0 | ok |
| 2/27/2013 | 0.0 | ok | 2/27/2013 | 0.0 | ok |
| 2/28/2013 | 0.1 | ok | 2/28/2013 | 0.1 | ok |
| 3/30/2013 | 0.0 | ok | 3/30/2013 | 0.0 | ok |
| 3/31/2013 | 0.0 | ok | 3/31/2013 | 0.0 | ok |
| 4/1/2013 | 0.0 | ok | 4/1/2013 | 0.0 | ok |
| 4/26/2013 | 0.0 | ok | 4/26/2013 | 0.0 | ok |
| 4/27/2013 | 0.0 | ok | 4/27/2013 | 0.0 | ok |
| 4/28/2013 | 0.0 | ok | 4/28/2013 | 0.0 | ok |
| 5/14/2013 | 0.0 | ok | 5/14/2013 | 0.0 | ok |
| 5/15/2013 | 0.0 | ok | 5/15/2013 | 0.1 | ok |
| 6/22/2013 | 0.0 | ok | 6/22/2013 | 0.0 | ok |
| 6/23/2013 | 0.0 | ok | 6/23/2013 | 0.0 | ok |

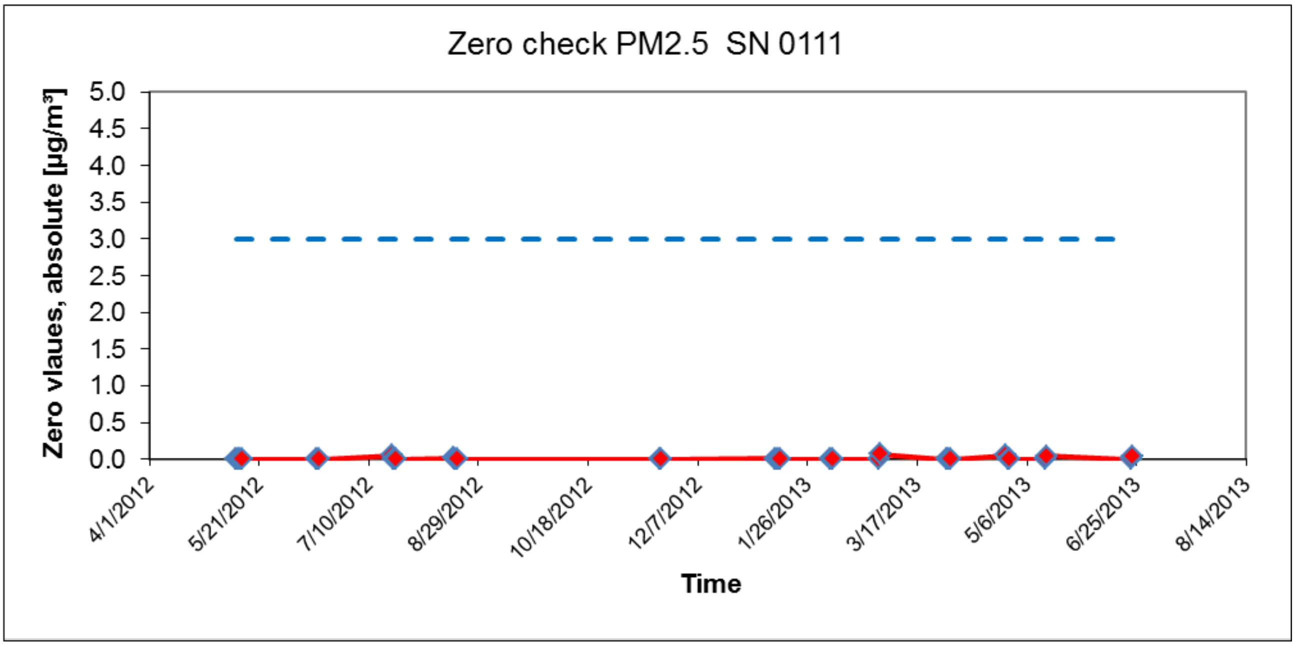



Figure 41: Zero drift SN 0111, measured component $PM_{2.5}$

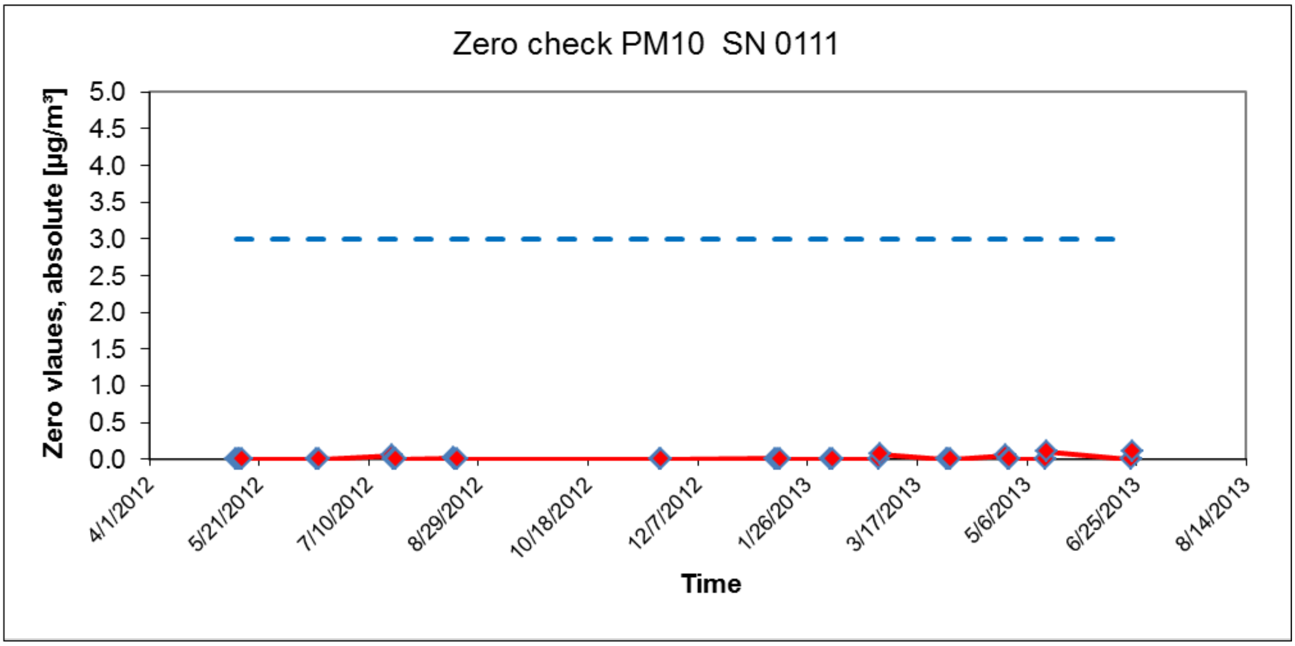



Figure 42: Zero drift SN 0111, measured component $PM_{10}$

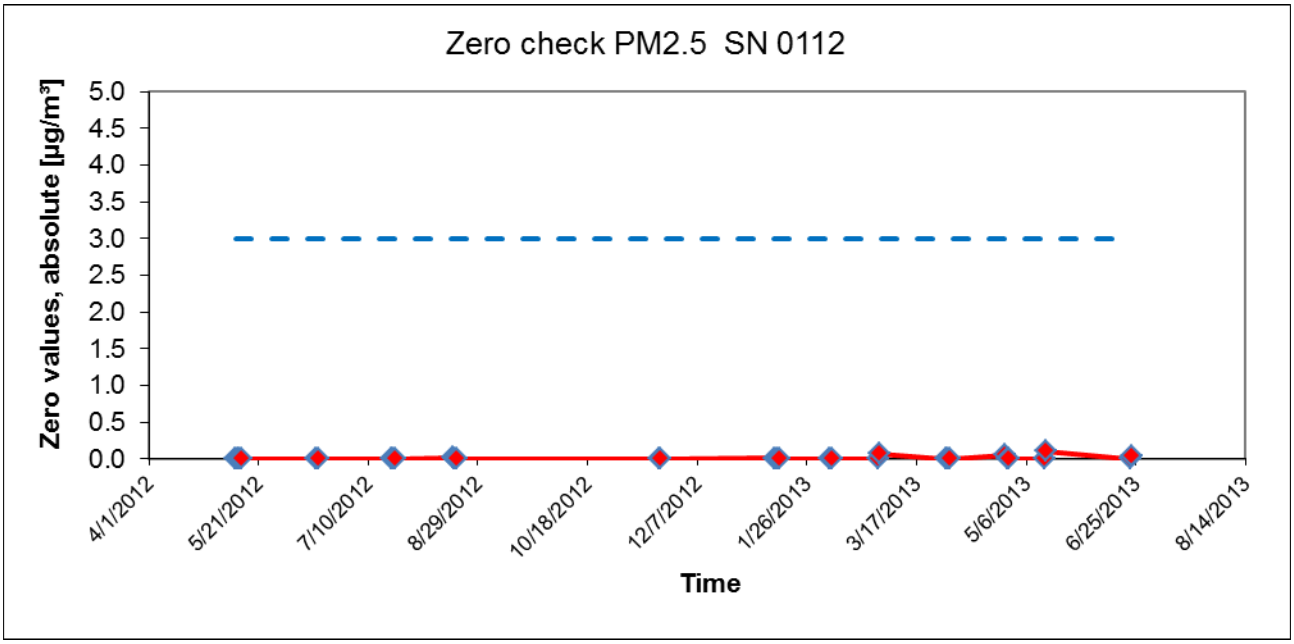



Figure 43: Zero drift SN 0112, measured component $PM_{2.5}$

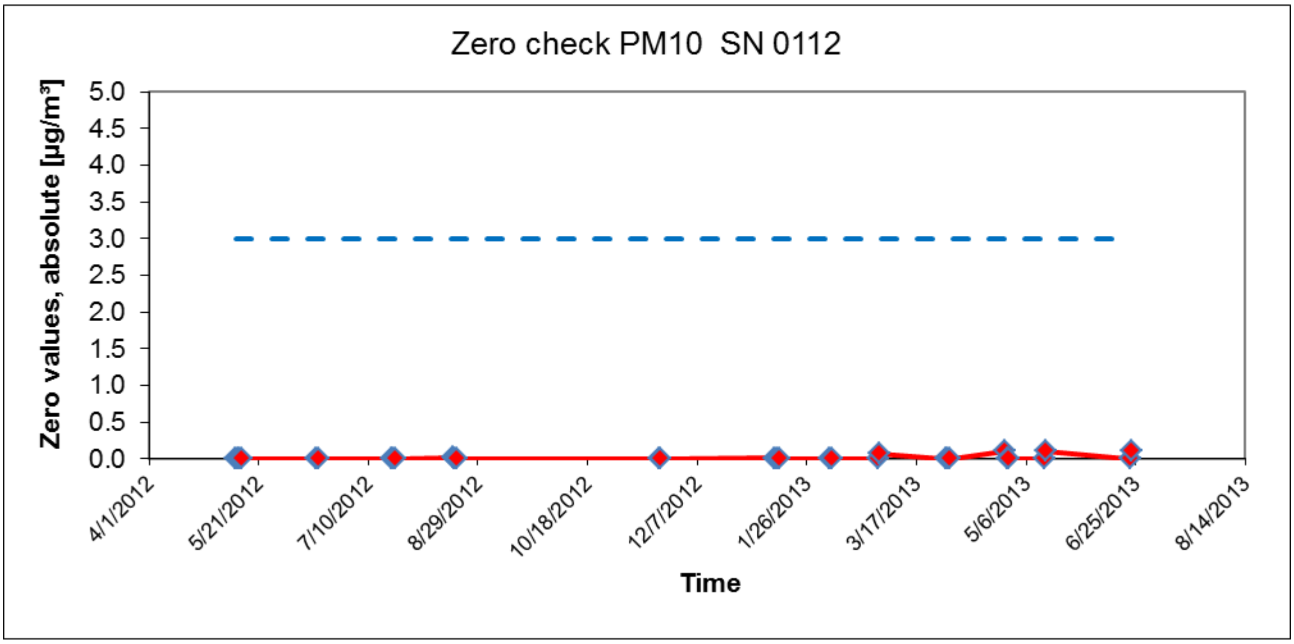



Figure 44: Zero drift SN 0112, measured component $PM_{10}$

## 6.1 13 Recording of operational parameters (7.5.4)

*Measuring systems shall be able to provide data of operational states for telemetric transmission of – at minimum – the following parameters:*

- *Flow rate;*
- *Pressure drop over sample filter (if relevant);*
- *Sampling time;*
- *Sampling volume (if relevant);*
- *Mass concentration of relevant PM fraction(s);*
- *Ambient temperature,*
- *Exterior air pressure,*
- *Air temperature in measuring section,*
- *Temperature of the sampling inlet if a heated inlet is used;*

*Results of automated/functional checks, where available, shall be recorded.*

## 6.2 Equipment

Computer for data acquisition

## 6.3 Testing

The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232) and is able to output measured values and status information via various protocols (e.g. Bayern-Hessen protocol or serial ASCII)

It is possible to communicate the operating statuses and relevant parameters including:

- Sample flow rate
- Mass concentrations of the relevant PM fraction
- Ambient temperature, pressure, humidity
- IADS temperature (sample processing)
- LED temperature

Furthermore, results of internal calibration checks are communicated.

Parameters such as “pressure drop via the sampling filter”, “sampling time”, “Sampling volume” and “temperature at the sample inlet” are irrelevant to the measuring system.

Remote monitoring and control is easily possible via routers or modems.

As part of the performance test, a PC was connected to the AMS via Ethernet/UMTS modem to test the transfer of data and the instrument status.

## 6.4 Evaluation

The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232). The instrument provides operating statuses and all relevant parameters.

## 6.5 Assessment

The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232). The instrument provides operating statuses and all relevant parameters.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 14 Daily averages (7.5.5)

*The AMS shall allow for the formation of daily averages or values.*

## 6.2 Equipment

For this test, a clock was additionally provided.

## 6.3 Testing

We verified whether the measuring system allows for the formation of daily averages.

## 6.4 Evaluation

The Fidas® 200 measuring systems use an optical method as a measuring principle and operate continuously and on-line to determine mass concentrations. Filter replacement or other types of recurring interruptions do not occur.

Thus, the formation of daily averages is ensured.

## 6.5 Assessment

It is possible to form valid daily averages.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Not applicable.

## 6.1 15 Availability (7.5.6)

*The availability of the measuring system shall be at least 90%.*

## 6.2 Equipment

Not required for this performance criterion

## 6.3 Testing

The start and end times at each of the four field test sites from the initial test (German sites) marked the start and end time for the availability test. Proper operation of the measuring system was verified during every on-site visit (usually every working day). This daily check consisted of plausibility checks on the measured values, status signals and other relevant parameters (see 7.5.4). Time, duration and nature of any error in functioning are recorded.

The total time during the field test in which valid measurement data of ambient air concentrations were obtained was used for calculating availability. Time needed for scheduled calibrations and maintenance (cleaning; change of consumables) should not be included.

Availability is calculated as

$$A = \frac{t_{valid} + t_{cal,maint}}{t_{field}}$$

Where:

$t_{valid}$ is the time during which valid data have been collected;

$t_{cal,maint}$ is the time spent for scheduled calibrations and maintenance;

$t_{field}$ is the total duration of the field test.

## 6.4 Evaluation

Operation times, maintenance and outage times are summarized in Table 40. During the field test, the measuring systems were operated for a total of 322 measuring days. This period covers 27 days with zero filter operation and a one-day loss caused by switching from the inlet to the zero filter (see annex 5).

Outages caused by external events not ascribed to the measuring system occurred on June 10, 2012, December 31, 2012 and January 1, 2013 (power failure). The externally-caused outages reduce the total time of operation to 319 measuring days.

The following errors in functioning were observed:

SN 0111:

The instrument was accidently switched off on 29 May 2012 by pressing “shut down” on the remote control.

A blown fuse of the enclosures heater caused system failure on 5 December 2012.

SN 0112:

Blown fuses of the enclosure’s heater caused further AMS outages on December 4, 8 and 9 2012.

No further errors in functioning were observed:

Regular checks of the particle sensor and maintenance of the sampling inlets. regular flow and leak tests resulted in outage times of 0.5 to 1h . Daily averages thus affected were not discarded.

## 6.5 Assessment

The availability for SN 0111 was 99.4%, for SN 0112 it was 99.1%.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 40: Determination of the availability

| | | System 1 (SN 0111) | System 2 (SN 0112) |
|---|---|---|---|
| Operation time ($t_{field}$) | d | 319 | 319 |
| Outage time | d | 2 | 3 |
| Maintenance time incl. zero filter ($t_{cal,maint}$) | d | 28 | 28 |
| Actual operating time ($t_{valid}$) | d | 289 | 288 |
| Availability | % | 99.4 | 99.1 |

## 6.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8)

The January 2010 Guideline [5] requires compliance with the following five criteria in order to recognise equivalence:

1. Of the full data set, at least 20% of the concentration values (determined with the reference method) shall be greater than the upper assessment threshold specified in 2008/50/EC [8], i.e. 28 µg/m³ for $PM_{10}$ and 17 µg/m³ for $PM_{2.5}$. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.
2. Between-AMS uncertainty shall remain below 2.5 µg/m³ for the overall data and for data sets with data larger than/equal to 30 µg/m³ $PM_{10}$ and 18 µg/m³ $PM_{2.5}$.
3. The uncertainty between reference systems shall not exceed 2.0 µg/m³.
4. The expanded uncertainty ($W_{CM}$) is calculated at 50 µg/m³ for $PM_{10}$ and at 30 µg/m³ for $PM_{2.5}$ for every individual candidate and checked against the average of the reference method. For each of the following cases, the expanded uncertainty shall not exceed 25%:
   - Full data set:
   - datasets representing PM concentrations greater than/equal to 30 µg/m³ for $PM_{10}$, or concentrations greater than/equal to 18 µg/m³ for $PM_{2.5}$, provided that the set contains 40 or more valid data pairs
   - Datasets for each individual site
5. Preconditions for acceptance of the full dataset are that the slope b is insignificantly different from $|b-1| \leq 2 \cdot u(b)$ and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept.

The following chapter address the issue of verifying compliance with the five criteria.

Chapter 6.1 16 Between-AMS uncertainty $u_{bs,AMS}$ (7.5.8.4) addresses verification of criteria 1 and 2.

Verification of criteria 3, 4 and 5 is reported on in chapter 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

Chapter 6.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8) contains an assessment for the case that criterion 5 is not complied with without applying correction factors.

## 6.1 16 Between-AMS uncertainty $u_{bs,AMS}$ (7.5.8.4)

*The between-AMS uncertainty $u_{bs}$ shall be ≤ 2.5 µg/m³.*

## 6.2 Equipment

Not required for this performance criterion.

## 6.3 Testing

The test was performed as part of the field test with six separate comparison campaigns. Different seasons as well as different concentrations of $PM_{2.5}$ and $PM_{10}$ were taken into consideration.

In the full dataset, at least 20% of the results obtained using the reference method should be greater than the upper assessment threshold of the annual limit value specified in 2008/50/EC [8]. The assessment threshold for $PM_{2.5}$ is 17 µg/m³, for $PM_{10}$ it is 28 µg/m³. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full data set (6 comparisons, for $PM_{10}$: 318 valid pairs of measured values for SN 0111, 318 valid pairs of measured values for SN 0112; for $PM_{2,5}$: 315 valid pairs of measured values for SN 0111, 315 valid pairs of measured values for SN 0112) 24.3% of the measured values are above the upper assessment threshold of 17 µg/m³ for $PM_{2.5}$ and 17.7% (corresponds to 56 > 32 pairs of measured values) of the measured values are above the upper assessment threshold of 28 µg/m³ for $PM_{10}$. The concentrations measured were related to the ambient conditions.

## 6.4 Evaluation

Chapter 7.5.8.4 of standard EN 16450 specifies that:

The between-AMS uncertainty $u_{bs}$ shall be ≤ 2.5 µg/m³. A between-AMS uncertainty > 2.5 µg/m$^3$ is an indication of unsuitable performance of one or both instruments, and equivalence should not be stated.

Uncertainty is determined for:

- All locations or comparisons together (full data set)
- 1 data set with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values ≥ 30 µg/m³ for $PM_{10}$ (basis: averages reference measurement)

Furthermore, this report also covers an evaluation of the following data sets:

- Every location or comparison separately
- 1 data set with measured values < 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values < 30 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)

The between-AMS uncertainty $u_{bs}$ is calculated from the differences of all daily averages (24h-values) of the AMS which are operated simultaneously as:

$$u_{bs,AMS}^2 = \frac{\sum_{i=1}^{n}(y_{i,1} - y_{i,2})^2}{2n}$$

Where: $y_{i,1}$ and $y_{i,2}$ = Results of the parallel measurements of individual 24h-values i

n = Number of 24h-values

## 6.5 Assessment

At no more than 0.85 µg/m³ for $PM_{2.5}$ and no more than 1.19 µg/m³ for $PM_{10}$, the uncertainty between the candidate $u_{bs}$ remains well below the permissible maximum of 2.5 µg/m³.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Table 41 and Table 42 list the calculated values for the between-AMS uncertainties $u_{bs}$. A corresponding chart is provided in Figure 45 to Figure 62.

Table 41: Between-AMS uncertainty $u_{bs,AMS}$ for systems SN 0111 and SN 0112, measured component $PM_{2.5}$, PM_ENVIRO_0011

| Tested instruments | Location | Number of measurements | Uncertainty $u_{bs,AMS}$ |
|---|---|---|---|
| SN | | | µg/m³ |
| **0111 / 0112** | **All locations** | **375** | **0.48** |
| Individual locations | | | |
| 0111 / 0112 | Cologne, Summer | 101 | 0.12 |
| 0111 / 0112 | Cologne, Winter | 66 | 0.55 |
| 0111 / 0112 | Bonn, Winter | 60 | 0.70 |
| 0111 / 0112 | Bornheim, Summer | 58 | 0.50 |
| 0111 / 0112 | Teddington, Winter | 45 | 0.55 |
| 0111 / 0112 | Teddington, Summer | 45 | 0.37 |
| Classing over reference values | | | |
| **0111 / 0112** | **Values ≥ 18 µg/m³** | **67** | **0.85** |
| 0111 / 0112 | Values < 18 µg/m³ | 246 | 0.32 |

Table 42: Between-AMS uncertainty $u_{bs,AMS}$ for systems SN 0111 and SN 0112, measured component $PM_{10}$, PM_ENVIRO_0011

| **Tested instruments** | **Location** | **Number of measurements** | **Uncertainty $u_{bs,AMS}$** |
|---|---|---|---|
| SN | | | µg/m³ |
| **0111 / 0112** | **All locations** | **375** | **0.67** |
| Individual locations | | | |
| 0111 / 0112 | Cologne, Summer | 101 | 0.27 |
| 0111 / 0112 | Cologne, Winter | 66 | 0.67 |
| 0111 / 0112 | Bonn, Winter | 60 | 0.90 |
| 0111 / 0112 | Bornheim, Summer | 58 | 0.87 |
| 0111 / 0112 | Teddington, Winter | 45 | 0.76 |
| 0111 / 0112 | Teddington, Summer | 45 | 0.56 |
| Classing over reference values | | | |
| **0111 / 0112** | **Values ≥ 30 µg/m³** | **44** | **1.19** |
| 0111 / 0112 | Values < 30 µg/m³ | 272 | 0.57 |

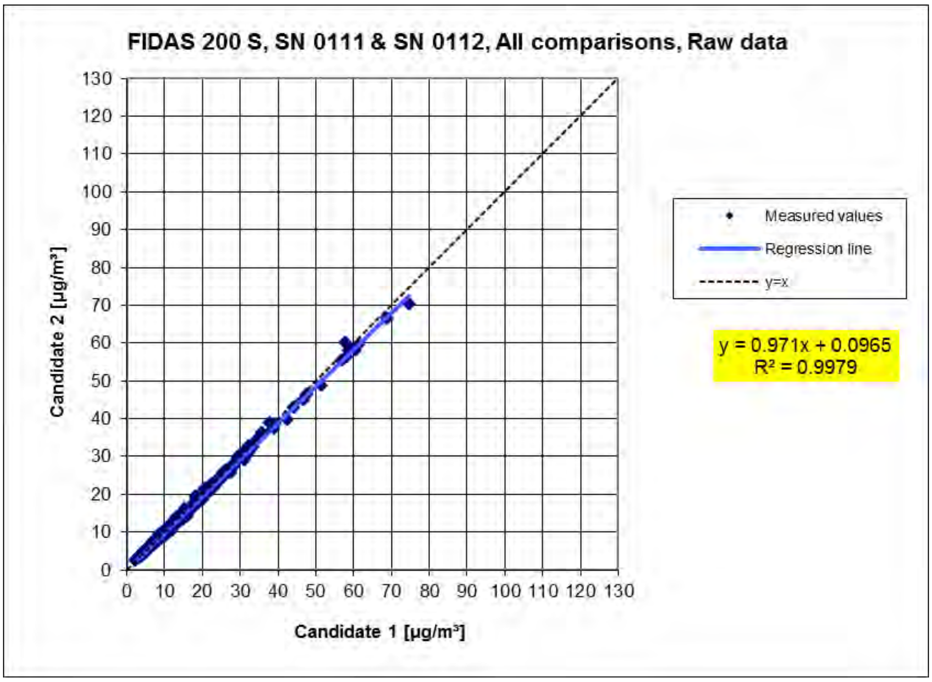



Figure 45: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, all test sites, PM_ENVIRO_0011

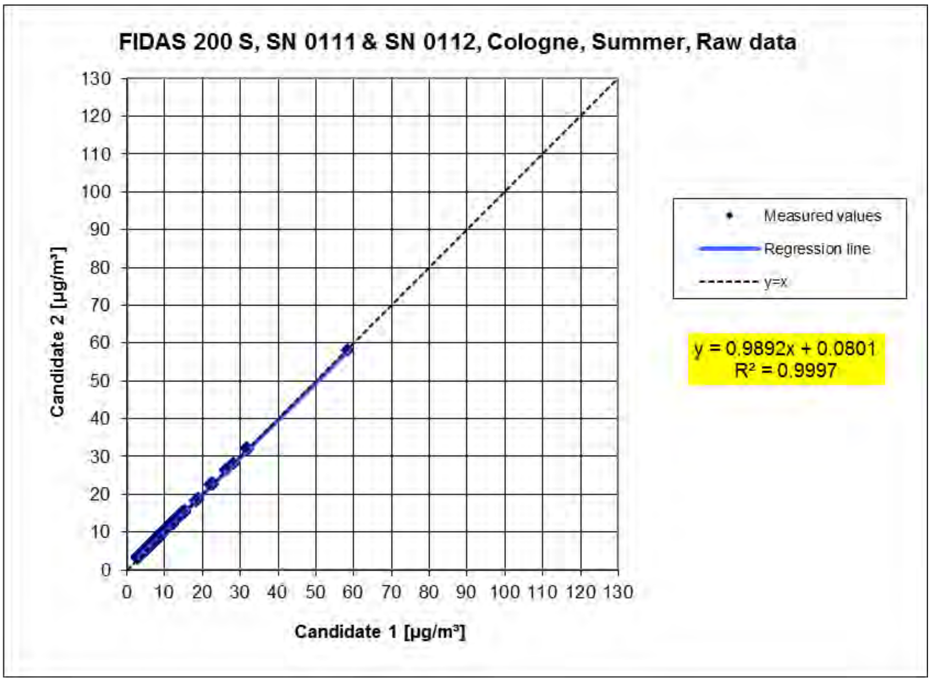



Figure 46: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2,5}$, Cologne, summer, PM_ENVIRO_0011

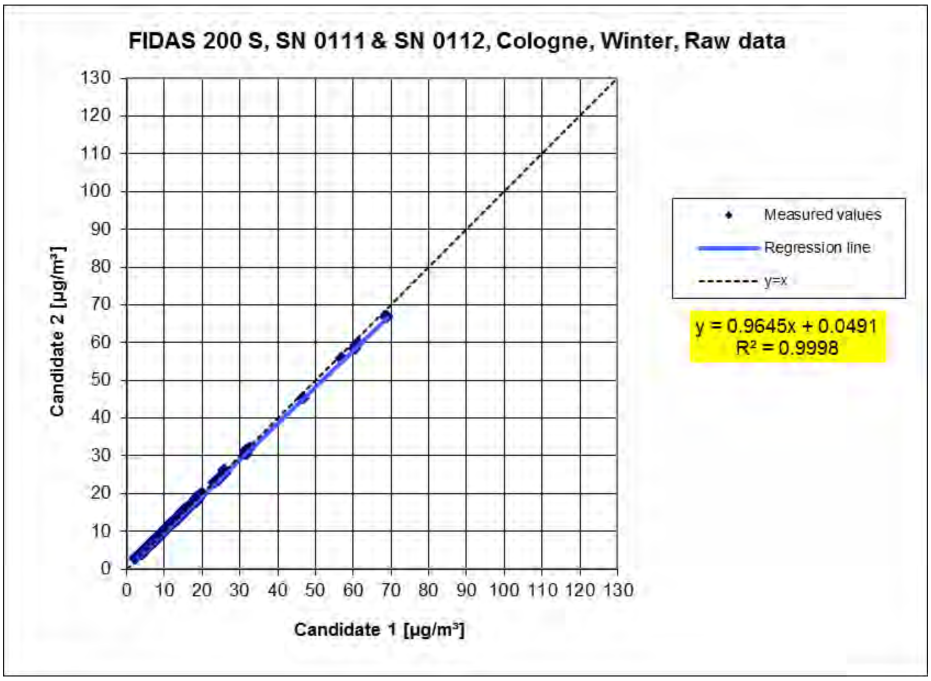



Figure 47: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, Cologne, winter, PM_ENVIRO_0011

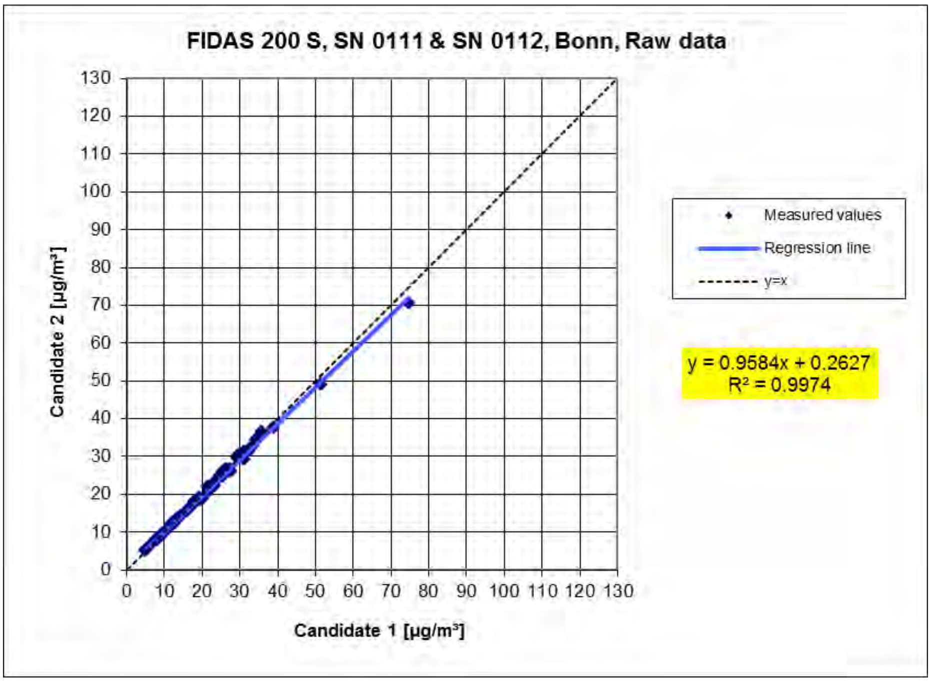



Figure 48: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, Bonn, winter, PM_ENVIRO_0011

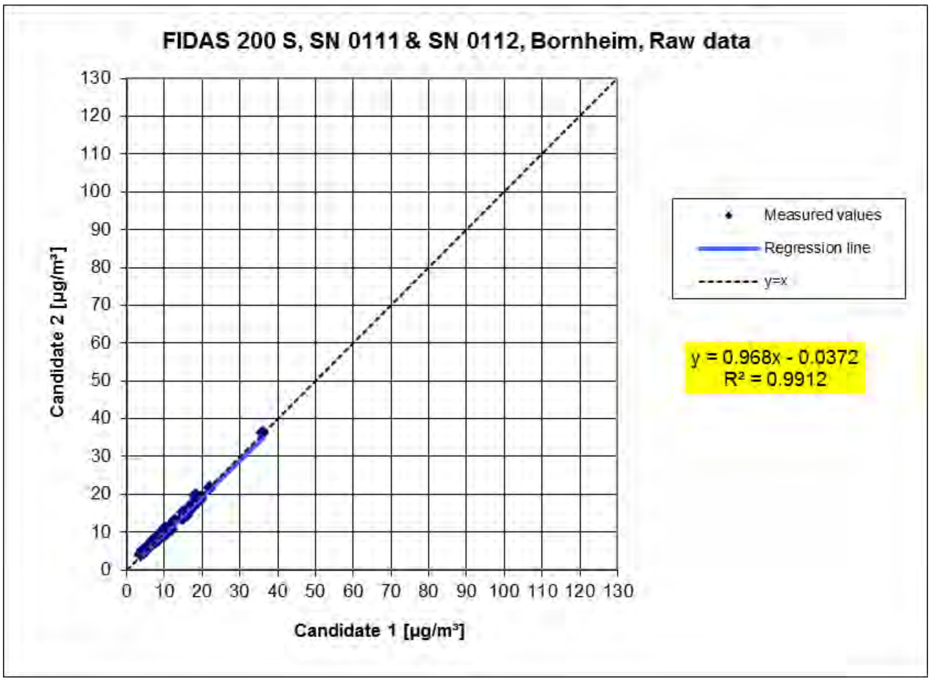



Figure 49: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, Bornheim, summer, PM_ENVIRO_0011

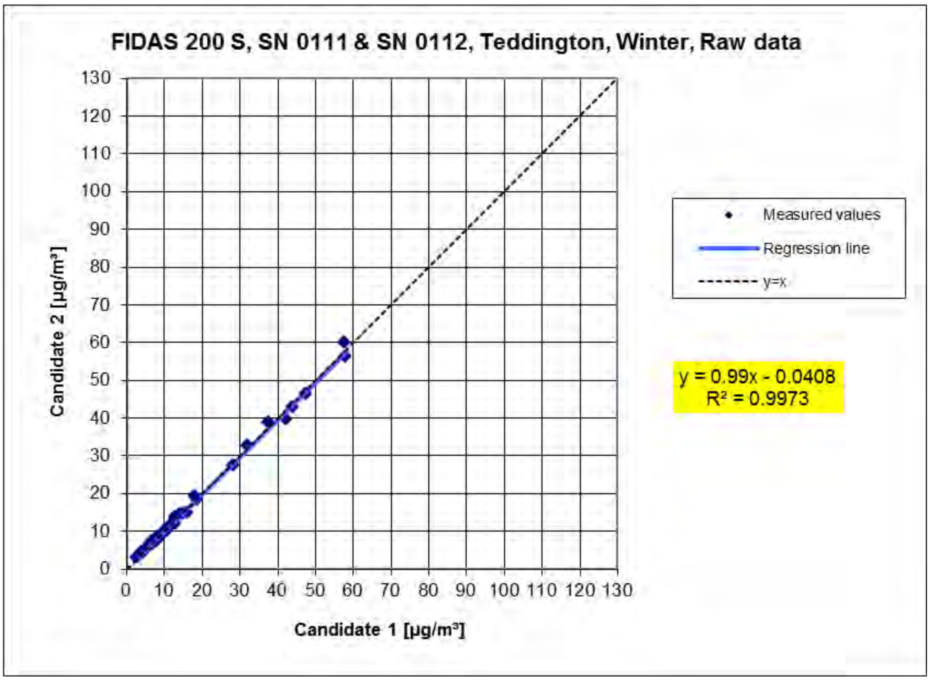



Figure 50: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, Teddington, winter PM_ENVIRO_0011

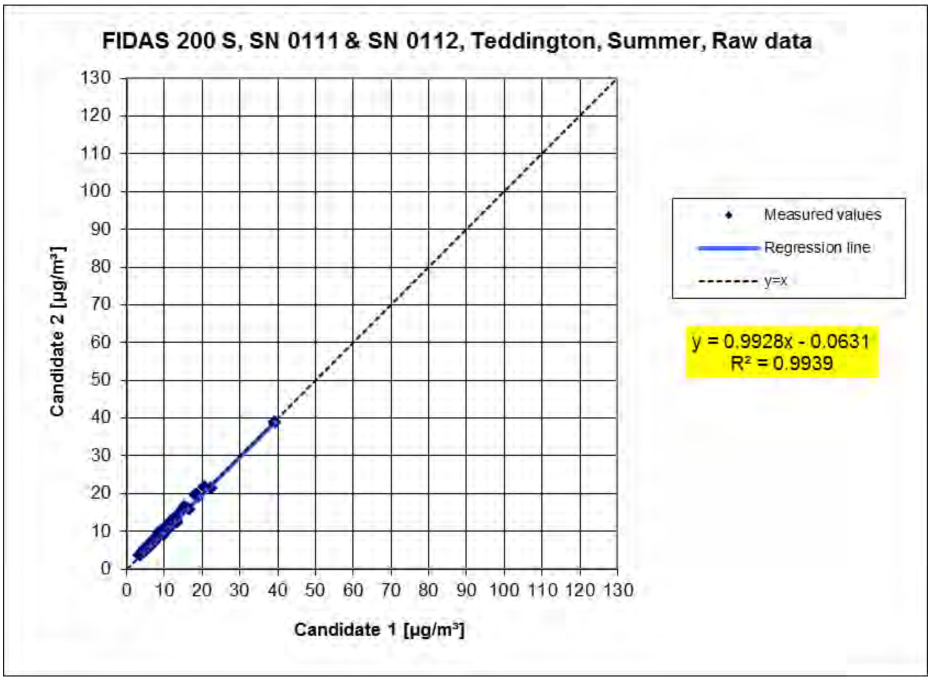



Figure 51: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, Teddington, summer, PM_ENVIRO_0011

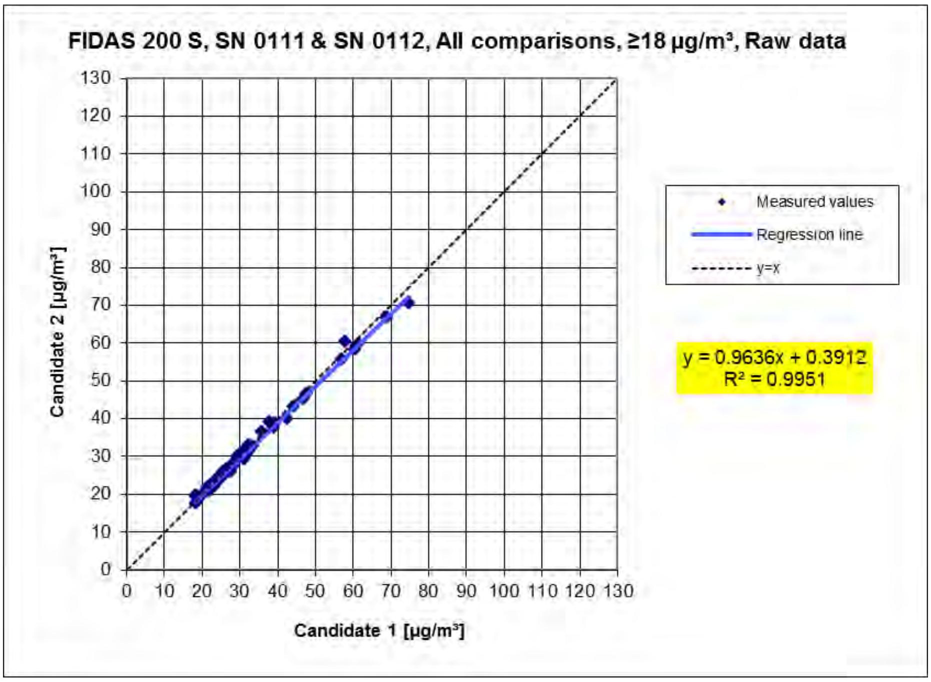



Figure 52: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2,5}$, all field test sites, values ≥ 18 µg/m³, PM_ENVIRO_0011

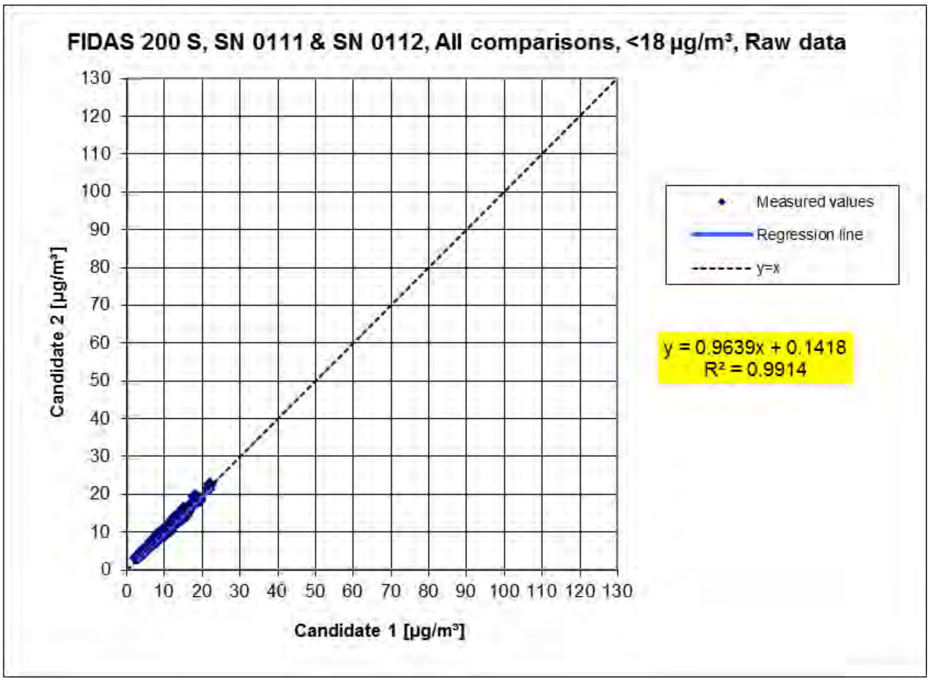



Figure 53: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{2.5}$, all field test sites, values < 18 µg/m³, PM_ENVIRO_0011

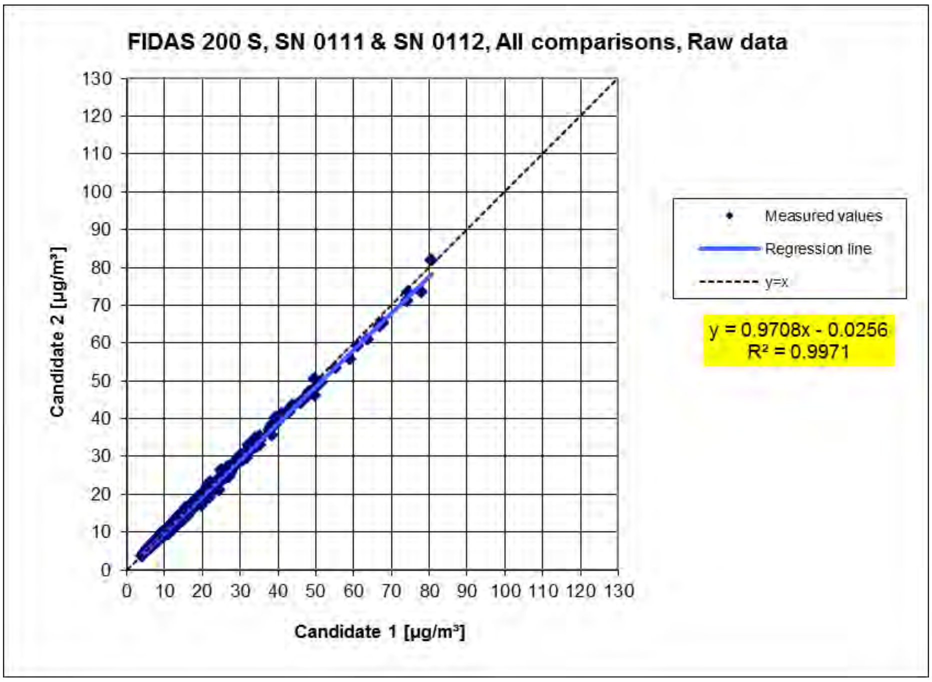



Figure 54: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$, all field test sites, PM_ENVIRO_0011

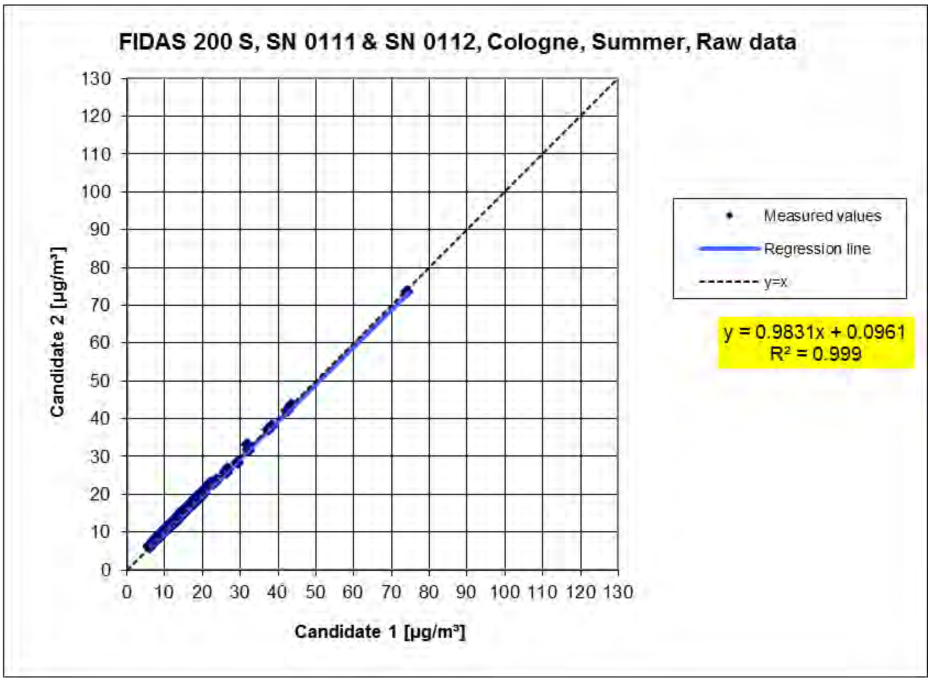



Figure 55: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$, Cologne, summer, PM_ENVIRO_0011

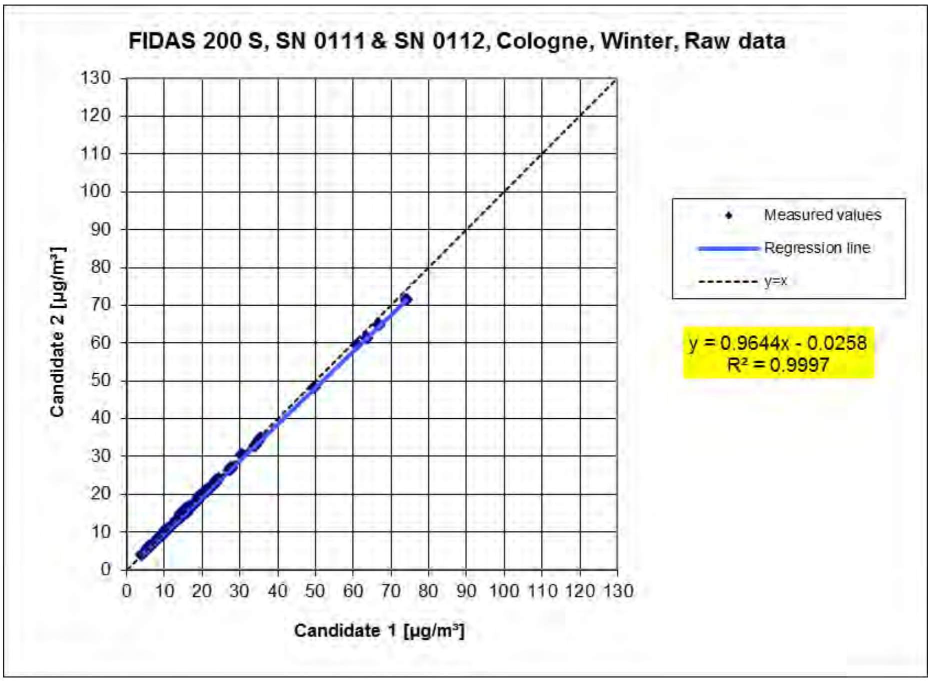



Figure 56: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$, Cologne, winter, PM_ENVIRO_0011

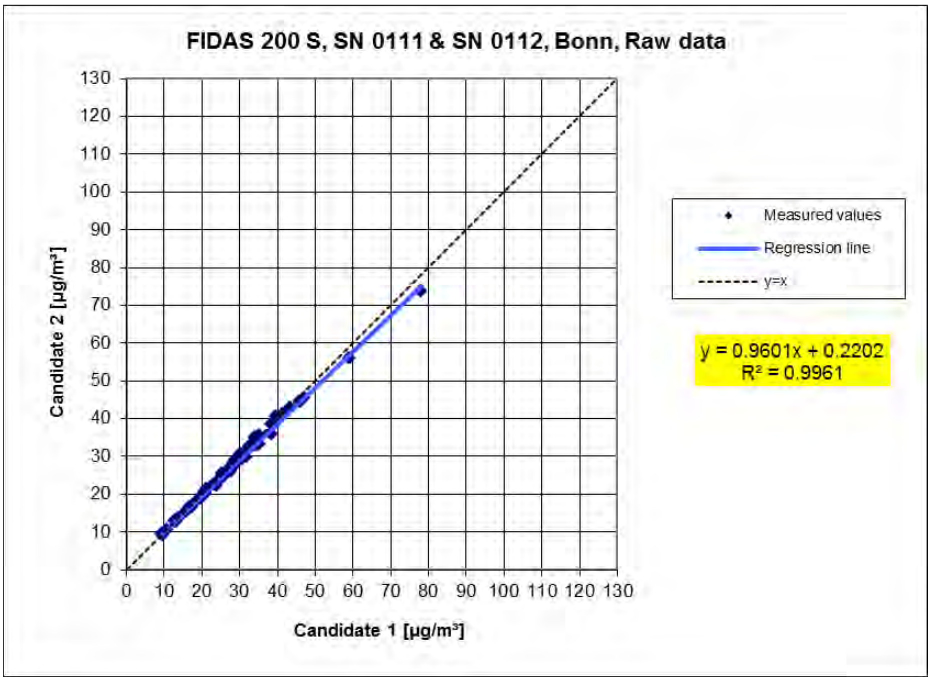



Figure 57: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$, Bonn, winter, PM_ENVIRO_0011

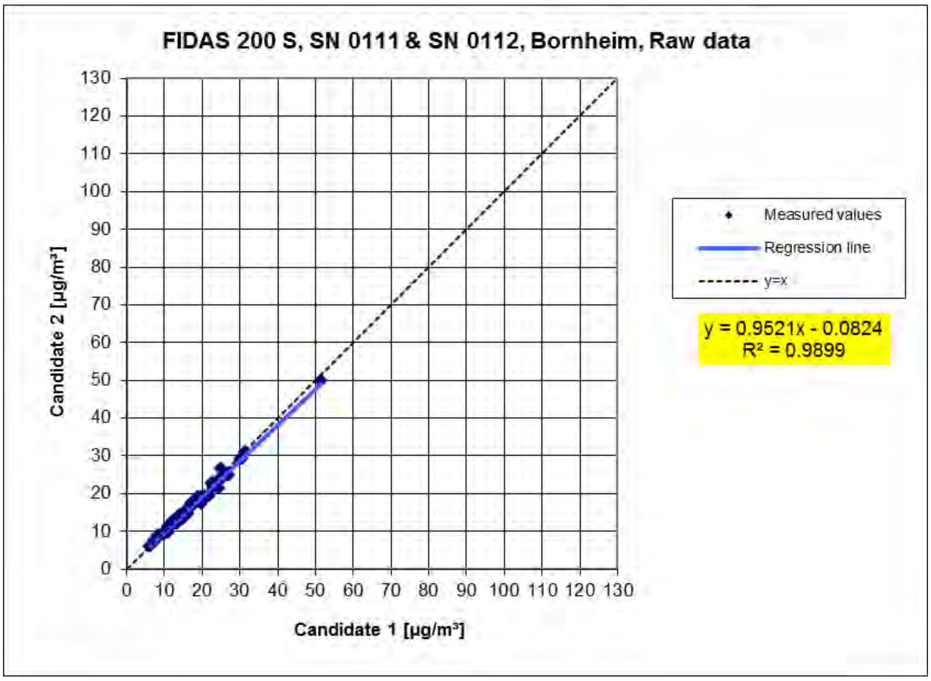



Figure 58: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$, Bornheim, summer, PM_ENVIRO_0011

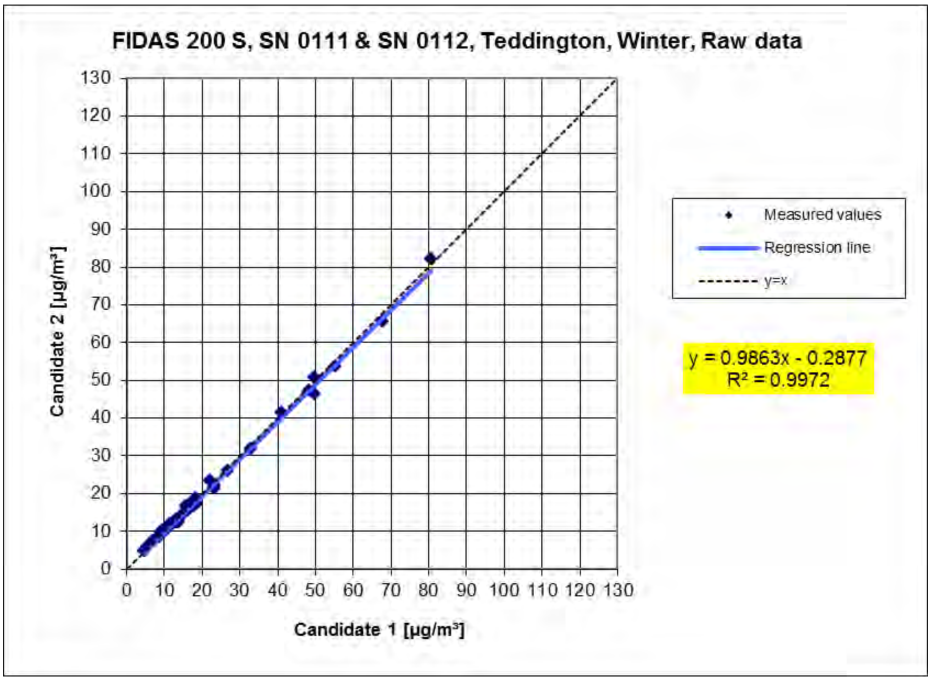



Figure 59: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$,Teddington, winter, PM_ENVIRO_0011

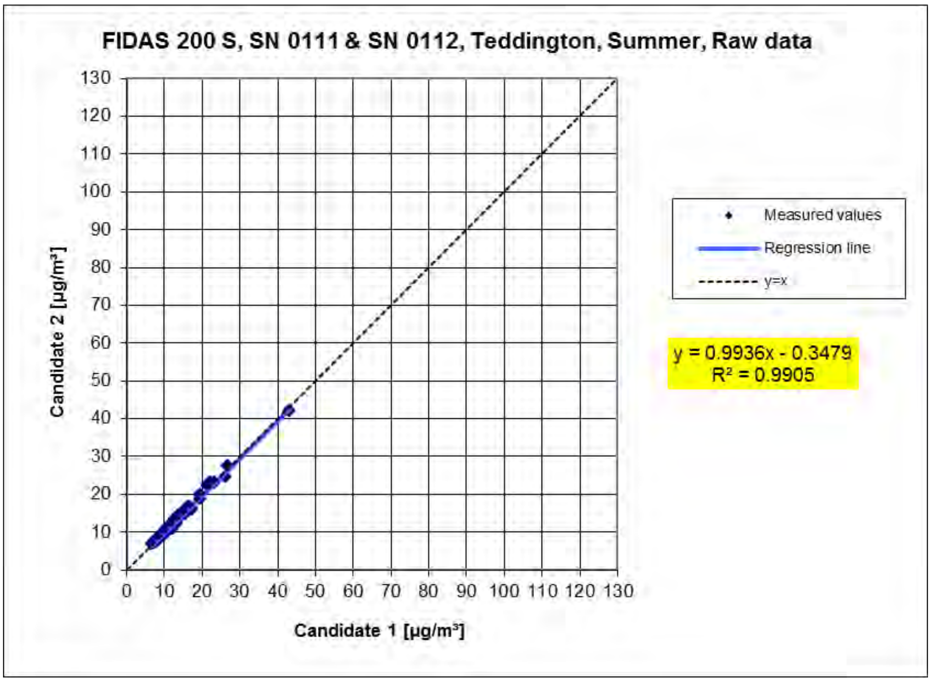



Figure 60: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$,Teddington, summer, PM_ENVIRO_0011

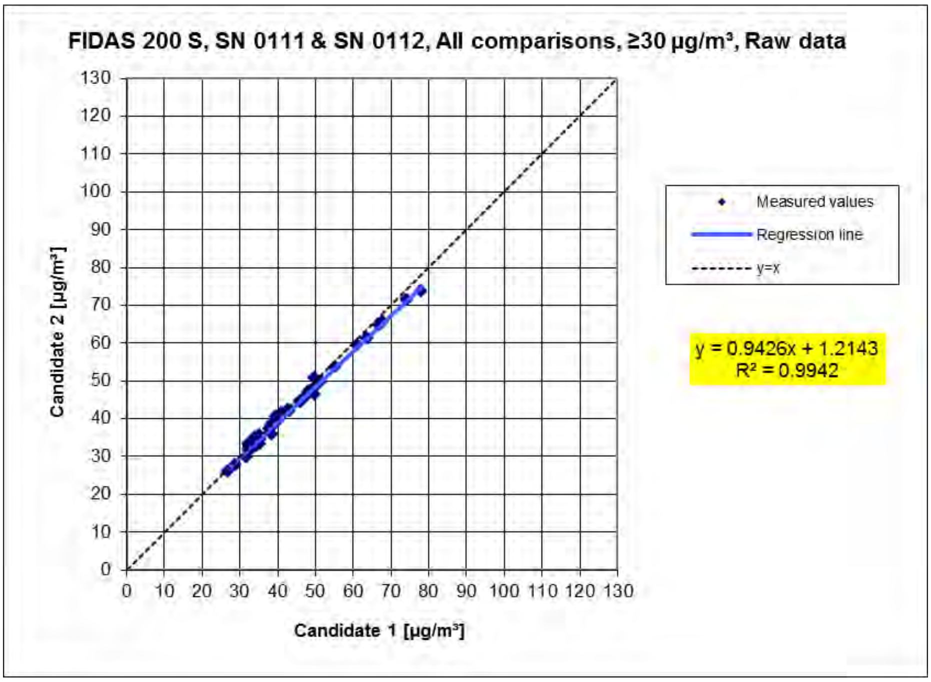



Figure 61: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$, all field test sites, values ≥ 30 µg/m³, PM_ENVIRO_0011

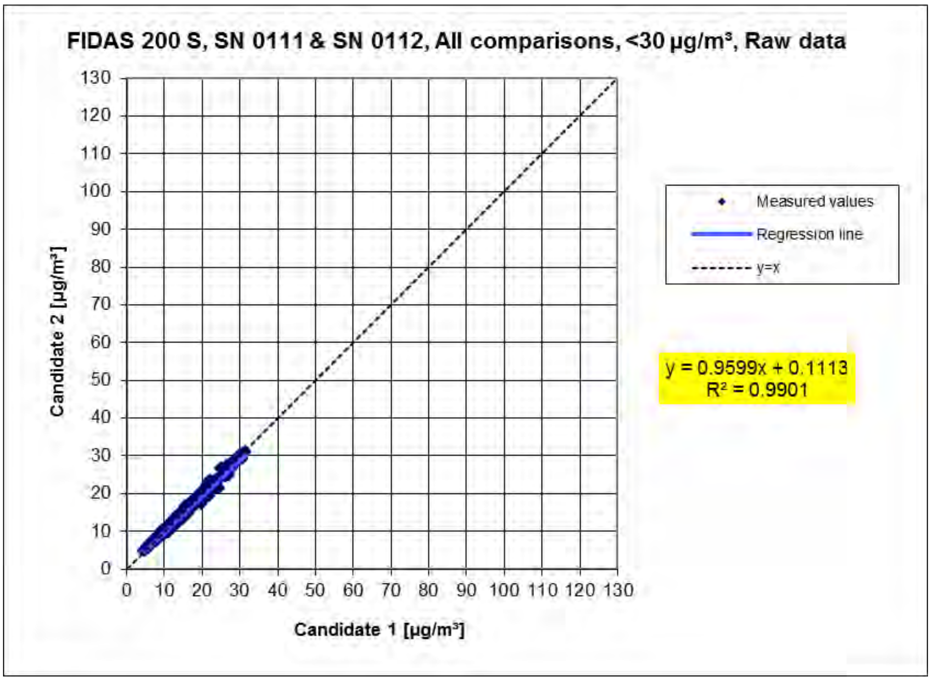



Figure 62: Results of the parallel measurements for instruments SN 0111 / SN 0112, Measured component $PM_{10}$, all field test sites, values < 30 µg/m³, PM_ENVIRO_0011

## 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

*The expanded uncertainty shall be ≤ 25% at the level of the relevant limit value related to the 24-hour average results – after a calibration where necessary.*

## 6.2 Equipment

Additional equipment as described in chapter 5 of this report was used for this test.

## 6.3 Testing

The test was performed as part of the field test with six separate comparison campaigns. Different seasons as well as different concentrations of $PM_{2.5}$ and $PM_{10}$ were taken into consideration.

In the full dataset, at least 20% of the results obtained using the reference method should be greater than the upper assessment threshold of the annual limit value specified in 2008/50/EC [8]. The assessment threshold for $PM_{2.5}$ is 17 µg/m³, for $PM_{10}$ it is 28 µg/m³. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full data set (6 comparisons, for $PM_{10}$: 318 valid pairs of measured values for SN 0111, 318 valid pairs of measured values for SN 0112; for $PM_{2,5}$: 315 valid pairs of measured values for SN 0111, 315 valid pairs of measured values for SN 0112) 24.3% of the measured values are above the upper assessment threshold of 17 µg/m³ for $PM_{2.5}$ and 17.7% (corresponds to 56 > 32 pairs of measured values) of the measured values are above the upper assessment threshold of 28 µg/m³ for $PM_{10}$. The concentrations measured were related to the ambient conditions.

## 6.4 Evaluation

[EN 16450, 7.5.8.3]

Before calculating the expanded uncertainty of the candidates, uncertainties were established between the simultaneously operated reference measuring systems ($u_{ref}$)

Uncertainties between the simultaneously operated reference measuring systems $u_{bs,RM}$ were established similar to the between-AMS uncertainties and shall be ≤ 2.0 µg/m³.

Results of the evaluation are summarised in section 6.6.

[EN 16450, 7.5.8.5 & 7.5.8.6]

In order to assess comparability of the tested instruments y with the reference method x, a linear relationship $y_i = a + bx_i$ between the measured values of both methods is assumed. The association between the means of the reference systems and each individual candidate to be assessed is established by means of orthogonal regression.

The regression is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- 1 data set with measured values $PM_{2.5}$ ≥ 18 µg/m³ (basis: averages of reference measurement)
- 1 data set with measured values $PM_{10}$ ≥ 30 µg/m³ (basis: averages of reference measurement)

For further assessment, the uncertainty $u_{c\_s}$ resulting from a comparison of the candidates with the reference method is described in the following equation which defines $u_{CR}$ as a function of the fine dust concentration $x_i$.

$$u_{yi}^2 = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [a + (b-1)L]^2$$

Where RSS is the sum of the (relative) residuals from orthogonal regression

$u_{RM}$ = is the random uncertainty of the reference method; $u_{RM}$ is calculated as $u_{bs,RM}/\sqrt{2}$, while $u_{bs,RM}$ is the uncertainty between the reference measurement

The algorithms for calculating axis intercept a and slope b as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

The sum of (relative) residuals RSS is calculated according to the following equation:

$$RSS = \sum_{i=1}^{n} (y_i - a - bx_i)^2$$

Uncertainty $u_{CR}$ is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- 1 data set with measured values $PM_{2.5}$ ≥ 18 µg/m³ (basis: averages of reference measurement)
- 1 data set with measured values $PM_{10}$ ≥ 30 µg/m³ (basis: averages of reference measurement)

The Guideline states the following prerequisite for accepting the full data set:

- The slope be is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$

and

- The axis intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$, where u(a) and u(b) describe the standard uncertainty of the slope and the axis intercept calculated as the square root of the variance. If the prerequisites are not met, it is possible to calibrate the measuring systems in accordance with section 9.7 of the Guideline (also see 6.1 17 Use of correction factors/terms ). The calibration may only be performed for the full data set.

[EN 16450, 7.5.8.7] For all datasets the combined relative uncertainty of the AMS $w_{c,CM}$ is calculated from a combination of contributions from 9.5.3.1 and 9.5.3.2 in accordance with the following equation:

$$w_{AMS}^2 = \frac{u_{yi=L}^2}{L^2}$$

For each data set the uncertainty $w_{AMS}$ is calculated at a level of L = 30 µg/m³ for $PM_{2.5}$ as well as L = 50 µg/m³ for $PM_{10}$.

[EN 16450 7.5.8.8] For each data set the expanded relative uncertainty of the results measured with the candidate is calculated by multiplying $w_{AMS}$ by an coverage factor k according to the following equation:

$$W_{AMS} = k \cdot w_{AMS}$$

In practice, k is specified at k=2 for large n.

[Item 9.6]

The largest resulting uncertainty $W_{AMS}$ is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive [8]. Two situations are conceivable:

1. $W_{AMS} \leq W_{dqo}$ → The test is deemed equivalent to the reference method.
2. $W_{AMS} > W_{dqo}$ → The tested instrument is not deemed equivalent to the reference method.

The expanded relative uncertainty $W_{dqo}$ specified is 25% [8].

## 7.5 Assessment

Without the need for any correction factors, the expanded uncertainties $W_{AMS}$ were below the expanded, relative uncertainty $W_{dqo}$ defined for fine dust at 25% for $PM_{2.5}$ and $PM_{10}$ for all data sets observed. The uncertainties $W_{AMS}$ determined for $PM_{2.5}$ remained below the expanded, relative uncertainty $W_{dqo}$ specified for fine dust at 25% for all data sets observed with the exception of Bornheim, summer. Correction factors shall be applied in accordance with item 6.1 17 Use of correction factors/terms .

Criterion satisfied? no

Correction factors in accordance with chapter 6.1 17 Use of correction factors/terms were applied given excessive uncertainty at the test site “Bornheim, summer”, the significant slope for the full data set for $PM_{2.5}$ and the significant slope and intercept for $PM_{10}$.

Table 43 and Table 44 below summarise all results for the equivalence tests of the Fidas® 200 S for $PM_{2.5}$ and $PM_{10}$. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 43: Overview of equivalence test results for the Fidas® 200 S for $PM_{2.5}$

| Standard EN 16450:2017 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 30 | µg/m³ |
| Status of measured values | Raw data | | Allowed uncertainty | 25 | % |
| **All comparisons** | | | | | |
| Uncertainty between Reference | 0.53 | µg/m³ | | | |
| Uncertainty between Candidates | 0.48 | µg/m³ | | | |
| | SN 0111 & SN 0112 | | | | |
| Number of data pairs | 313 | | | | |
| Slope b | 1.060 | significant | | | |
| Uncertainty of b | 0.008 | | | | |
| Ordinate intercept a | -0.210 | not significant | | | |
| Uncertainty of a | 0.144 | | | | |
| Expanded meas. uncertainty $W_{CM}$ | 14.65 | % | | | |
| **All comparisons, ≥18 µg/m³** | | | | | |
| Uncertainty between Reference | 0.60 | µg/m³ | | | |
| Uncertainty between Candidates | 0.85 | µg/m³ | | | |
| | SN 0111 & SN 0112 | | | | |
| Number of data pairs | 67 | | | | |
| Slope b | 1.041 | | | | |
| Uncertainty of b | 0.021 | | | | |
| Ordinate intercept a | 0.300 | | | | |
| Uncertainty of a | 0.668 | | | | |
| Expanded meas. uncertainty $W_{CM}$ | 16.87 | % | | | |
| **All comparisons, <18 µg/m³** | | | | | |
| Uncertainty between Reference | 0.51 | µg/m³ | | | |
| Uncertainty between Candidates | 0.32 | µg/m³ | | | |
| | SN 0111 & SN 0112 | | | | |
| Number of data pairs | 246 | | | | |
| Slope b | 1.133 | | | | |
| Uncertainty of b | 0.024 | | | | |
| Ordinate intercept a | -0.866 | | | | |
| Uncertainty of a | 0.237 | | | | |
| Expanded meas. uncertainty $W_{CM}$ | 22.67 | % | | | |

| Comparison candidate with reference according to Standard EN 16450:2017 | | | | |
|---|---|---|---|---|
| Candidate | FIDAS 200 S | SN | SN 0111 & SN 0112 | |
| | | Limit value | 30 | µg/m³ |
| Status of measured values | Raw data | Allowed uncertainty | 25 | % |
| **Cologne, Summer** | | | | |
| Uncertainty between Reference | 0.66 | µg/m³ | | |
| Uncertainty between Candidates | 0.12 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 81 | | 82 | |
| Slope b | 1.119 | | 1.116 | |
| Uncertainty of b | 0.034 | | 0.035 | |
| Ordinate intercept a | -0.925 | | -0.885 | |
| Uncertainty of a | 0.363 | | 0.378 | |
| Expanded meas. uncertainty $W_{CM}$ | 20.35 | % | 20.37 | % |
| **Cologne, Winter** | | | | |
| Uncertainty between Reference | 0.54 | µg/m³ | | |
| Uncertainty between Candidates | 0.55 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 51 | | 50 | |
| Slope b | 1.051 | | 1.014 | |
| Uncertainty of b | 0.014 | | 0.014 | |
| Ordinate intercept a | 0.691 | | 0.679 | |
| Uncertainty of a | 0.313 | | 0.326 | |
| Expanded meas. uncertainty $W_{CM}$ | 17.24 | % | 11.70 | % |
| **Bonn** | | | | |
| Uncertainty between Reference | 0.62 | µg/m³ | | |
| Uncertainty between Candidates | 0.70 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 50 | | 50 | |
| Slope b | 1.114 | | 1.070 | |
| Uncertainty of b | 0.025 | | 0.027 | |
| Ordinate intercept a | -0.783 | | -0.519 | |
| Uncertainty of a | 0.571 | | 0.619 | |
| Expanded meas. uncertainty $W_{CM}$ | 21.42 | % | 16.89 | % |
| **Bornheim** | | | | |
| Uncertainty between Reference | 0.42 | µg/m³ | | |
| Uncertainty between Candidates | 0.50 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 45 | | 45 | |
| Slope b | 1.214 | | 1.186 | |
| Uncertainty of b | 0.054 | | 0.054 | |
| Ordinate intercept a | -1.487 | | -1.606 | |
| Uncertainty of a | 0.644 | | 0.643 | |
| Expanded meas. uncertainty $W_{CM}$ | 35.08 | % | 29.18 | % |
| **Teddington, Winter** | | | | |
| Uncertainty between Reference | 0.42 | µg/m³ | | |
| Uncertainty between Candidates | 0.55 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 44 | | 44 | |
| Slope b | 1.022 | | 1.022 | |
| Uncertainty of b | 0.012 | | 0.012 | |
| Ordinate intercept a | -0.007 | | -0.154 | |
| Uncertainty of a | 0.237 | | 0.220 | |
| Expanded meas. uncertainty $W_{CM}$ | 7.97 | % | 6.94 | % |
| **Teddington, Summer** | | | | |
| Uncertainty between Reference | 0.25 | µg/m³ | | |
| Uncertainty between Candidates | 0.37 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 44 | | 44 | |
| Slope b | 0.991 | | 0.982 | |
| Uncertainty of b | 0.021 | | 0.021 | |
| Ordinate intercept a | 0.483 | | 0.418 | |
| Uncertainty of a | 0.246 | | 0.243 | |
| Expanded meas. uncertainty $W_{CM}$ | 6.01 | % | 5.80 | % |
| **All comparisons, ≥18 µg/m³** | | | | |
| Uncertainty between Reference | 0.60 | µg/m³ | | |
| Uncertainty between Candidates | 0.85 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 67 | | 67 | |
| Slope b | 1.060 | | 1.024 | |
| Uncertainty of b | 0.022 | | 0.022 | |
| Ordinate intercept a | 0.117 | | 0.443 | |
| Uncertainty of a | 0.681 | | 0.68 | |
| Expanded meas. uncertainty $W_{CM}$ | 18.73 | % | 15.77 | % |
| **All comparisons, <18 µg/m³** | | | | |
| Uncertainty between Reference | 0.51 | µg/m³ | | |
| Uncertainty between Candidates | 0.32 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 248 | | 248 | |
| Slope b | 1.152 | | 1.119 | |
| Uncertainty of b | 0.024 | | 0.024 | |
| Ordinate intercept a | -0.929 | | -0.827 | |
| Uncertainty of a | 0.241 | | 0.239 | |
| Expanded meas. uncertainty $W_{CM}$ | 25.91 | % | 20.48 | % |
| **All comparisons** | | | | |
| Uncertainty between Reference | 0.53 | µg/m³ | | |
| Uncertainty between Candidates | 0.48 | µg/m³ | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | 315 | | 315 | |
| Slope b | 1.075 | significant | 1.045 | significant |
| Uncertainty of b | 0.009 | | 0.009 | |
| Ordinate intercept a | -0.247 | not significant | -0.154 | not significant |
| Uncertainty of a | 0.146 | | 0.146 | |
| Expanded meas. uncertainty $W_{CM}$ | 16.89 | % | 12.99 | % |

Results for testing the five criteria from chapter 6.1 Method used for equivalence testing were as follows:

Criterion 1: More than 20% of the data exceed 17 µg/m³.

Criterion 2: Between-AMS uncertainty of the AMS tested did not exceed 2.5 µg/m³.

Criterion 3: Uncertainty between reference instruments did not exceed 2.0 µg/m³.

Criterion 4: Except for Bornheim, summer, all expanded uncertainties remained below 25%.

Criterion 5: For both tested systems, the slope determined when assessing the full data set exceeded permissible limits.

Additional: The slope determined for the full data set regarding both candidates combined was at 1.060, the axis intercept was at -0.210 at a total expanded uncertainty of 14.65%.

Table 44: Overview of equivalence test results for the Fidas® 200 S for $PM_{10}$

| Comparison candidate with reference according to Standard EN 16450: 2017 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 50 | µg/m³ |
| Status of measured values | Raw data | | Allowed uncertainty | 25 | % |
| | | | | | |
| **All comparisons** | | | | | |
| Uncertainty between Reference | **0.58** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.67** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **316** | | | | |
| Slope b | **1.037** | significant | | | |
| Uncertainty of b | **0.009** | | | | |
| Ordinate intercept a | **-1.390** | significant | | | |
| Uncertainty of a | **0.216** | | | | |
| Expanded measured uncertainty WCM | **7.72** | **%** | | | |
| **All comparisons, ≥30 µg/m³** | | | | | |
| Uncertainty between Reference | **0.68** | **µg/m³** | | | |
| Uncertainty between Candidates | **1.19** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **44** | | | | |
| Slope b | **0.991** | | | | |
| Uncertainty of b | **0.035** | | | | |
| Ordinate intercept a | **0.704** | | | | |
| Uncertainty of a | **1.545** | | | | |
| Expanded measured uncertainty WCM | **11.09** | **%** | | | |
| **All comparisons, <30 µg/m³** | | | | | |
| Uncertainty between Reference | **0.56** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.57** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **272** | | | | |
| Slope b | **1.045** | | | | |
| Uncertainty of b | **0.018** | | | | |
| Ordinate intercept a | **-1.543** | | | | |
| Uncertainty of a | **0.311** | | | | |
| Expanded measured uncertainty WCM | **7.26** | **%** | | | |

| Comparison candidate with reference according to Standard EN 16450: 2017 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 50 | µg/m³ |
| Status of measured values | Raw data | | Allowed uncertainty | 25 | % |
| **Cologne, Summer** | | | | | |
| Uncertainty between Reference | 0.80 | µg/m³ | | | |
| Uncertainty between Candidates | 0.27 | µg/m³ | | | |
| | SN 0111 | | | SN 0112 | |
| Number of data pairs | 81 | | | 82 | |
| Slope b | 1.045 | | | 1.028 | |
| Uncertainty of b | 0.028 | | | 0.028 | |
| Ordinate intercept a | -1.637 | | | -1.524 | |
| Uncertainty of a | 0.490 | | | 0.489 | |
| Expanded measured uncertainty $W_{CM}$ | 7.34 | % | | 6.93 | % |
| **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 $W_{CM}$ | 9.78 | % | | 5.73 | % |
| **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 $W_{CM}$ | 12.03 | % | | 9.36 | % |
| **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 $W_{CM}$ | 19.11 | % | | 10.74 | % |
| **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 $W_{CM}$ | 9.26 | % | | 13.97 | % |
| **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 $W_{CM}$ | 12.33 | % | | 14.32 | % |
| **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 $W_{CM}$ | 12.14 | % | | 11.37 | % |
| **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 $W_{CM}$ | 9.51 | % | | 6.68 | % |
| **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 $W_{CM}$ | 9.28 | % | | 7.65 | % |

Results for testing the five criteria from chapter 6.1 Method used for equivalence testing were as follows:

| | |
|---|---|
| Criterion 1: | More than 38 valid value pairs exceed 28 µg/m³. |
| Criterion 2: | Between-AMS uncertainty of the AMS tested did not exceed 2.5 µg/m³. |
| Criterion 3: | Uncertainty between reference instruments did not exceed 2.0 µg/m³. |
| Criterion 4: | All expanded uncertainties remained below 25%. |
| Criterion 5: | For both candidate systems, the evaluation showed that the slope and the axis intercept significantly exceeded the permissible thresholds. |
| Additional: | The slope determined for the full data set regarding both candidates combined was at 1.037, the axis intercept was at -1.390 at a total expanded uncertainty of 7.72%. |

The January 2010 version of the Guideline does not specify clearly which axis intercept and which slope to use for correcting candidates if a candidate does not meet the requirements for equivalence testing. After double-checking with the chair of the EU working group responsible for issuing the Guideline (Mr Theo Hafkenscheid), we decided to apply the requirements of the November 2005 version of the Guideline and to use the slope and the intercept determined by means of orthogonal regression for the full data set. These are listed for each criterion under "Additional"

Consequently and according to Table 43, the slope and intercept of SN 0111 for $PM_{2.5}$ need to be corrected. Given the significance determined for $PM_{10}$ for both sets of candidate systems as illustrated in Table 44, the slope and axis intercept had to be corrected.

It should be noted here that the uncertainty $W_{CM}$ determined without applying correction factors for all observed data sets is below the determined expanded relative uncertainty $W_{dqo}$ of 25% for $PM_{10}$.

For $PM_{2.5}$:

The slope for the entire data set is 1.060. This is why chapter 6.1 17 Use of correction factors/terms contains an additional assessment for which the corresponding calibration factor was applied to the data sets.

For $PM_{10}$:

The slope for the entire data set is 1.037. The intercept for the full data set is -1.390. This is why chapter 6.1 17 Use of correction factors/terms contains an additional assessment for which the corresponding calibration factors were applied to the data sets.

For compliant monitoring, the revised version of the January 2010 Guideline and standard EN 16450 require continuous random checks of a certain number of instruments in a measurement grid and specify the number of measurement sites to be checked as a function of the expanded uncertainty of a measuring system. The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation. However, TÜV Rheinland recommend that the expanded uncertainty of the entire data set (in the present case, the uncorrected raw data) be used for this purpose: 14.65% for $PM_{2.5}$, implying annual checks at three measurement sites and 7.72% for $PM_{10}$ implying checks a year at two measurement sites (Guideline [5], Chapter 9.9.2, Table 6 or EN 16450 [9], Chapter 8.6.2, Table 5). As a result of the necessary use of calibration factors, this assessment should be based on the evaluation of the corrected data sets (see chapter 6.1 17 Use of correction factors/terms ).

## 6.6 Detailed presentation of test results

Table 45 and Table 46 provide an overview of the between-RM uncertainties $u_{bs,RM}$ determined during the field tests.

Table 45: Between RM uncertainty $u_{bs,RM}$ for $PM_{2.5}$

| Reference instruments | Location | Number of measurements | Uncertainty $u_{bs,RM}$ |
|---|---|---|---|
| No. | | | µg/m³ |
| 1 / 2 | Cologne, Summer | 82 | 0.66 |
| 1 / 2 | Cologne, Winter | 52 | 0.54 |
| 1 / 2 | Bonn, Winter | 50 | 0.62 |
| 1 / 2 | Bornheim, Summer | 47 | 0.42 |
| 1 / 2 | Teddington, Winter | 44 | 0.42 |
| 1 / 2 | Teddington, Summer | 44 | 0.25 |
| 1 / 2 | All locations | 319 | 0.53 |

Table 46: Between RM uncertainty $u_{bs,RM}$ for $PM_{10}$

| Reference instruments | Location | Number of measurements | Uncertainty $u_{bs,RM}$ |
|---|---|---|---|
| No. | | | µg/m³ |
| 1 / 2 | Cologne, Summer | 82 | 0.80 |
| 1 / 2 | Cologne, Winter | 52 | 0.53 |
| 1 / 2 | Bonn, Winter | 50 | 0.38 |
| 1 / 2 | Bornheim, Summer | 49 | 0.54 |
| 1 / 2 | Teddington, Winter | 44 | 0.48 |
| 1 / 2 | Teddington, Summer | 45 | 0.46 |
| 1 / 2 | All locations | 322 | 0.58 |

At all sites, between-RM uncertainty $u_{bs,RM}$ was < 2.0 µg/m³.

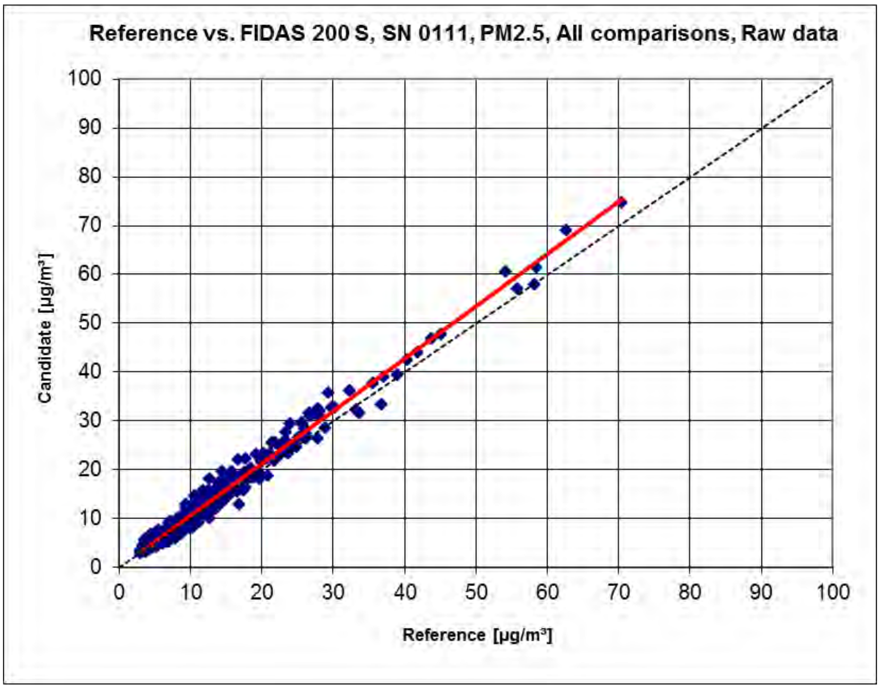



Figure 63: Reference vs. tested instrument, SN 0111, component $PM_{2.5}$, all sites, PM_ENVIRO_0011

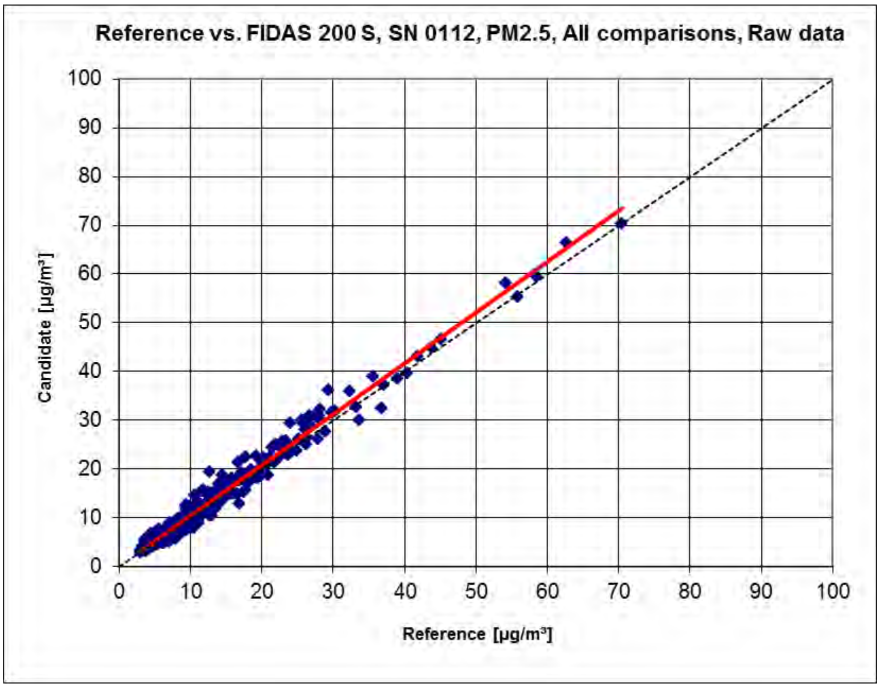



Figure 64: Reference vs. tested instrument, SN 112, component $PM_{2.5}$, all sites, PM_ENVIRO_0011

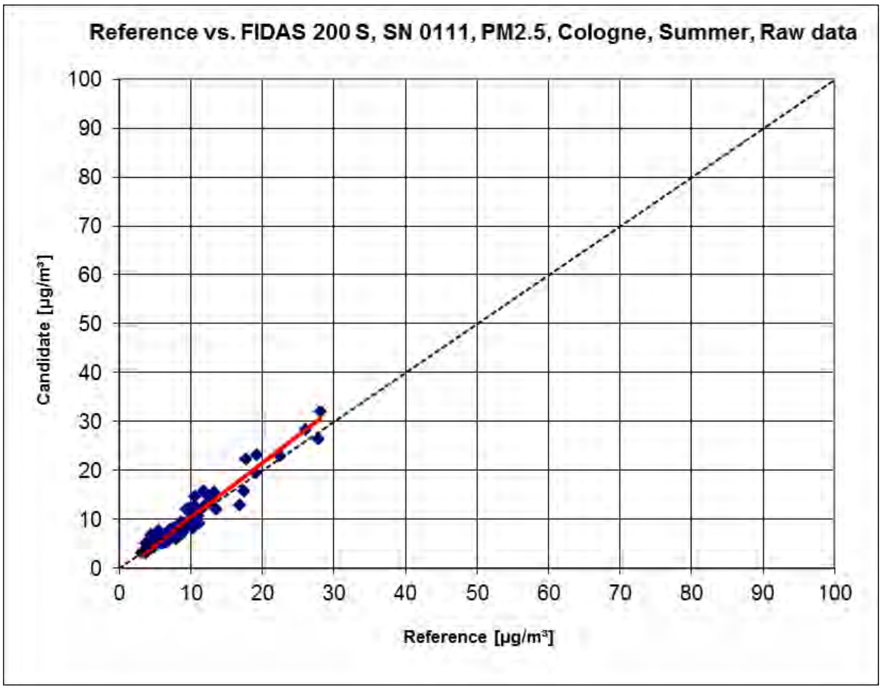



Figure 65: Reference vs. tested instrument, SN 0111, component $PM_{2.5}$, Cologne, summer PM_ENVIRO_0011

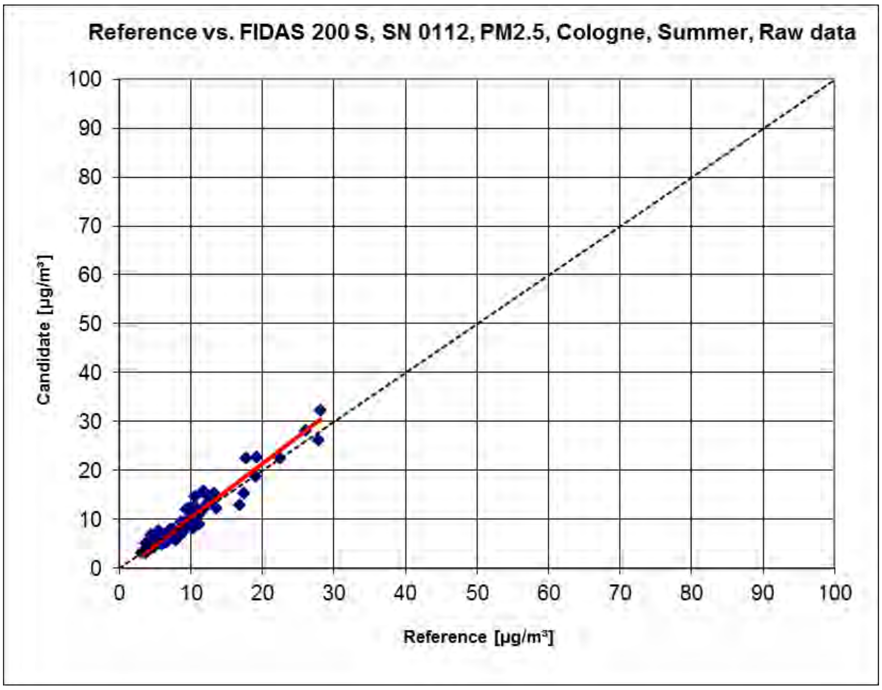



Figure 66: Reference vs. tested instrument, SN 112, component $PM_{2.5}$, Cologne, summer PM_ENVIRO_0011

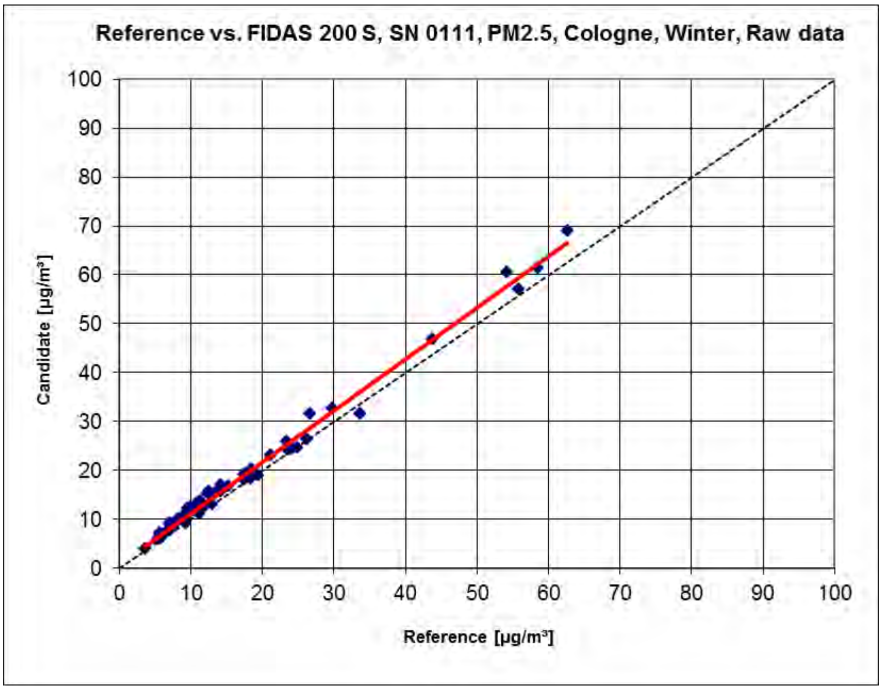



Figure 67: Reference vs. tested instrument, SN 0111, component $PM_{2.5}$, Cologne, winter PM_ENVIRO_0011

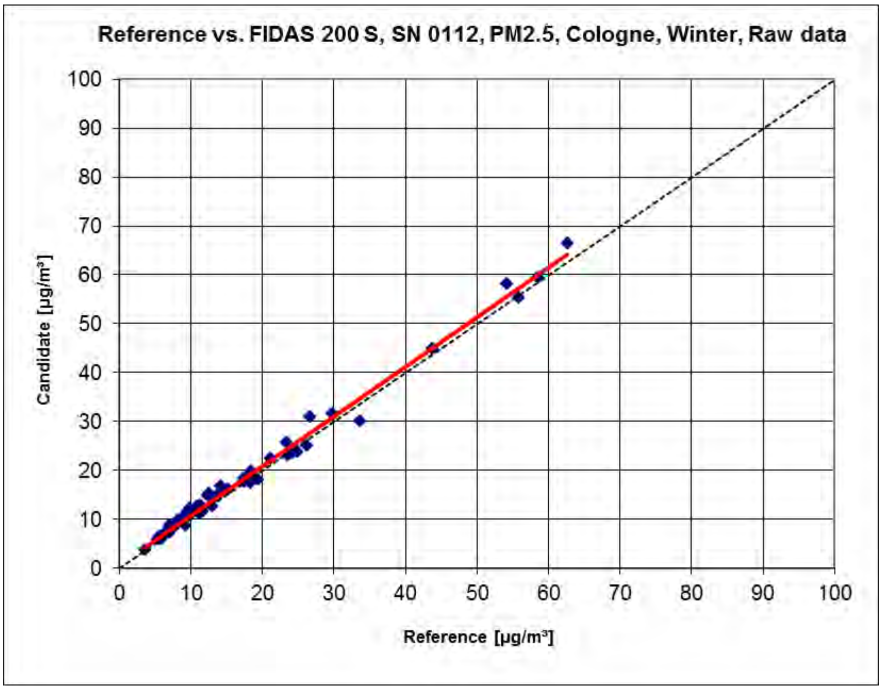



Figure 68: Reference vs. tested instrument, SN 0112, component $PM_{2.5}$, Cologne, winter, PM_ENVIRO_0011

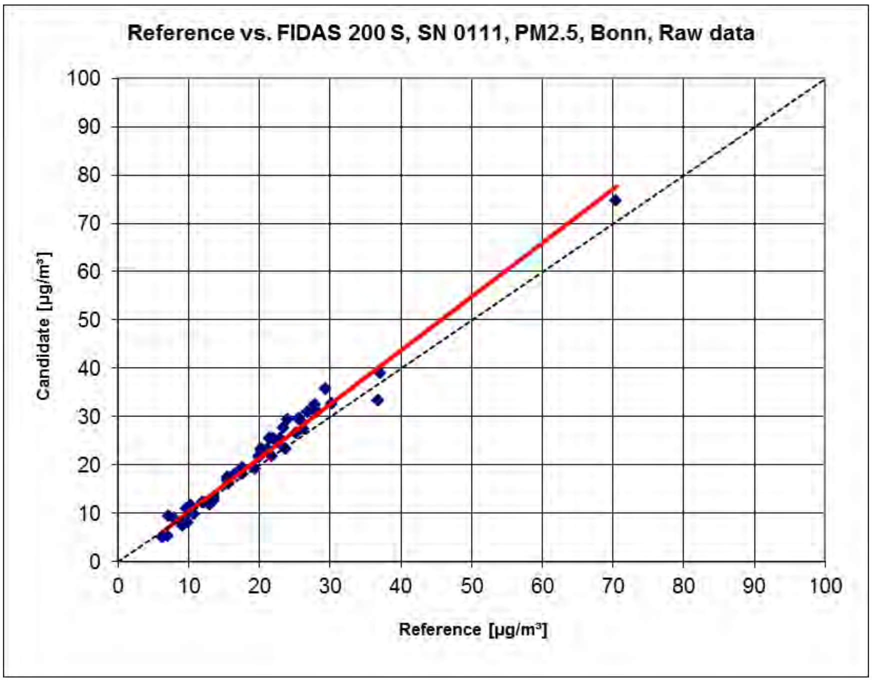



Figure 69: Reference vs. tested instrument, SN 0111, component $PM_{2.5}$, Bonn, winter, PM_ENVIRO_0011

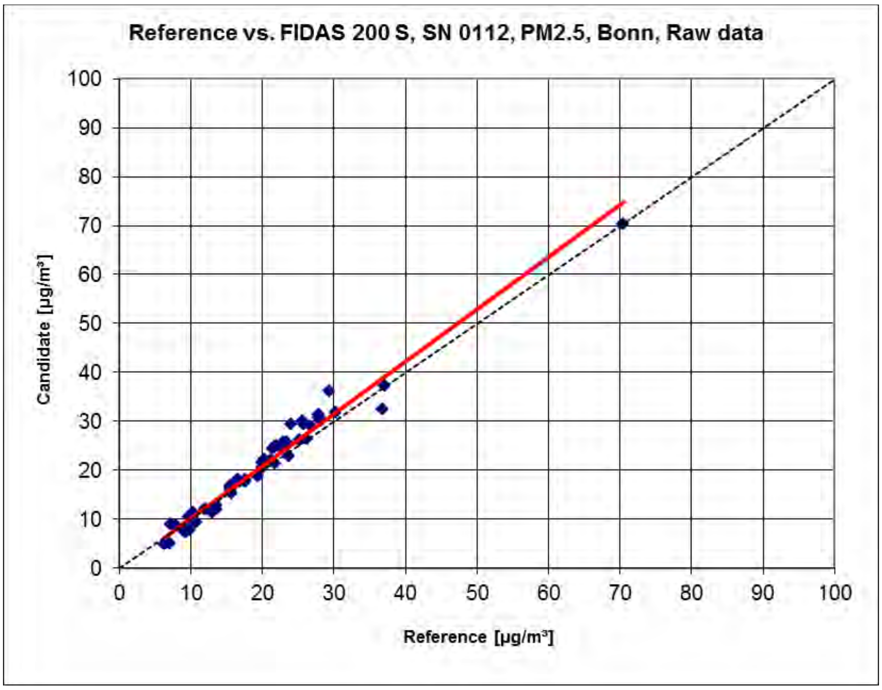



Figure 70: Reference vs. tested instrument, SN 0112, component $PM_{2.5}$, Bonn, winter, PM_ENVIRO_0011

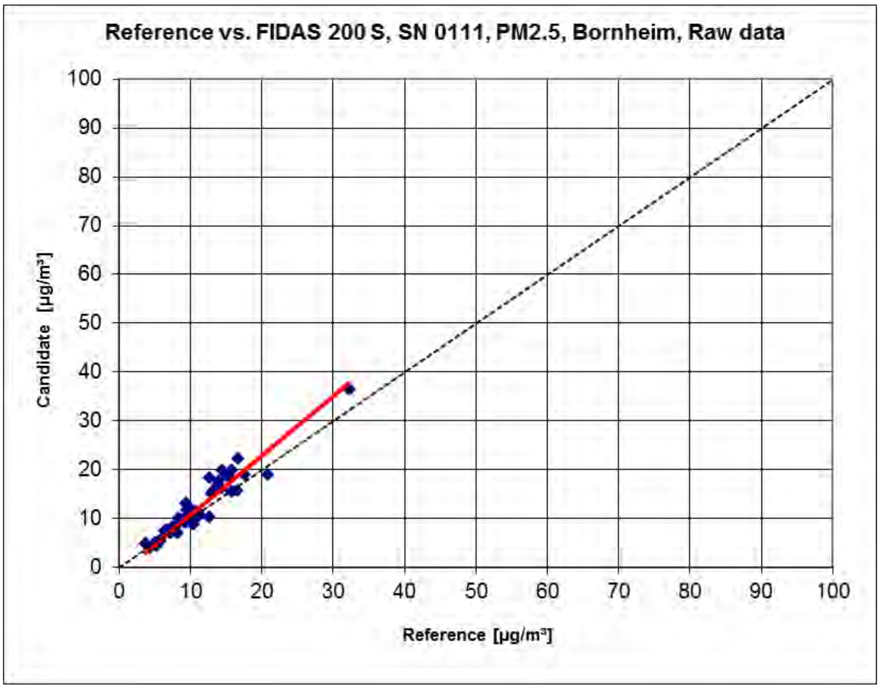



Figure 71: Reference vs. tested instrument, SN 0111, component $PM_{2.5}$, Bornheim, summer, PM_ENVIRO_0011

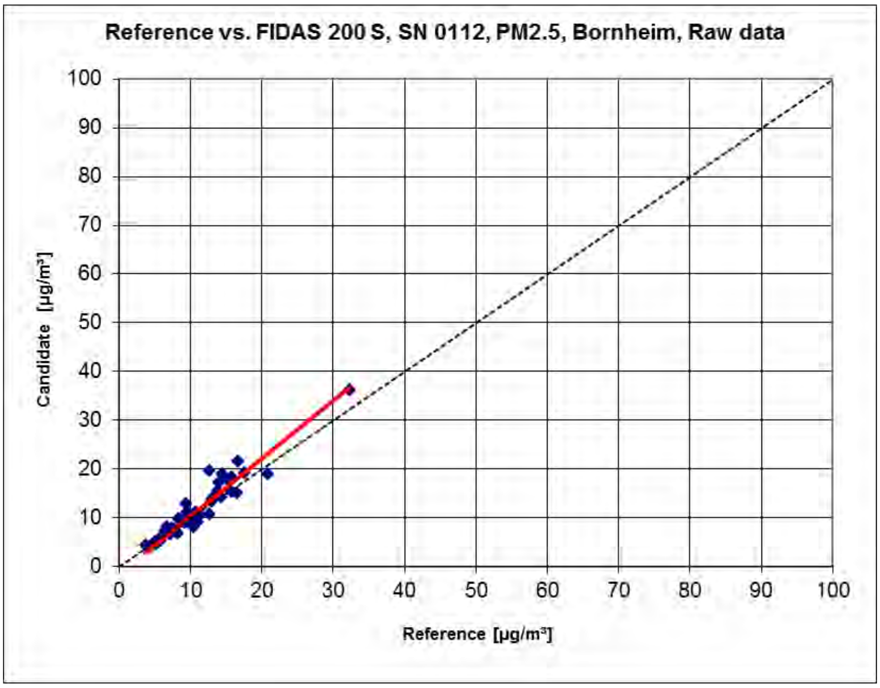



Figure 72: Reference vs. tested instrument, SN 0112, component $PM_{2.5}$, Bornheim, summer, PM_ENVIRO_0011

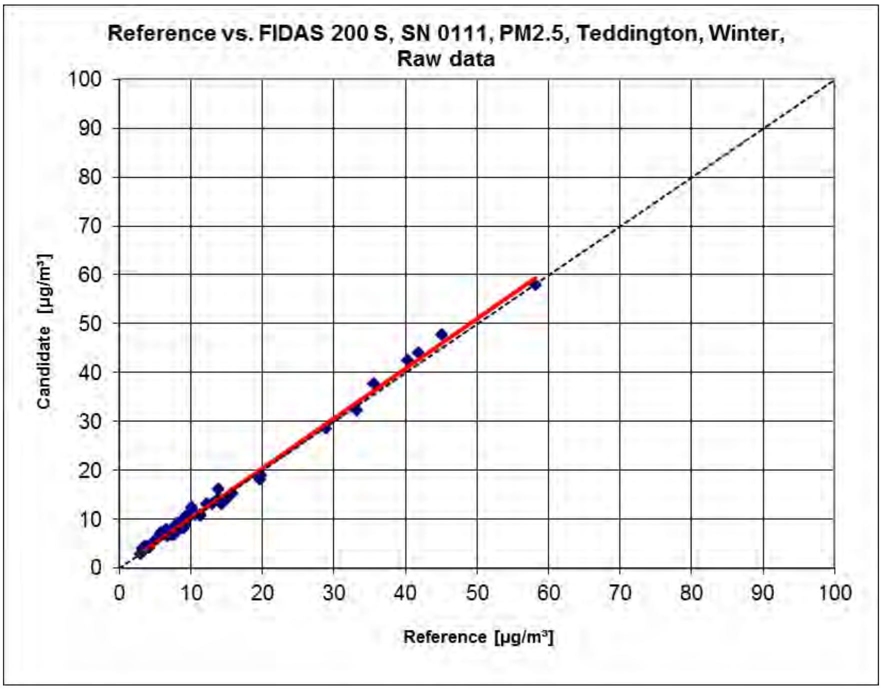



Figure 73: Reference vs. tested instrument, SN 0111, component $PM_{2.5}$, Teddington, winter, PM_ENVIRO_0011

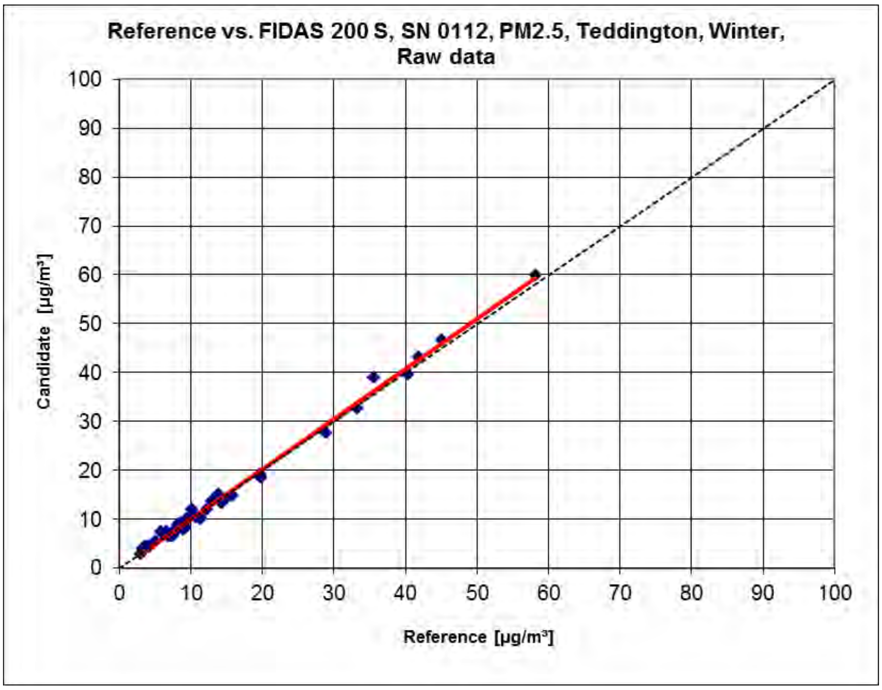



Figure 74: Reference vs. tested instrument, SN 0112, component $PM_{2.5}$, Teddington, winter, PM_ENVIRO_0011

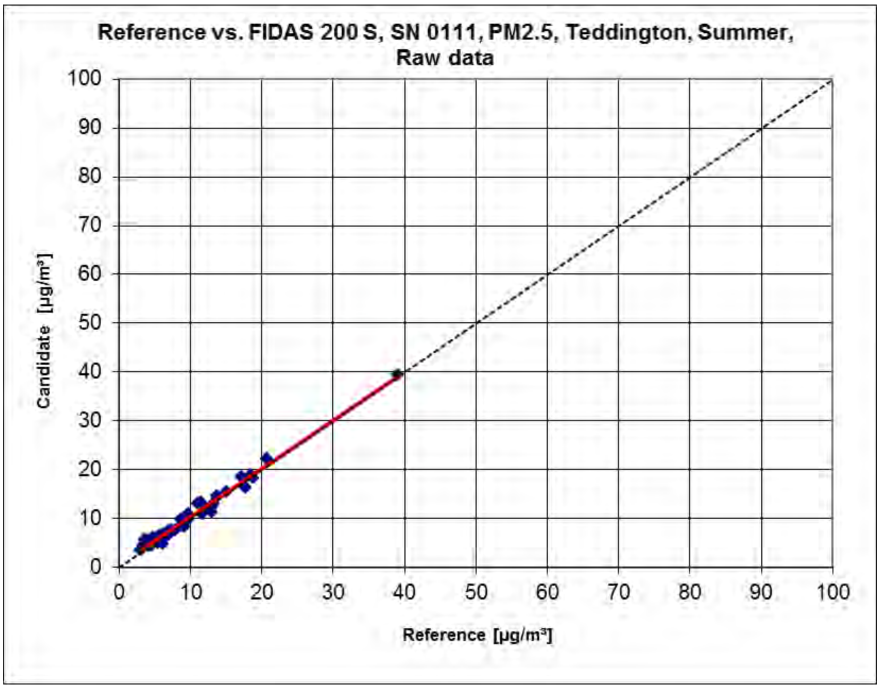



Figure 75: Reference vs. Tested instrument, SN 0111, component $PM_{2.5}$, Teddington, summer, PM_ENVIRO_0011

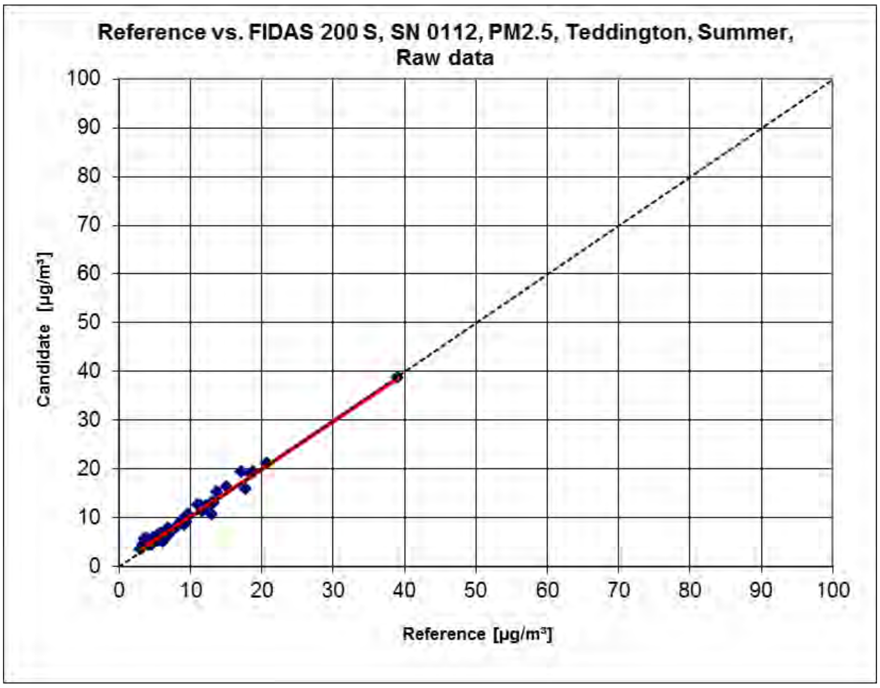



Figure 76: Reference vs. Tested instrument, SN 0112, component $PM_{2.5}$, Teddington, summer, PM_ENVIRO_0011

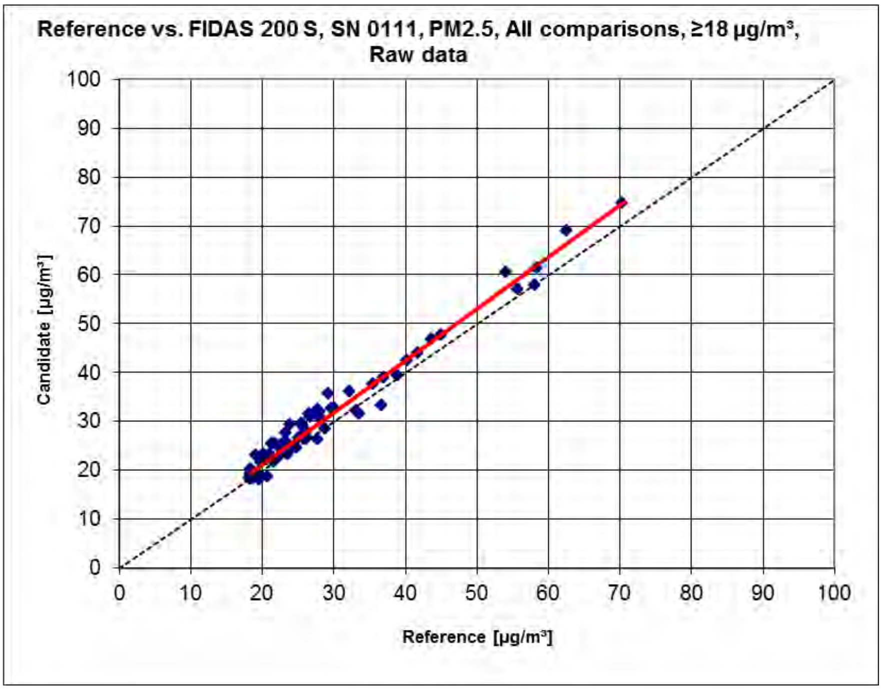



Figure 77: Reference vs. tested instrument, SN 0111, measured component $PM_{2.5}$, values ≥ 18 µg/m³, PM_ENVIRO_0011

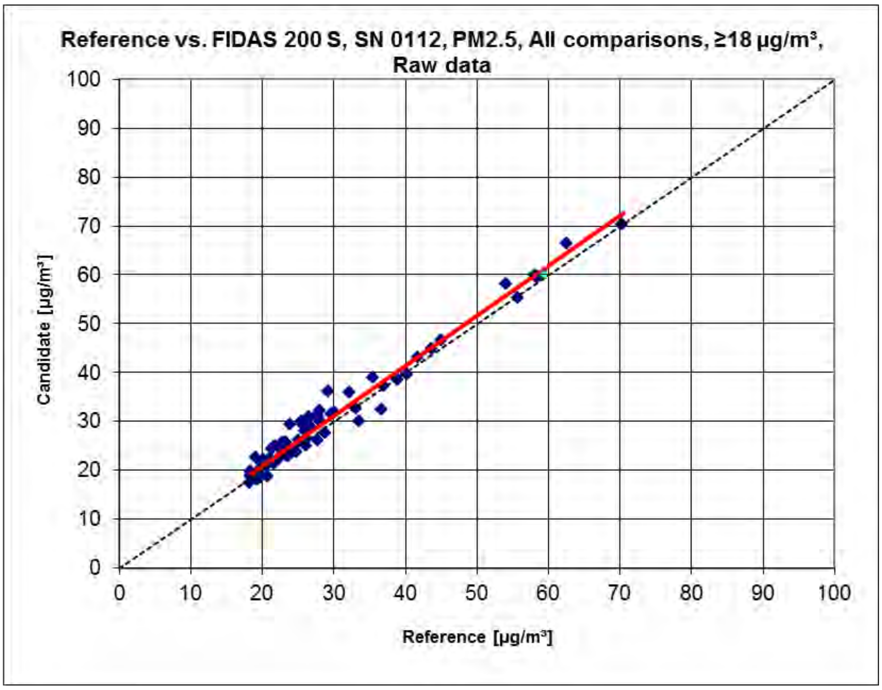



Figure 78: Reference vs. tested instrument, SN 0112, measured component $PM_{2.5}$, values ≥ 18 µg/m³, PM_ENVIRO_0011

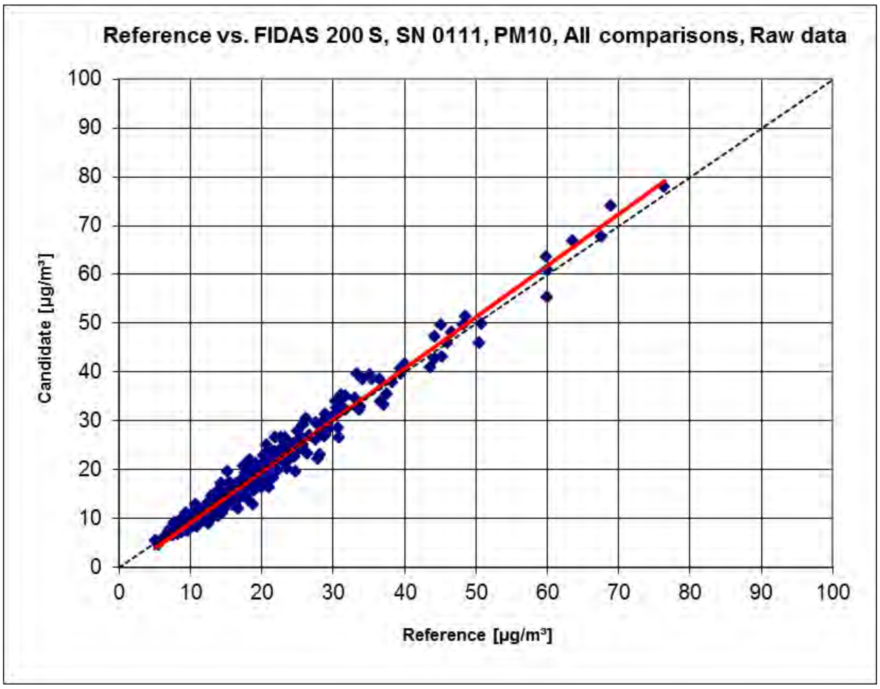



Figure 79: Reference vs. tested instrument SN 0111, measured component $PM_{10}$, all sites, PM_ENVIRO_0011

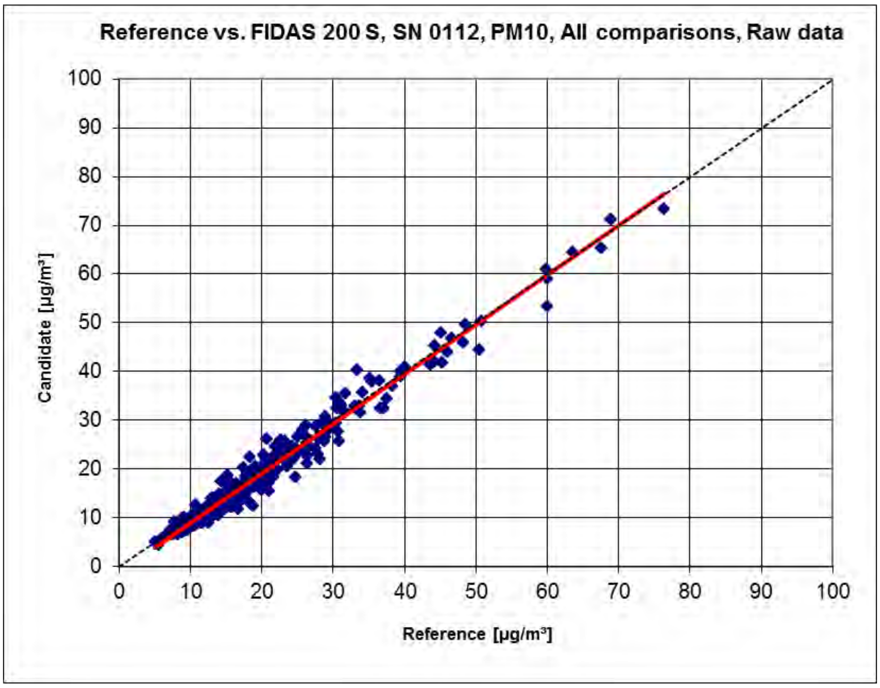



Figure 80: Reference vs. tested instrument SN 0112, measured component $PM_{10}$, all sites, PM_ENVIRO_0011

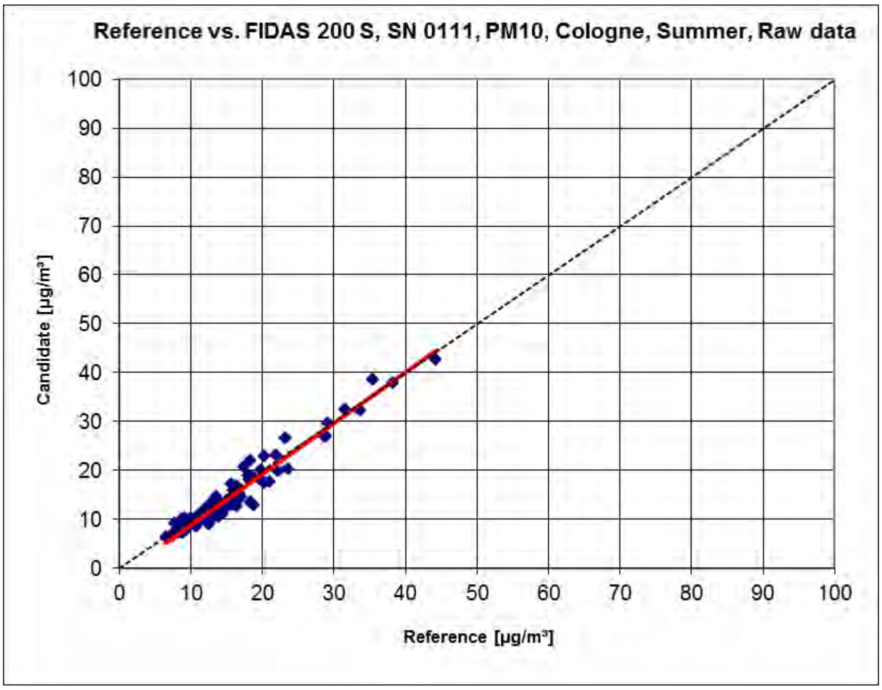



Figure 81: Reference vs. tested instrument SN 0111, measured component $PM_{10}$, Cologne, summer, PM_ENVIRO_0011

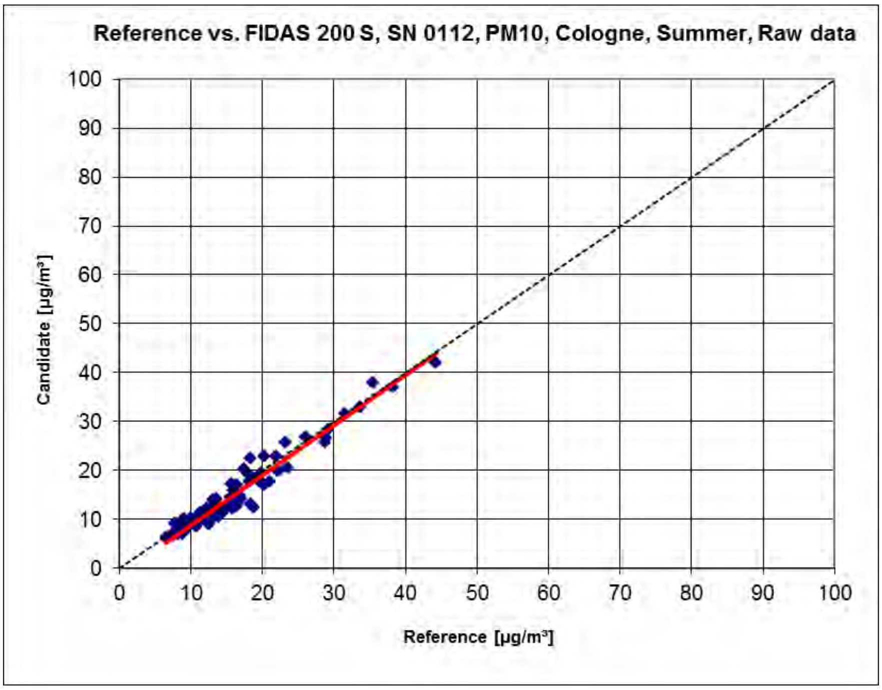



Figure 82: Reference vs. tested instrument SN 0112, measured component $PM_{10}$, Cologne, summer, PM_ENVIRO_0011

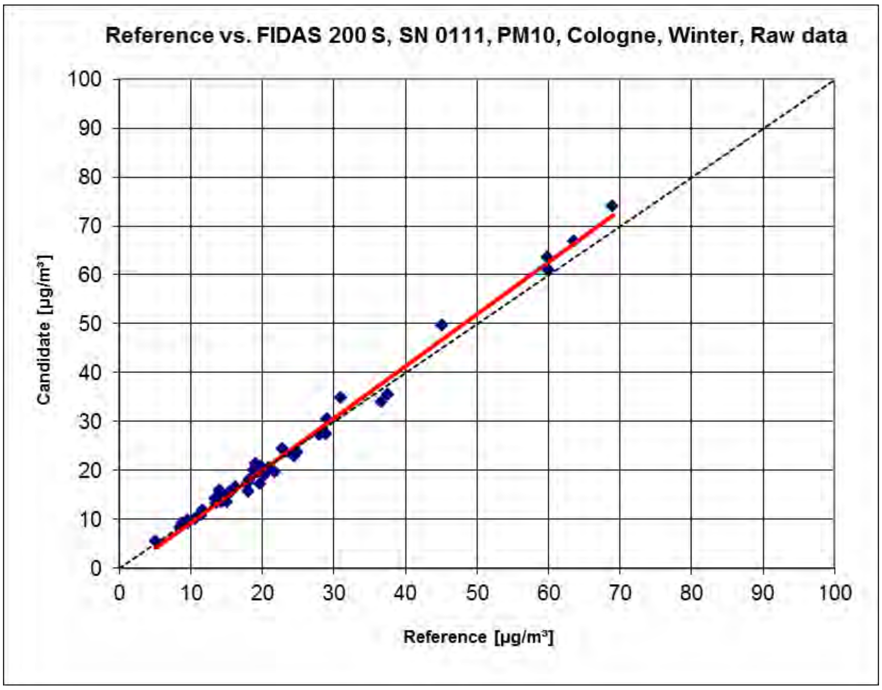



Figure 83: Reference vs. tested instrument SN 0111, measured component $PM_{10}$, Cologne, winter, PM_ENVIRO_0011

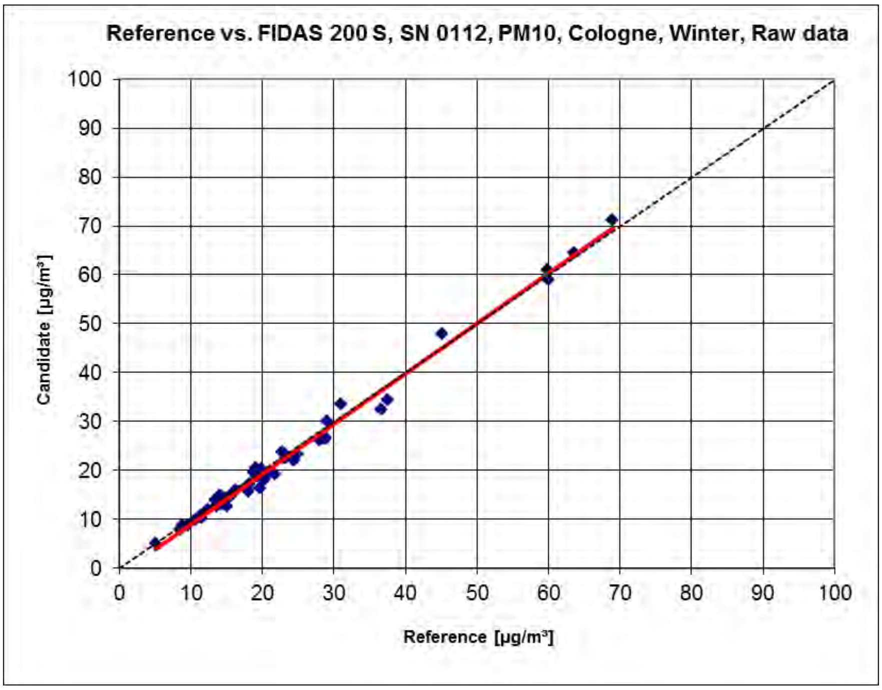



Figure 84: Reference vs. tested instrument SN 0112, measured component $PM_{10}$, Cologne, winter, PM_ENVIRO_0011

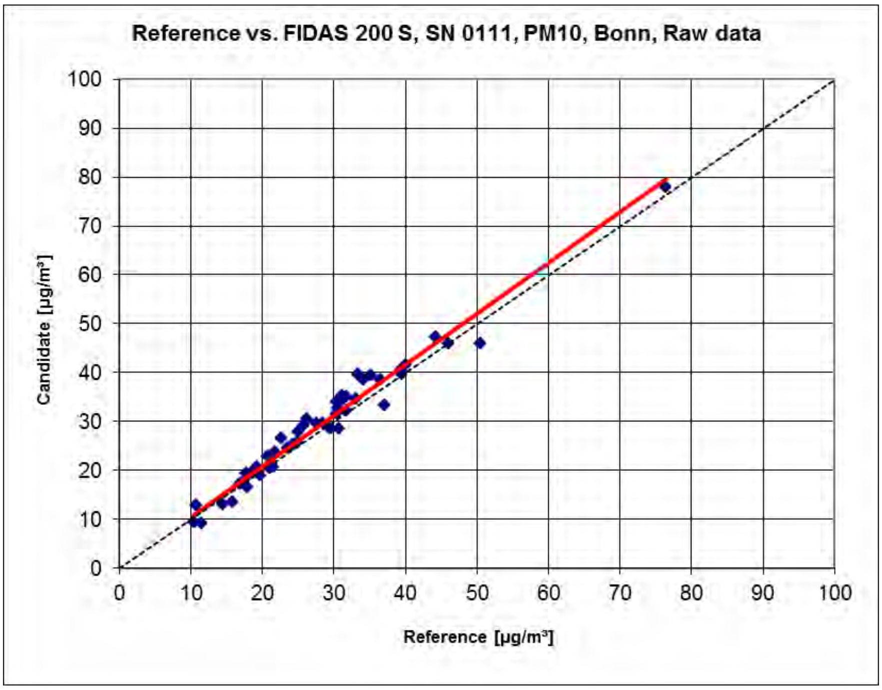



Figure 85: Reference vs. tested instrument SN 0111, measured component $PM_{10}$, Bonn, winter, PM_ENVIRO_0011

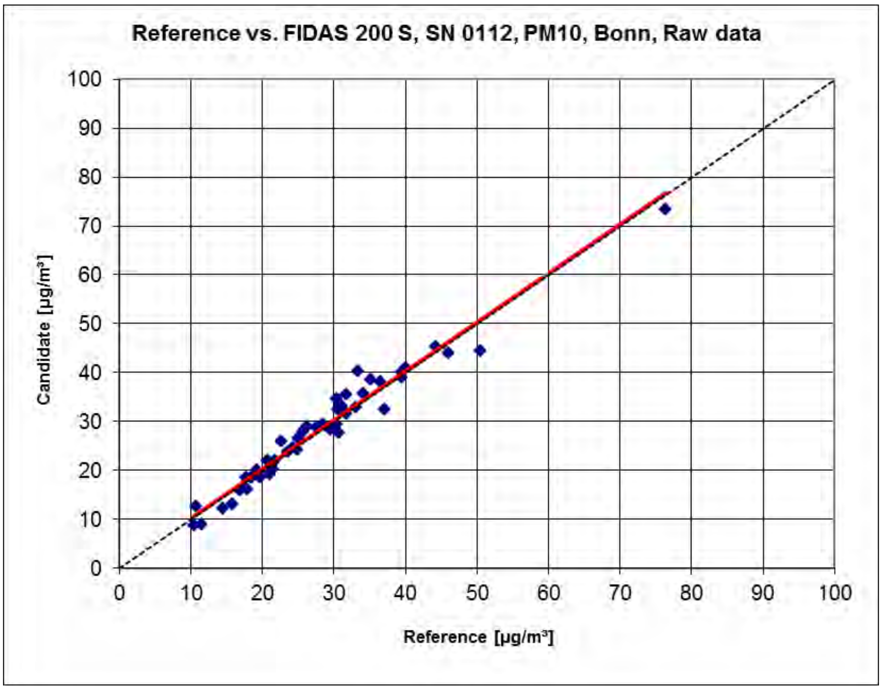



Figure 86: Reference vs. tested instrument SN 0112, measured component $PM_{10}$, Bonn, winter, PM_ENVIRO_0011

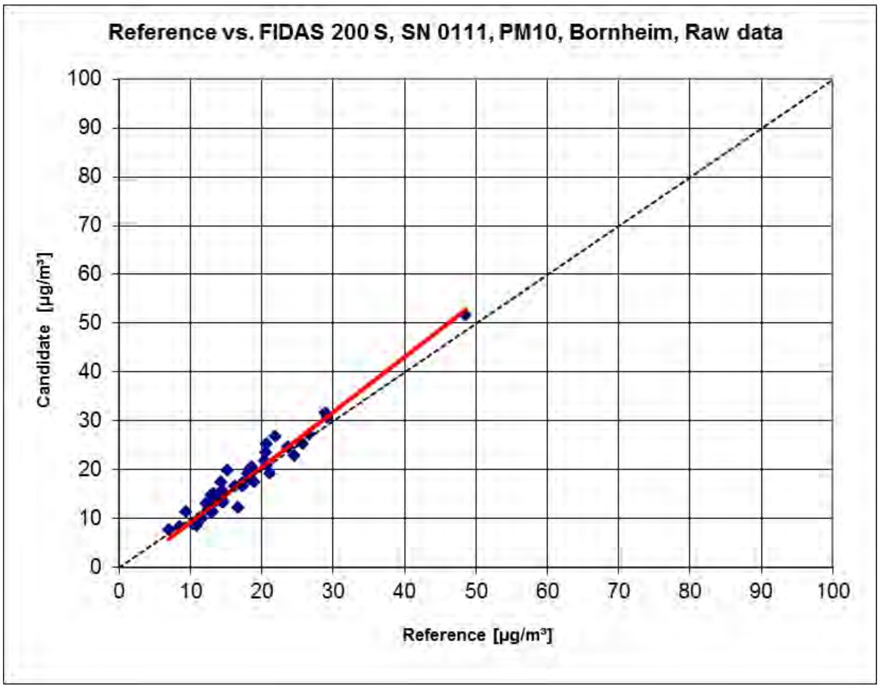



Figure 87: Reference vs. tested instrument SN 0111, measured component $PM_{10}$, Bornheim, summer,
PM_ENVIRO_0011

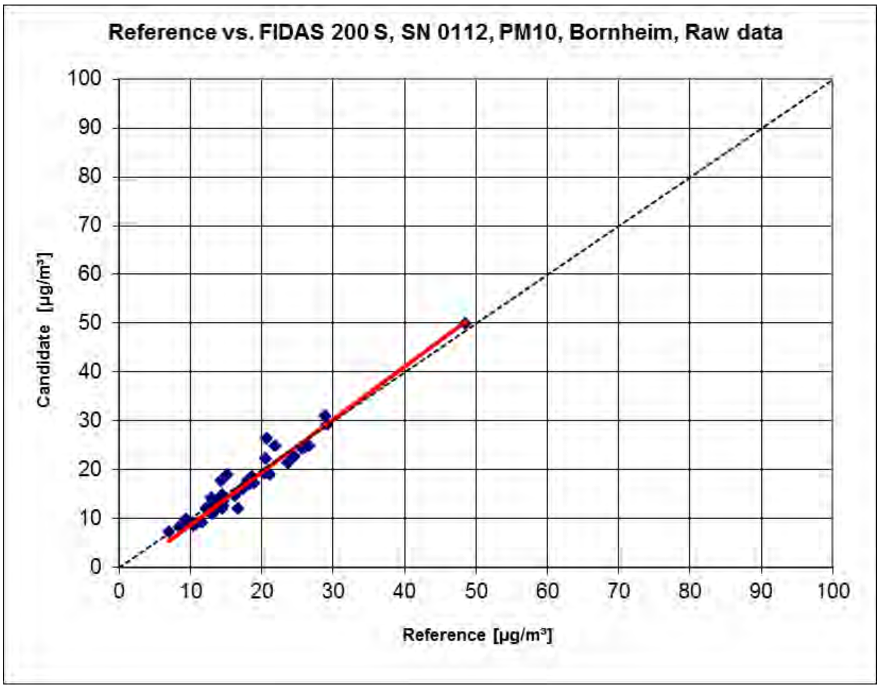



Figure 88: Reference vs. tested instrument SN 0112, measured component $PM_{10}$, Bornheim, summer, PM_ENVIRO_0011

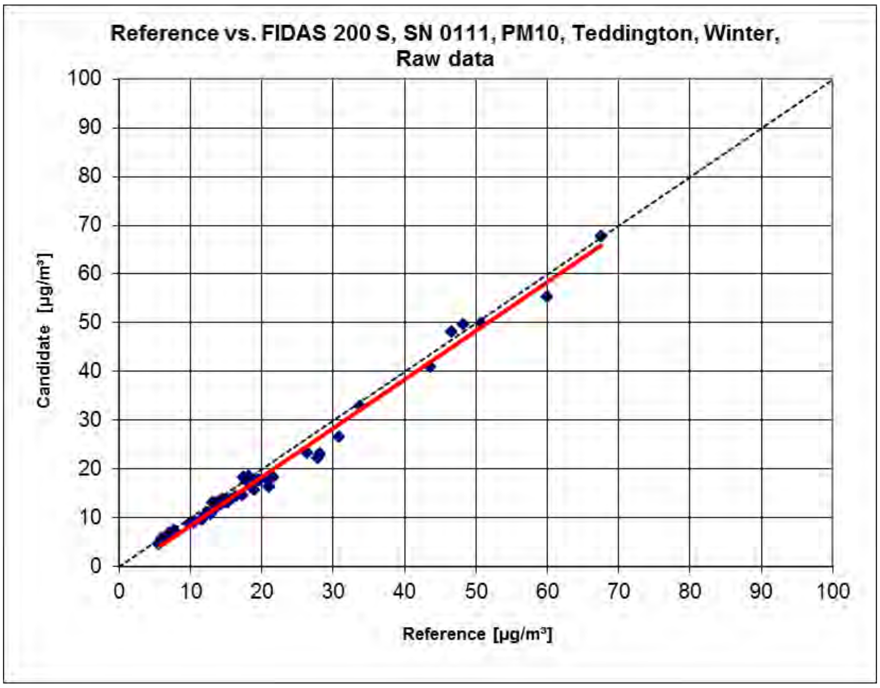



Figure 89: Reference vs. tested instrument SN 0111, measured component $PM_{10}$, Teddington, Winter, PM_ENVIRO_0011

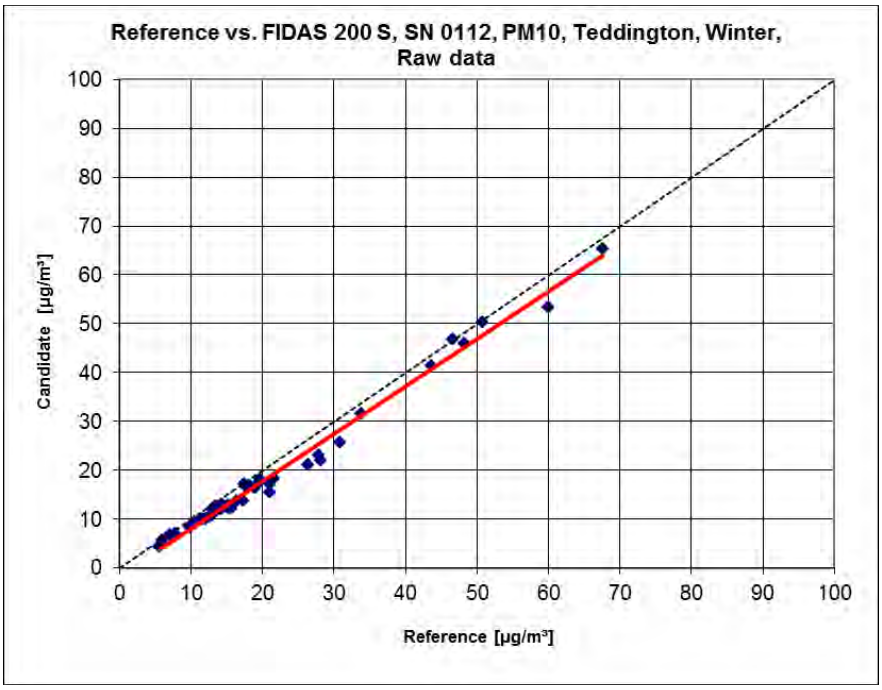



Figure 90: Reference vs. tested instrument SN 0112, measured component $PM_{10}$, Teddington, Winter, PM_ENVIRO_0011

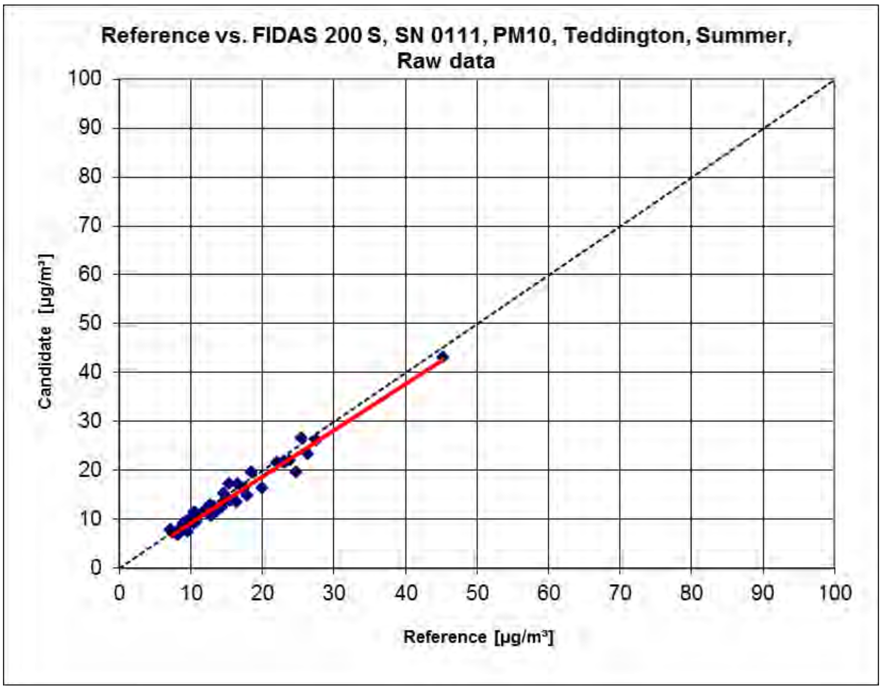



Figure 91: Reference vs. tested instrument SN 0111, measured component $PM_{10}$, Teddington, summer, PM_ENVIRO_0011

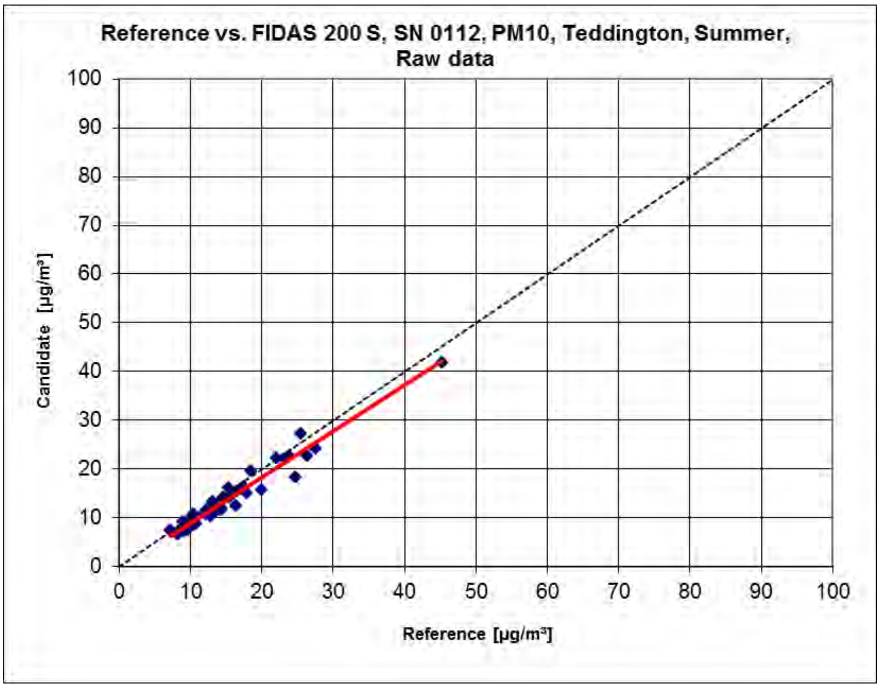



Figure 92: Reference vs. tested instrument SN 0112, measured component $PM_{10}$, Teddington, summer, PM_ENVIRO_0011

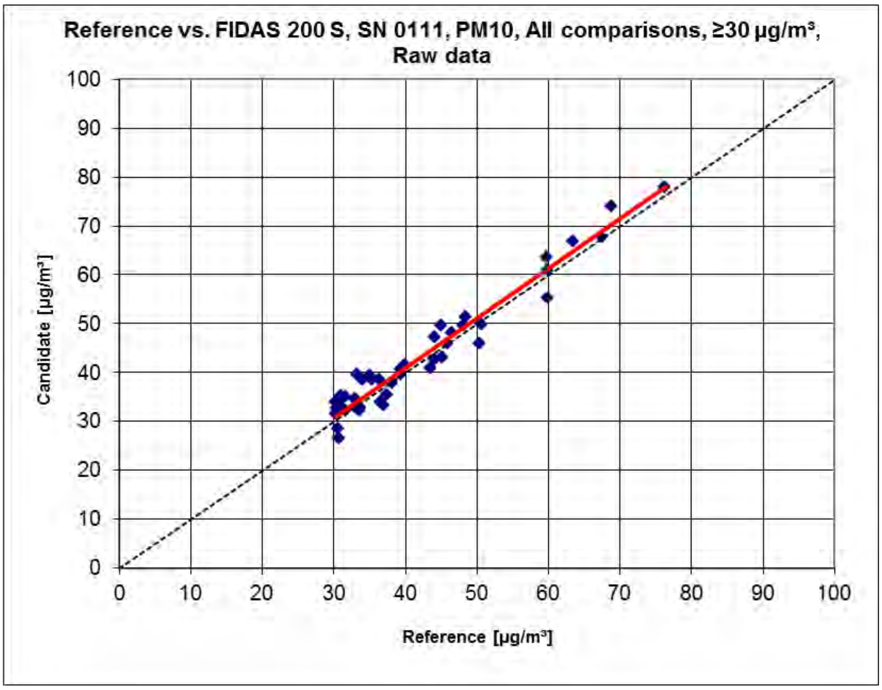



Figure 93: Reference vs. Tested instrument, SN 0111, measured component $PM_{10}$, values ≥ 30 µg/m³, PM_ENVIRO_0011

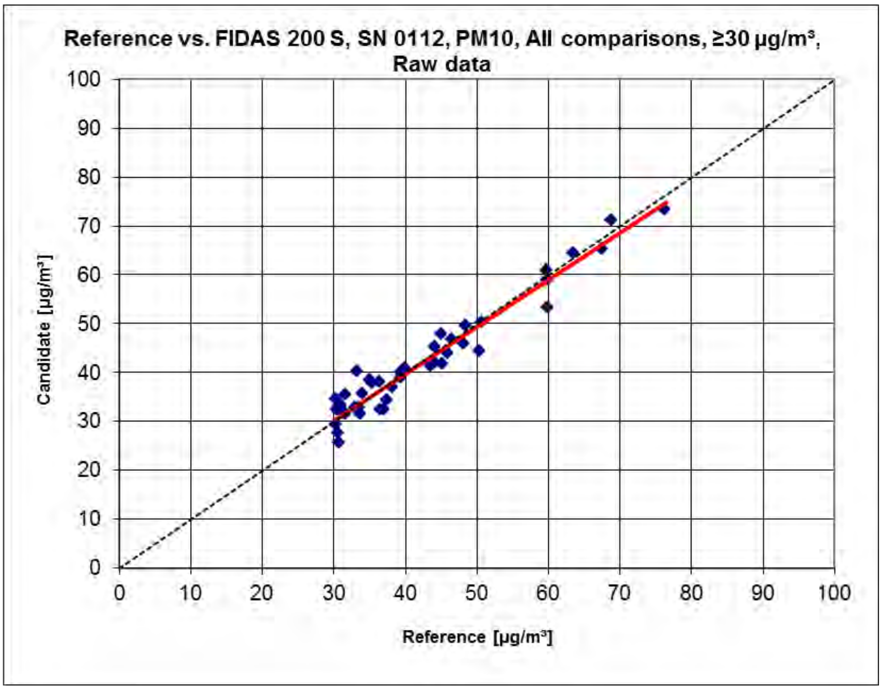



Figure 94: Reference vs. Tested instrument, SN 0112, measured component $PM_{10}$, values ≥ 30 µg/m³, PM_ENVIRO_0011

## 6.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8)

*Correction factors/terms (=calibration) shall be applied in the event the highest expanded uncertainty calculated for the tested instruments exceeds the relative expanded uncertainty specified under requirements for data quality or the test demonstrates that the slope is significantly different from 1 and/or the ordinate intercept is significantly different from 0.*

## 6.2 Equipment

Not required for this performance criterion.

## 6.3 Testing

See item 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

## 6.4 Evaluation

If it emerges from the evaluation of raw data in accordance with 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8) that $W_{AMS} > W_{dqo}$, i.e. the tested instrument is not found to be equivalent with the reference method, then it is permissible to use a correction factor or term which results from the regression equation for the full data set. The corrected values have to meet the requirements for all data sets or sub data sets. Moreover, a correction may also be used for the case that $W_{AMS} \leq W_{dqo}$ in order to improve the accuracy of the tested instruments.

Three different situations may occur:

a) Slope b is not significantly different from 1: $|b-1| \leq 2u(b)$

Axis intercept a is significantly different from 0: $|a| > 2u(a)$

b) Slope b is significantly different from 1: $|b-1| > 2u(b)$

axis intercept a is not significantly different from 0: $|a| \leq 2u(a)$

b) Slope b is significantly different from 1: $|b-1| > 2u(b)$

Axis intercept a is significantly different from 0: $|a| > 2u(a)$

concerning a)

The value of the axis intercept a may be used as a correction term to correct all input values $y_i$ according to the following equation:

$$y_{i,corr} = y_i - a$$

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u_{yi,corr}^2 = \frac{RSS}{(n-2)} - u_{RM}^{\ 2} + [c + (d-1)L]^2 + u^2(a)$$

where u(a) = uncertainty of the axis intercept a, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

concerning b)

The value of the slope b may be used as a correction term to correct all input values $y_i$ according to the following equation:

$$y_{i,corr} = \frac{y_i}{b}$$

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using a new linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u_{yi,corr}^2 = \frac{RSS}{(n-2)} - u_{RM}^{\ 2} + [c + (d-1)L]^2 + L^2 u^2(b)$$

where u(b) = uncertainty of the original slope b, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

concerning c)

The values of the slope b and the axis intercept a may be used as a correction terms to correct all input values $y_i$ according to the following equation:

$$y_{i,corr} = \frac{y_i - a}{b}$$

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using a new linear regression:

$$y_{i,corr} = c + dx_i$$

and

$$u_{yi,corr}^{2} = \frac{RSS}{(n-2)} - u_{RM}^{\ \ 2} + \left[c + (d-1)L\right]^{2} + L^{2}u^{2}(b) + u^{2}(a)$$

where u(b) = uncertainty of the original slope b, whose value was used to determine $y_{i,corr}$ and u(a) = uncertainty of the original axis intercept a, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

The values for $u_{c\_s,corr}$ are then used to calculate the combined relative uncertainty of the AMS after correction in accordance with the following equation:

$$w_{AMS,corr}^{2} = \frac{u_{corr,yi=L}^{2}}{L^{2}}$$

The uncertainty $w_{AMS,corr}$ for the corrected data set is calculated at the 24h limit value using $y_i$ as concentration at the limit value.

The relative expanded uncertainty $W_{AMS,corr}$ is calculated using the following equation:

$$W_{AMS',corr} = k \cdot w_{AMS,corr}$$

In practice, k is specified at k=2 for large n.

The largest resulting uncertainty $W_{AMS,corr}$ is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive [8]. Two situations are conceivable:

1. $W_{AMS,corr} \leq W_{dqo}$ → The tested instrument is deemed equivalent to the reference method.
2. $W_{AMS,corr} > W_{dqo}$ → The tested instrument is not deemed equivalent to the reference method.

The expanded relative uncertainty $W_{dqo}$ specified is 25% [8].

## 6.5 Assessment

After the use of correction factors, the candidate systems met the requirements for data quality of air quality monitors for all data sets, both for $PM_{2.5}$ and for $PM_{10}$. Requirements for $PM_{10}$ have been met without the need for a correction factor. The correction of the slope and the axis intercept however, have led to a further (slight) improvement of the expanded uncertainty.

Criterion satisfied? yes

The evaluation of the full data set resulted in a significant slope for $PM_{2.5}$ and a significant slope and intercept for $PM_{10}$.

For $PM_{2.5}$:

The slope for the entire data set is 1.060. The intercept for the full data set is -0.210 (see Table 43)

For $PM_{10}$:

The slope for the entire data set is 1.037. The intercept for the full data set is -1.390 (see Table 44)

For the component $PM_{2,5}$, the full data set was corrected in terms of the slope. All data sets were re-evaluated using the corrected values.

For the component $PM_{10}$, the full data set was corrected in terms of the slope and intercept. All data sets were re-evaluated using the corrected values.

After applying the correction, all datasets comply with the requirements for data quality and measurement uncertainty improved considerably for some sites.

When a measuring system is operated in the context of a measurement grid, the January 2010 version of the Guideline and standard EN 16450 require that the instruments are tested annually at a number of sites which in turn depends on the highest's expanded uncertainty determined during equivalence testing. The criterion used for specifying the number of sites for annual testing is grouped into 5% steps (Guideline [4], Chapter 9.9.2, Table 6 and/or EN 16450 [9], Chapter 8.6.2, Table 5). It should be noted that the highest expanded uncertainty determined for $PM_{2.5}$ after applying the correction was in the range 20 % to 25 %. The highest expanded uncertainty determined for $PM_{10}$ after the correction was in the range 15 % to 20 %.

The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation of the requirements for regular tests as described above. TÜV Rheinland recommends the use of the expanded uncertainty of the full data set for this purpose: 14.65% ($PM_{2.5}$ uncorrected data set) and 9.37% ($PM_{2.5}$ data set after correcting intercept). This would imply annual tests at 3 sites (uncorrected) or 2 sites (corrected); 7.72% ($PM_{10}$ uncorrected data set) and 7.51% ($PM_{10}$ data set after correction of the slope/intercept). This would imply annual tests at 2 (uncorrected or corrected) sites.

## 6.6 Detailed presentation of test results

Table 47 and Table 48 show the evaluation results of the equivalence test after applying the correction factor to the full data set.

Table 47: Overview of results of the equivalence test, SN 0111 & SN 0112, measured component $PM_{2.5}$ after slope correction, PM_ENVIRO_0011

| Comparison candidate with reference according to Standard EN 16450: 2017 | | | | |
|---|---|---|---|---|
| Candidate | FIDAS 200 S | SN | SN 0111 & SN 0112 | |
| | | Limit value | 30 | µg/m³ |
| Status of measured values | Slope corrected | Allowed uncertainty | 25 | % |
| **All comparisons** | | | | |
| Uncertainty between Reference | **0.53** | **µg/m³** | | |
| Uncertainty between Candidates | **0.45** | **µg/m³** | | |
| | **SN 0111 & SN 0112** | | | |
| Number of data pairs | **313** | | | |
| Slope b | **0.999** | **not significant** | | |
| Uncertainty of b | **0.008** | | | |
| Ordinate intercept a | **-0.190** | **not significant** | | |
| Uncertainty of a | **0.136** | | | |
| Expanded meas. uncertainty $W_{CM}$ | **9.67** | **%** | | |
| **All comparisons, ≥18 µg/m³** | | | | |
| Uncertainty between Reference | **0.60** | **µg/m³** | | |
| Uncertainty between Candidates | **0.80** | **µg/m³** | | |
| | **SN 0111 & SN 0112** | | | |
| Number of data pairs | **67** | | | |
| Slope b | **0.981** | | | |
| Uncertainty of b | **0.020** | | | |
| Ordinate intercept a | **0.306** | | | |
| Uncertainty of a | **0.630** | | | |
| Expanded meas. uncertainty $W_{CM}$ | **12.83** | **%** | | |
| **All comparisons, <18 µg/m³** | | | | |
| Uncertainty between Reference | **0.51** | **µg/m³** | | |
| Uncertainty between Candidates | **0.31** | **µg/m³** | | |
| | **SN 0111 & SN 0112** | | | |
| Number of data pairs | **246** | | | |
| Slope b | **1.065** | | | |
| Uncertainty of b | **0.023** | | | |
| Ordinate intercept a | **-0.782** | | | |
| Uncertainty of a | **0.224** | | | |
| Expanded meas. uncertainty $W_{CM}$ | **11.59** | **%** | | |

| Comparison candidate with reference according to Standard EN 16450: 2017 | | | | |
|---|---|---|---|---|
| Candidate | FIDAS 200 S | SN | SN 0111 & SN 0112 | |
| | | Limit value | 30 | µg/m³ |
| Status of measured values | Slope corrected | Allowed uncertainty | 25 | % |
| **Cologne, Summer** | | | | |
| Uncertainty between Reference | 0.66 | µg/m³ | | |
| Uncertainty between Candidates | 0.11 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 81 | | 82 | |
| Slope b | 1.053 | | 1.050 | |
| Uncertainty of b | 0.032 | | 0.033 | |
| Ordinate intercept a | -0.850 | | -0.810 | |
| Uncertainty of a | 0.342 | | 0.357 | |
| Expanded meas. uncertainty $W_{CM}$ | 10.92 | % | 11.21 | % |
| **Cologne, Winter** | | | | |
| Uncertainty between Reference | 0.54 | µg/m³ | | |
| Uncertainty between Candidates | 0.52 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 51 | | 50 | |
| Slope b | 0.991 | | 0.956 | |
| Uncertainty of b | 0.013 | | 0.013 | |
| Ordinate intercept a | 0.656 | | 0.645 | |
| Uncertainty of a | 0.296 | | 0.307 | |
| Expanded meas. uncertainty $W_{CM}$ | 8.87 | % | 9.77 | % |
| **Bonn** | | | | |
| Uncertainty between Reference | 0.62 | µg/m³ | | |
| Uncertainty between Candidates | 0.66 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 50 | | 50 | |
| Slope b | 1.050 | | 1.008 | |
| Uncertainty of b | 0.024 | | 0.026 | |
| Ordinate intercept a | -0.723 | | -0.471 | |
| Uncertainty of a | 0.539 | | 0.584 | |
| Expanded meas. uncertainty $W_{CM}$ | 12.67 | % | 12.67 | % |
| **Bornheim** | | | | |
| Uncertainty between Reference | 0.42 | µg/m³ | | |
| Uncertainty between Candidates | 0.47 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 45 | | 45 | |
| Slope b | 1.142 | | 1.115 | |
| Uncertainty of b | 0.051 | | 0.050 | |
| Ordinate intercept a | -1.370 | | -1.482 | |
| Uncertainty of a | 0.607 | | 0.607 | |
| Expanded meas. uncertainty $W_{CM}$ | 22.49 | % | 17.60 | % |
| **Teddington, Winter** | | | | |
| Uncertainty between Reference | 0.42 | µg/m³ | | |
| Uncertainty between Candidates | 0.52 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 44 | | 44 | |
| Slope b | 0.964 | | 0.963 | |
| Uncertainty of b | 0.012 | | 0.011 | |
| Ordinate intercept a | -0.004 | | -0.143 | |
| Uncertainty of a | 0.223 | | 0.208 | |
| Expanded meas. uncertainty $W_{CM}$ | 9.67 | % | 10.21 | % |
| **Teddington, Summer** | | | | |
| Uncertainty between Reference | 0.25 | µg/m³ | | |
| Uncertainty between Candidates | 0.35 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 44 | | 44 | |
| Slope b | 0.934 | | 0.926 | |
| Uncertainty of b | 0.020 | | 0.020 | |
| Ordinate intercept a | 0.461 | | 0.399 | |
| Uncertainty of a | 0.232 | | 0.229 | |
| Expanded meas. uncertainty $W_{CM}$ | 11.56 | % | 13.45 | % |
| **All comparisons, ≥18 µg/m³** | | | | |
| Uncertainty between Reference | 0.60 | µg/m³ | | |
| Uncertainty between Candidates | 0.80 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 67 | | 67 | |
| Slope b | 0.999 | | 0.965 | |
| Uncertainty of b | 0.020 | | 0.021 | |
| Ordinate intercept a | 0.134 | | 0.443 | |
| Uncertainty of a | 0.642 | | 0.65 | |
| Expanded meas. uncertainty $W_{CM}$ | 12.99 | % | 13.69 | % |
| **All comparisons, <18 µg/m³** | | | | |
| Uncertainty between Reference | 0.51 | µg/m³ | | |
| Uncertainty between Candidates | 0.31 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 248 | | 248 | |
| Slope b | 1.083 | | 1.052 | |
| Uncertainty of b | 0.023 | | 0.023 | |
| Ordinate intercept a | -0.841 | | -0.744 | |
| Uncertainty of a | 0.227 | | 0.226 | |
| Expanded meas. uncertainty $W_{CM}$ | 14.04 | % | 10.25 | % |
| **All comparisons** | | | | |
| Uncertainty between Reference | 0.53 | µg/m³ | | |
| Uncertainty between Candidates | 0.45 | µg/m³ | | |
| | SN 0111 | | SN 0112 | |
| Number of data pairs | 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 $W_{CM}$ | 9.82 | % | 10.47 | % |

Table 48: Overview of results of the equivalence test, SN 0111 & SN 0112, measured component $PM_{10}$ after slope/intercept correction, PM_ENVIRO_0011

| Comparison candidate with reference according to Standard EN 16450: 2017 | | | | | |
|---|---|---|---|---|---|
| Candidate | FIDAS 200 S | | SN | SN 0111 & SN 0112 | |
| | | | Limit value | 50 | µg/m³ |
| Status of measured values | Slope & offset corrected | | Allowed uncertainty | 25 | % |
| | | | | | |
| **All comparisons** | | | | | |
| Uncertainty between Reference | **0.58** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.65** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **316** | | | | |
| Slope b | **1.000** | **not significant** | | | |
| Uncertainty of b | **0.009** | | | | |
| Ordinate intercept a | **0.010** | **not significant** | | | |
| Uncertainty of a | **0.208** | | | | |
| Expanded measured uncertainty WCM | **7.51** | **%** | | | |
| **All comparisons, ≥30 µg/m³** | | | | | |
| Uncertainty between Reference | **0.68** | **µg/m³** | | | |
| Uncertainty between Candidates | **1.15** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **44** | | | | |
| Slope b | **0.955** | | | | |
| Uncertainty of b | **0.034** | | | | |
| Ordinate intercept a | **2.060** | | | | |
| Uncertainty of a | **1.490** | | | | |
| Expanded measured uncertainty WCM | **10.86** | **%** | | | |
| **All comparisons, <30 µg/m³** | | | | | |
| Uncertainty between Reference | **0.56** | **µg/m³** | | | |
| Uncertainty between Candidates | **0.55** | **µg/m³** | | | |
| | **SN 0111 & SN 0112** | | | | |
| Number of data pairs | **272** | | | | |
| Slope b | **1.006** | | | | |
| Uncertainty of b | **0.018** | | | | |
| Ordinate intercept a | **-0.122** | | | | |
| Uncertainty of a | **0.300** | | | | |
| Expanded measured uncertainty WCM | **6.82** | **%** | | | |

| Comparison candidate with reference according to Standard EN 16450: 2017 | | | | |
|---|---|---|---|---|
| Candidate | FIDAS 200 S | SN | SN 0111 & SN 0112 | |
| | | Limit value | 50 | µg/m³ |
| Status of measured values | Slope & offset corrected | Allowed uncertainty | 25 | % |
| **Cologne, Summer** | | | | |
| Uncertainty between Reference | **0.80** | **µg/m³** | | |
| Uncertainty between Candidates | **0.26** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **81** | | **82** | |
| Slope b | **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 $W_{CM}$ | **6.97** | **%** | **7.35** | **%** |
| **Cologne, Winter** | | | | |
| Uncertainty between Reference | **0.53** | **µg/m³** | | |
| Uncertainty between Candidates | **0.64** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **51** | | **50** | |
| Slope b | **1.026** | | **0.990** | |
| Uncertainty of b | **0.014** | | **0.014** | |
| Ordinate intercept a | **0.130** | | **0.107** | |
| Uncertainty of a | **0.385** | | **0.384** | |
| Expanded measured uncertainty $W_{CM}$ | **8.33** | **%** | **6.08** | **%** |
| **Bonn** | | | | |
| Uncertainty between Reference | **0.38** | **µg/m³** | | |
| Uncertainty between Candidates | **0.87** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **50** | | **50** | |
| Slope b | **1.005** | | **0.968** | |
| Uncertainty of b | **0.026** | | **0.028** | |
| Ordinate intercept a | **1.279** | | **1.419** | |
| Uncertainty of a | **0.792** | | **0.834** | |
| Expanded measured uncertainty $W_{CM}$ | **10.65** | **%** | **9.22** | **%** |
| **Bornheim** | | | | |
| Uncertainty between Reference | **0.54** | **µg/m³** | | |
| Uncertainty between Candidates | **0.84** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **47** | | **47** | |
| Slope b | **1.086** | | **1.043** | |
| Uncertainty of b | **0.038** | | **0.038** | |
| Ordinate intercept a | **-0.555** | | **-0.731** | |
| Uncertainty of a | **0.707** | | **0.694** | |
| Expanded measured uncertainty $W_{CM}$ | **16.81** | **%** | **9.28** | **%** |
| **Teddington, Winter** | | | | |
| Uncertainty between Reference | **0.48** | **µg/m³** | | |
| Uncertainty between Candidates | **0.73** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **44** | | **44** | |
| Slope b | **0.963** | | **0.934** | |
| Uncertainty of b | **0.017** | | **0.016** | |
| Ordinate intercept a | **-0.195** | | **-0.179** | |
| Uncertainty of a | **0.426** | | **0.405** | |
| Expanded measured uncertainty $W_{CM}$ | **10.49** | **%** | **15.24** | **%** |
| **Teddington, Summer** | | | | |
| Uncertainty between Reference | **0.46** | **µg/m³** | | |
| Uncertainty between Candidates | **0.54** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **45** | | **45** | |
| Slope b | **0.912** | | **0.910** | |
| Uncertainty of b | **0.028** | | **0.029** | |
| Ordinate intercept a | **1.264** | | **0.868** | |
| Uncertainty of a | **0.457** | | **0.489** | |
| Expanded measured uncertainty $W_{CM}$ | **13.74** | **%** | **15.68** | **%** |
| **All comparisons, ≥30 µg/m³** | | | | |
| Uncertainty between Reference | **0.68** | **µg/m³** | | |
| Uncertainty between Candidates | **1.15** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **44** | | **44** | |
| Slope b | **0.983** | | **0.928** | |
| Uncertainty of b | **0.035** | | **0.034** | |
| Ordinate intercept a | **1.474** | | **2.590** | |
| Uncertainty of a | **1.518** | | **1.50** | |
| Expanded measured uncertainty $W_{CM}$ | **11.33** | **%** | **11.63** | **%** |
| **All comparisons, <30 µg/m³** | | | | |
| Uncertainty between Reference | **0.56** | **µg/m³** | | |
| Uncertainty between Candidates | **0.55** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **274** | | **274** | |
| Slope b | **1.025** | | **0.990** | |
| Uncertainty of b | **0.018** | | **0.017** | |
| Ordinate intercept a | **-0.172** | | **-0.102** | |
| Uncertainty of a | **0.308** | | **0.297** | |
| Expanded measured uncertainty $W_{CM}$ | **8.20** | **%** | **7.17** | **%** |
| **All comparisons** | | | | |
| Uncertainty between Reference | **0.58** | **µg/m³** | | |
| Uncertainty between Candidates | **0.65** | **µg/m³** | | |
| | **SN 0111** | | **SN 0112** | |
| Number of data pairs | **318** | | **318** | |
| Slope b | **1.016** | **not significant** | **0.983** | **not significant** |
| Uncertainty of b | **0.009** | | **0.009** | |
| Ordinate intercept a | **-0.019** | **not significant** | **0.043** | **not significant** |
| Uncertainty of a | **0.212** | | **0.209** | |
| Expanded measured uncertainty $W_{CM}$ | **8.32** | **%** | **8.18** | **%** |

## 6.1 18 Maintenance interval (7.5.7)

*The maintenance interval shall be at least 2 weeks.*

## 6.2 Equipment

Not required for this performance criterion

## 6.3 Testing

With regard to this minimum requirement, the maintenance tasks required in a specific period and the length of that period for the correct functioning of the measuring system were identified. Furthermore, in determining the maintenance interval, the drift determined for zero and reference point (see [11] and [15]) have been taken into consideration.

## 6.4 Evaluation

Over the entire period of the field test, no unacceptable drift was observed.

Accordingly, the maintenance interval is defined by the need for regular inspections of the particle sensor using CalDust 1100 or MonoDust 1500.

Regular reference point checks as part of the original field test [11] with test standard CalDust 1100 demonstrated that permissible deviations of 130 ± 1.5 channels cannot be ensured within the test interval proposed by the manufacturer and that tests should consequently be performed on a monthly basis. In the context of the initial publication of the Federal Environment Agency of 27 February 2014 (BAnz AT 01.04.2014 B12, chapter IV number 5.1), the maintenance interval was specified at one month accordingly. Drift effects had been caused by adhesive gases deposited on the optical glass surfaces.

This problem was solved as part of the change procedure in compliance with standard EN 15267-2. The implemented change (additional bore hole) potentially reduced the number or necessary comparisons with CalDust 1100 or MonoDust 1500.

An additional test of the long-term stability in the period between 19.08.2015 and 26.08.2016 served to validate this. The results as presented in section 6.6 of that test criterion demonstrate that the drift at reference point consistently remained below the permissible deviation of 5%. Consequently, it was possible to extend the interval for testing the particle sensor to three months (see [15] and UBA announcement dated 22 February 2017 (BAnz AT 15.03.2017 B6, chapter V 10th notification).

During operation times, maintenance is generally limited to contamination and plausibility checks and potential status/error messages.

## 6.5 Assessment

The maintenance interval is defined by the need for regular inspections of the particle sensor using CalDust 1100 or MonoDust 1500 and is at three months.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

The necessary maintenance works are listed in chapter 4 of the operation manual.

Table 49 to Table 51 present the results of the long-term stability test with CalDust 1100 or MonoDust 1500 taken from [15].

Table 49: Raw data from the stability test using MonoDust 1500

| | SN 6231 | | | SN 6230 | | |
|---|---|---|---|---|---|---|
| Date | Peak position | v at Peak | PM voltage | Peak position | v at Peak | PM voltage |
| 8/19/2015 | 141 | 9.1 | 1.619 | 141.06 | 9.82 | 1.402 |
| 9/2/2015 | 141.1 | 9.1 | 1.619 | 141.08 | 9.8 | 1.402 |
| 9/14/2015 | 141.08 | 9.42 | 1.619 | 141.08 | 9.87 | 1.402 |
| 9/28/2015 | 140.92 | 9 | 1.619 | 141 | 9.83 | 1.402 |
| 10/12/2015 | 140.62 | 9 | 1.619 | 140.94 | 9.75 | 1.402 |
| 10/26/2015 | 140.79 | 9.1 | 1.619 | 141.03 | 9.82 | 1.402 |
| 11/9/2015 | 140.75 | 9.2 | 1.619 | 141.41 | 9.42 | 1.402 |
| 11/23/2015 | 140.52 | 9.2 | 1.619 | 141.11 | 9.42 | 1.402 |
| 12/7/2015 | 140.56 | 9.1 | 1.619 | 141.29 | 9.42 | 1.402 |
| 12/18/2015 | 140.44 | 9.1 | 1.619 | 141.19 | 9.42 | 1.402 |
| 1/6/2016 | 140.29 | 9.31 | 1.619 | 141.06 | 9.64 | 1.402 |
| 1/18/2016 | 140.47 | 9.1 | 1.619 | 140.98 | 9.64 | 1.402 |
| 1/29/2016 | 140.39 | 9.1 | 1.619 | 140.6 | 9.64 | 1.402 |
| 2/15/2016 | 140.4 | 9.31 | 1.619 | 140.95 | 9.64 | 1.402 |
| 2/29/2016 | 140.4 | 9.2 | 1.619 | 140.87 | 9.53 | 1.402 |
| 3/14/2016 | 140.24 | 9.2 | 1.619 | 140.88 | 9.41 | 1.402 |
| 3/29/2016 | 140.19 | 9.2 | 1.619 | 141.18 | 9.64 | 1.402 |
| 4/11/2016 | 140.29 | 9.2 | 1.619 | 140.94 | 9.64 | 1.402 |
| 4/25/2016 | 140.38 | 9.31 | 1.619 | 140.94 | 9.64 | 1.402 |
| 5/10/2016 | 140.42 | 9.2 | 1.619 | 141.06 | 9.53 | 1.402 |
| 5/10/2016 | 140.23 | 9.2 | 1.619 | 141.06 | 9.53 | 1.402 |
| 5/25/2016 | 140.18 | 9.2 | 1.619 | 140.96 | 9.53 | 1.402 |
| 6/6/2016 | 140.44 | 9.1 | 1.619 | 141.25 | 9.53 | 1.402 |
| 6/20/2016 | 140.51 | 9.8 | 1.619 | 141.01 | 9.53 | 1.402 |
| 7/6/2016 | 140.59 | 9.64 | 1.619 | 141.3 | 9.53 | 1.402 |
| 7/18/2016 | 140.62 | 9.64 | 1.619 | 141.2 | 9.2 | 1.402 |
| 8/1/2016 | 140.56 | 9.64 | 1.619 | 141.25 | 9.42 | 1.402 |
| 8/15/2016 | 140.37 | 9.2 | 1.619 | 141.05 | 9.1 | 1.402 |
| 8/26/2016 | 140.39 | 9.1 | 1.619 | 141.13 | 9.1 | 1.402 |

Table 50: Evaluation of the long-term stability SN 6230

| | SN: 6230 | $PM_{2,5}$ | 25 | $PM_{10}$ | 40 | $PM_{2,5}$ in µg/m³ | $PM_{10}$ in µg/m³ |
|---|---|---|---|---|---|---|---|
| Date | Deviation | slope | offset | slope | offset | | |
| 8/19/2015 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 9/2/2015 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 9/14/2015 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 9/28/2015 | -0.1 | 1.0029 | 0.0012 | 1.0028 | 0.0048 | 24.93 | 39.88 |
| 10/12/2015 | -0.2 | 1.0058 | 0.0024 | 1.0056 | 0.0096 | 24.85 | 39.77 |
| 10/26/2015 | -0.1 | 1.0029 | 0.0012 | 1.0028 | 0.0048 | 24.93 | 39.88 |
| 11/9/2015 | 0.3 | 0.9919 | -0.0024 | 0.9928 | -0.0014 | 25.21 | 40.29 |
| 11/23/2015 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 12/7/2015 | 0.2 | 0.9946 | -0.0016 | 0.9952 | -0.0009 | 25.14 | 40.19 |
| 12/18/2015 | 0.1 | 0.9973 | -0.0008 | 0.9976 | -0.0005 | 25.07 | 40.10 |
| 1/6/2016 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 1/18/2016 | -0.1 | 1.0029 | 0.0012 | 1.0028 | 0.0048 | 24.93 | 39.88 |
| 1/29/2016 | -0.5 | 1.0145 | 0.0061 | 1.0140 | 0.0240 | 24.64 | 39.42 |
| 2/15/2016 | -0.2 | 1.0058 | 0.0024 | 1.0056 | 0.0096 | 24.85 | 39.77 |
| 2/29/2016 | -0.2 | 1.0058 | 0.0024 | 1.0056 | 0.0096 | 24.85 | 39.77 |
| 3/14/2016 | -0.2 | 1.0058 | 0.0024 | 1.0056 | 0.0096 | 24.85 | 39.77 |
| 3/29/2016 | 0.1 | 0.9973 | -0.0008 | 0.9976 | -0.0005 | 25.07 | 40.10 |
| 4/11/2016 | -0.2 | 1.0058 | 0.0024 | 1.0056 | 0.0096 | 24.85 | 39.77 |
| 4/25/2016 | -0.2 | 1.0058 | 0.0024 | 1.0056 | 0.0096 | 24.85 | 39.77 |
| 5/10/2016 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 5/10/2016 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 5/25/2016 | -0.1 | 1.0029 | 0.0012 | 1.0028 | 0.0048 | 24.93 | 39.88 |
| 6/6/2016 | 0.2 | 0.9946 | -0.0016 | 0.9952 | -0.0009 | 25.14 | 40.19 |
| 6/20/2016 | -0.1 | 1.0029 | 0.0012 | 1.0028 | 0.0048 | 24.93 | 39.88 |
| 7/6/2016 | 0.2 | 0.9946 | -0.0016 | 0.9952 | -0.0009 | 25.14 | 40.19 |
| 7/18/2016 | 0.1 | 0.9973 | -0.0008 | 0.9976 | -0.0005 | 25.07 | 40.10 |
| 8/1/2016 | 0.2 | 0.9946 | -0.0016 | 0.9952 | -0.0009 | 25.14 | 40.19 |
| 8/15/2016 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 8/26/2016 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |

Table 51: Evaluation of the long-term stability SN 6231

| | SN: 6231 | $PM_{2,5}$ | 25 | $PM_{10}$ | 40 | $PM_{2,5}$ in µg/m³ | $PM_{10}$ in µg/m³ |
|---|---|---|---|---|---|---|---|
| Date | Deviation | slope | offset | slope | offset | | |
| 8/19/2015 | -0.1 | 1.0029 | 0.0012 | 1.0028 | 0.0048 | 24.93 | 39.88 |
| 9/2/2015 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 9/14/2015 | 0.0 | 1.0000 | 0.0000 | 1.0000 | 0.0000 | 25.00 | 40.00 |
| 9/28/2015 | -0.2 | 1.0058 | 0.0024 | 1.0056 | 0.0096 | 24.85 | 39.77 |
| 10/12/2015 | -0.5 | 1.0145 | 0.0061 | 1.0140 | 0.0240 | 24.64 | 39.42 |
| 10/26/2015 | -0.3 | 1.0087 | 0.0037 | 1.0084 | 0.0144 | 24.78 | 39.65 |
| 11/9/2015 | -0.3 | 1.0087 | 0.0037 | 1.0084 | 0.0144 | 24.78 | 39.65 |
| 11/23/2015 | -0.6 | 1.0174 | 0.0073 | 1.0168 | 0.0288 | 24.57 | 39.31 |
| 12/7/2015 | -0.5 | 1.0145 | 0.0061 | 1.0140 | 0.0240 | 24.64 | 39.42 |
| 12/18/2015 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |
| 1/6/2016 | -0.8 | 1.0232 | 0.0098 | 1.0224 | 0.0384 | 24.42 | 39.09 |
| 1/18/2016 | -0.6 | 1.0174 | 0.0073 | 1.0168 | 0.0288 | 24.57 | 39.31 |
| 1/29/2016 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |
| 2/15/2016 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |
| 2/29/2016 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |
| 3/14/2016 | -0.9 | 1.0261 | 0.0110 | 1.0252 | 0.0432 | 24.35 | 38.97 |
| 3/29/2016 | -0.9 | 1.0261 | 0.0110 | 1.0252 | 0.0432 | 24.35 | 38.97 |
| 4/11/2016 | -0.8 | 1.0232 | 0.0098 | 1.0224 | 0.0384 | 24.42 | 39.09 |
| 4/25/2016 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |
| 5/10/2016 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |
| 5/10/2016 | -0.9 | 1.0261 | 0.0110 | 1.0252 | 0.0432 | 24.35 | 38.97 |
| 5/25/2016 | -0.9 | 1.0261 | 0.0110 | 1.0252 | 0.0432 | 24.35 | 38.97 |
| 6/6/2016 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |
| 6/20/2016 | -0.6 | 1.0174 | 0.0073 | 1.0168 | 0.0288 | 24.57 | 39.31 |
| 7/6/2016 | -0.5 | 1.0145 | 0.0061 | 1.0140 | 0.0240 | 24.64 | 39.42 |
| 7/18/2016 | -0.5 | 1.0145 | 0.0061 | 1.0140 | 0.0240 | 24.64 | 39.42 |
| 8/1/2016 | -0.5 | 1.0145 | 0.0061 | 1.0140 | 0.0240 | 24.64 | 39.42 |
| 8/15/2016 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |
| 8/26/2016 | -0.7 | 1.0203 | 0.0085 | 1.0196 | 0.0336 | 24.49 | 39.20 |

## 6.1 19 Automatic diagnostic check (7.5.4)

*Results of automated/functional checks, where available, shall be recorded.*

## 6.2 Equipment

Not required for this performance criterion

## 6.3 Testing

The current operating status of the measuring system is continuously monitored and any issues will be flagged via a series of different error messages. The current state of monitored parameters can be displayed on the instrument itself and is recorded as part of data logging. When a monitored parameter falls outside the permissible ranges of tolerance, an error bit appears.

The instrument performs internal sensitivity checks of the particle sensor (calibration checks). in the event of deviations in the 40h-average from the target exceeding 3.5 raw data channels, an error status is signalled. The results of calibration checks are documented by way of data recording.

## 6.4 Evaluation

All instrument functions described in the operation manual are available and can be activated. The current operating status is continuously monitored and any issues will be flagged via a series of different warning messages. Data on monitored parameters incl. automated calibration monitoring are collected during data recording.

## 6.5 Assessment

All instrument functions described in the operation manual are available and can be activated. The current operating status is continuously monitored and any issues will be flagged via a series of different warning messages. Data on monitored parameters incl. automated calibration checks are collected during data recording.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Available status signals are listed in chapter 4 of the operation manual.

## 6.1 20 Checks of temperature sensors, pressure and/or humidity sensors

*The verifiability of temperature sensors, pressure and/or humidity sensors shall be checked for the AMS. Deviations determined shall be within the following criteria:*

*T ±2 °C*
*p ±1 kPa*
*rF ± 5 %*

## 6.2 Equipment

Not required for this performance criterion

## 6.3 Testing

This minimum requirement serves to verify whether AMS sensors for temperature, pressure and humidity, which are necessary for correct AMS performance, are accessible and can be checked at the field test site location. In the event, checks cannot be performed on-site, this has to be documented.

## 6.4 Evaluation

For recording ambient temperature, air pressure and relative humidity, the Fidas® 200 measuring system uses a weather station, type WS300-UMB or WS600-UMB, manufactured by Lufft.

The manufacturer of the weather station indicate the sensors' accuracy as follows: ±0.2°C (ambient temperature), ±2% (relative humidity) ±0.05kPa (air pressure).

Relying on transfer standards, it is easily possible to perform comparison measurements on-site at any time and to adjust the sensors using slope or intercept corrections in the event of any deviation.

An adjustment may take the form of a 1-point-adjustment (usually in the field) by determining a slope (intercept remains at 0) or as 2- or multiple-point-adjustment (e.g. in a calibration laboratory) by determining the slope and intercept by means of regression calculation).

It is also possible to check the temperature sensor of the IADS (humidity compensation). This, however, requires exposition of the entire IADS system in a controlled temperature environment and is therefore usually not possible on-site without disassembly of the sampling system.

## 6.5 Assessment

It is easy to check and adjust the sensors for determining ambient temperature, ambient pressure and relative humidity on-site. It is also possible to check the temperature sensor of the IADS (humidity compensation). This, however, requires exposition of the entire IADS system in a controlled temperature environment and is therefore usually not possible on-site without disassembly of the sampling system.

Criterion satisfied? yes

## 6.6 Detailed presentation of test results

Not required for this performance criterion

# 7. Recommendations for use in practice

## 7.1 Work in the maintenance interval (3 months)

The tested measuring systems require regular performance of the following tasks:

- Regular visual inspections/telemetric inspections
- Checking the operational status
  The instrument status can be verified by checking the AMS; alternatively it can be monitored online.
- The sampling inlet generally needs to be cleaned following the manufacturer's instruction and taking into account local concentrations of suspended particulate matter (approximately every 3 months during performance testing).
- The manufacturer specifies the interval for perfuming leak tests at three months.
- The manufacturer specifies the interval for checking the flow rate at three months.
- Every three months, the sensitivity of the particle sensor has to be checked using CalDust 1100 or MonoDust 1500; the sensitivity of the particle sensor has to be adjusted in the event of deviations exceeding ±1.5 channels from the targeted 130 (CalDust 1100) or the target value (MonoDust 1500).

Apart from that please consider the manufacturer's instructions.

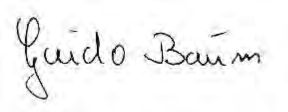
## 7.2 Additional maintenance tasks

In addition to the regular tasks to be performed during the maintenance interval, the following tasks need to be performed.

- The manufacturer recommends checks of the sensors integrated in the WS300-UMB or WS600-UMB weather stations once a year or when necessary.
- Cleaning of the optical sensor is only required when a calibration of the optical sensor shows the photomultiplier voltage to exceed the value determined for the previous cleansing or the delivery state by more than 15%.
- The filter needs to be cleaned or replaced if the performance of the exhaust pump exceeds 50%.

Further details are provided in the operation manual.

Environmental Protection/Air Pollution Control



Dipl.-Ing. Guido Baum

Dipl.-Ing. Karsten Pletscher

Cologne, 7 September 2018
936/21239834/B

# 8. Bibliography

[1] VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated June 2002 and September 2010

[2] VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated August 2004 and September 2010

[3] EN 12341 "Air Quality - Determination of the $PM_{10}$ fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341 1998

[4] European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005

[5] Guideline "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated January 2010

[6] Operation manual Fidas® 200 S and Fidas® 200, comprising manuals Fidas®, Fidas® Firmware, PDAnalyze Software, compact weather station WS300-UMB/WS600-UMB, dated 2014 and 2016

[7] Operation manual LVS3 of 2000

[9] 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] European standard EN 16450 "Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2.5, German version dated July 2017)

[10] "UK Equivalence Programme for Monitoring of Particulate Matter" report, Report No.: BV/AQ/AD202209/DH/2396 dated 5 June 2006

[11] TÜV Rheinland report 936/21218896/A dated 20 September 2013, Report on the performance testing of the Fidas® 200 S ambient air monitoring system manufactured by Palas GmbH for suspended particulate matter $PM_{10}$ and $PM_{2.5}$

[12] TÜV Rheinland report 936/21227195/C dated 12 October 2016, Report on the supplementary testing of the Fidas® 200 S and Fidas® 200 ambient air monitoring system manufactured by Palas GmbH for suspended particulate matter $PM_{10}$ and $PM_{2.5}$

[13] Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 27 September 2014

[14] Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 6 November 2015

[15] Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 12 October 2016

5.1 Fidas® 200 S für Schwebstaub $PM_{10}$ und $PM_{2,5}$

Hersteller:
PALAS GmbH, Karlsruhe

Eignung:
Zur kontinuierlichen parallelen Immissionsmessung der $PM_{10}$- und der $PM_{2,5}$-Fraktion im Schwebstaub im stationären Einsatz

Messbereiche in der Eignungsprüfung:

| Komponente | Zertifizierungsbereich | Einheit |
|---|---|---|
| $PM_{10}$ | 0 – 10 000 | µg/m³ |
| $PM_{2,5}$ | 0 – 10 000 | µg/m³ |

Softwareversionen: Messsystem: 100327
Implementierter Auswertealgorithmus: PM_ENVIRO_0011
Auswertesoftware PDAnalyze: 1.010

Einschränkungen:
Keine

Hinweise:

1. Die Anforderungen gemäß des Leitfadens „Demonstration of Equivalence of Ambient Air Monitoring Methods“ werden für die Messkomponenten $PM_{10}$ und $PM_{2,5}$ eingehalten.
2. Die Anforderungen an den Variationskoeffizienten $R^2$ gemäß Richtlinie EN 12341 wurden für den Standort Köln, Sommer für einen der beiden Prüflinge nicht eingehalten.
3. Die Empfindlichkeit des Partikelsensors muss monatlich mit CalDust 1100 überprüft werden.
4. Die Messeinrichtung ist mit dem gravimetrischen $PM_{10}$-Referenzverfahren nach DIN EN 12341 regelmäßig am Standort zu kalibrieren.
5. Die Messeinrichtung ist mit dem gravimetrischen $PM_{2,5}$-Referenzverfahren nach DIN EN 14907 regelmäßig am Standort zu kalibrieren.
6. Der Prüfbericht über die Eignungsprüfung ist im Internet unter www.qal1.de einsehbar.

Prüfinstitut: TÜV Rheinland Energie und Umwelt GmbH, Köln
Bericht-Nr.: 936/21218896/A vom 20. September 2013

Figure 95: Initial public announcement BAnz AT 01.04.2014 B12, chapter IV number 5.1

**14 Mitteilung zu der Bekanntmachung des Umweltbundesamtes vom 27. Februar 2014 (BAnz AT 01.04.2014 B12, Kapitel IV Nummer 5.1)**

Die Messeinrichtung Fidas® 200 S für Schwebstaub $PM_{10}$ und $PM_{2,5}$ der Fa. PALAS GmbH ist auch als Indoor-Variante zur Installation an temperaturkontrollierten Orten unter der Bezeichnung Fidas® 200 für Schwebstaub $PM_{10}$ und $PM_{2,5}$ verfügbar.

Die Messeinrichtung erhält auf der Geräterückseite eine zusätzliche Buchse für ein digitales Ausgangssignal.

Die LED im Fidas® Sensor vom Typ Osram Ostar Projektion Art.-Nr. LE B H3W wurde abgekündigt und durch die LED vom Typ Osram Ostar Stage Art.-Nr. LE ATB S2W ersetzt.

Die Darstellung der Softwareversion der Messeinrichtung wurde überarbeitet.

Die bislang bekannt gegebene 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 96: Notification published in BAnz AT 02.04.2015 B5, chapter IV 14th Notification

2.1 Fidas® 200 S bzw. Fidas® 200 für Schwebstaub $PM_{10}$ und $PM_{2,5}$

Hersteller:

PALAS GmbH, Karlsruhe

Eignung:

Zur kontinuierlichen parallelen Immissionsmessung der $PM_{10}$- und der $PM_{2,5}$-Fraktion im Schwebstaub im stationären Einsatz

Messbereiche in der Eignungsprüfung:

| Komponente | Zertifizierungsbereich | Einheit |
|---|---|---|
| $PM_{10}$ | 0 – 10 000 | µg/m³ |
| $PM_{2,5}$ | 0 – 10 000 | µg/m³ |

Softwareversion: 100380.0014.0001.0001.0011

Einschränkungen:

Keine

Hinweise:

1. Die Messeinrichtung Fidas® 200 S ist auch als Indoor-Variante zur Installation an temperaturkontrollierten Orten unter der Bezeichnung Fidas® 200 verfügbar.
2. Die Anforderungen gemäß des Leitfadens „Demonstration of Equivalence of Ambient Air Monitoring Methods" werden sowohl für die vier Vergleichskampagnen (Erstprüfung) wie auch für die sechs Vergleichskampagnen (Ergänzungsprüfung) für die Messkomponenten $PM_{10}$ und $PM_{2,5}$ eingehalten.
3. Die Anforderungen an den Variationskoeffizienten $R^2$ gemäß Richtlinie EN 12341 (Ausgabe: 1998) wurden für den Standort Köln, Sommer für einen der beiden Prüflinge nicht eingehalten.
4. Die Empfindlichkeit des Partikelsensors muss monatlich mit CalDust 1100 oder MonoDust1500 überprüft werden.
5. Die Messeinrichtung ist mit dem gravimetrischen Referenzverfahren für die Bestimmung von $PM_{2,5}$ und $PM_{10}$ nach DIN EN 12341 (Ausgabe: 2014) regelmäßig am Standort zu kalibrieren.
6. Der Prüfbericht über die Eignungsprüfung ist im Internet unter www.qal1.de einsehbar.
7. Ergänzungsprüfung (Erweiterung Äquivalenzprüfung, Darstellung Geräteänderungen, Aufnahme Prüfstandard Mono-Dust1500) zu den Bekanntmachungen des Umweltbundesamtes vom 27. Februar 2014 (BAnz AT 01.04.2014 B12, Kapitel IV Nummer 5.1) und vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel IV 14. Mitteilung).

Prüfinstitut: TÜV Rheinland Energie und Umwelt GmbH, Köln

Bericht-Nr.: 936/21227195/A vom 9. März 2015

Figure 97: Notification of the supplementary test published in BAnz AT 26.08.2015 B4, chapter III number 2.1

**6 Mitteilung zu der Bekanntmachung des Umweltbundesamtes vom 22. Juli 2015 (BAnz AT 26.08.2015 B4, Kapitel III Nummer 2.1)**

Im Handbuch der Messeinrichtung Fidas® 200 S bzw. Fidas® 200 für $PM_{10}$ und $PM_{2,5}$ der PALAS GmbH wurde ein Fehler hinsichtlich der Beschreibung der Funktionalität der IADS-Regelung festgestellt. Die Beschreibung muss richtig lauten wie folgt:

*„Die Temperatur des IADS wird geregelt in Abhängigkeit von der Umgebungstemperatur und Luftfeuchtigkeit (gemessen mit Wetterstation). Die Minimaltemperatur beträgt 23 °C. Die Feuchtekompensation erfolgt dabei durch eine dynamische Anpassung der IADS-Temperatur bis zu einer maximalen Heizleistung von 90 Watt.“*

Der Hersteller hat ab Handbuchversion V0140815 diesen Fehler korrigiert. Der Prüfbericht 936/21227195/A vom 9. März 2015 der TÜV Rheinland Energie und Umwelt GmbH wurde ebenfalls korrigiert und wird durch den Prüfbericht 936/21227195/B vom 5. Oktober 2015 ersetzt.

Die Messeinrichtung kann zukünftig alternativ mit der Wetterstation Typ WS300-UMB betrieben werden. Für die Messeinrichtung steht eine verlängerte IADS zur Verfügung, anpassbar für einen Längenbereich von 1,20 m bis 2,10 m. Außerdem ist die Geräteversion Fidas® 200 E mit externem Sensor einsetzbar.

Die aktuelle Softwareversion lautet:

100396.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 6. November 2015

Figure 98: Notification published in BAnz AT 14.03.2016 B7, chapter V 6th Notification

**35 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 27. Februar 2014 (BAnz AT 01.04.2014 B12, Kapitel IV Nummer 5.1) und vom 18. Februar 2016 (BAnz AT 14.03.2016 B7, Kapitel V 6. Mitteilung)**

Bei der Messeinrichtung Fidas® 200, Fidas® 200 S bzw. Fidas® 200 E für $PM_{10}$ und $PM_{2,5}$ der Firma PALAS GmbH kann die Überprüfung der Empfindlichkeit des Partikelsensors mit MonoDust 1500 bei einer IADS-Temperatur von 35 °C oder 50 °C durchgeführt werden.

Die Messeinrichtung kann auf der Geräterückseite zwei zusätzliche Buchsen für die Ansteuerung einer externen Pumpe/Durchflussregelung (nicht relevant für die eignungsgeprüfte Geräteversion) enthalten.

Die aktuelle Softwareversion der Messeinrichtung lautet:

100408.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 24. Februar 2016

Figure 99: Notification published in BAnz AT 01.08.2016 B11, chapter V 35th Notification

**10 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 27. Februar 2014 (BAnz AT 01.04.2014 B12, Kapitel IV Nummer 5.1) und vom 14. Juli 2016 (BAnz AT 01.08.2016 B11, Kapitel V 35. Mitteilung)**

Bei den Messeinrichtungen Fidas® 200, Fidas® 200 S bzw. Fidas® 200 E für $PM_{10}$ und $PM_{2,5}$ der Firma PALAS GmbH muss die Empfindlichkeit des Partikelsensors alle drei Monate mit CalDust 1100 oder MonoDust 1500 überprüft werden.

Die Messeinrichtungen können alternativ mit dem neuen Flowsensor vom Typ Siargo FS4008-10-O6-CV-A statt der bisher verwendeten Variante Honeywell AWM5102VN genutzt werden.

Die neuen Temperaturkompensationsfaktoren lauten für die jeweiligen Geräte wie folgt: 0.15 (Fidas® 200 S), 0.19 (Fidas® 200 E) und 0.17 (Fidas® 200).

Um eine effizientere Beheizung des Outdoorgehäuses für die Variante Fidas® 200 S zu gewährleisten, ist die Position des Heizlüfters verändert worden. Der Luftstrom des Heizlüfters durchströmt das Gehäuse nun von unten nach oben.

Ein Fehler im Prüfbericht 936/21227195/B vom 5. Oktober 2015 der TÜV Rheinland Energie und Umwelt GmbH wurde korrigiert. Die Immissionsmesseinrichtungen Fidas® 200 S, Fidas® 200 E bzw. Fidas® 200 arbeiten mit einem gleitenden Mittelwert über 900 s (15 Minuten) anstatt wie an zwei Stellen im Bericht dargestellt mit einem gleitenden 30-Minuten-Mittelwert. Der oben genannte Bericht wird durch den Prüfbericht 936/21227195/C vom 12. Oktober 2016 der TÜV Rheinland Energy GmbH ersetzt.

Die aktuelle Softwareversion der Messeinrichtung lautet: 100417.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energy GmbH vom 12. Oktober 2016

Figure 100: Notification published in BAnz AT 15.03.2017 B6, chapter V 10th Notification

**30 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 27. Februar 2014 (BAnz AT 01.04.2014 B12, Kapitel IV Nummer 5.1) und vom 22. Februar 2017 (BAnz AT 15.03.2017 B6, Kapitel V 10. Mitteilung)**

Die aktuelle Softwareversion für die Messeinrichtungen Fidas® 200, Fidas® 200 S bzw. Fidas® 200 E für $PM_{10}$ und $PM_{2,5}$ der Firma PALAS GmbH lautet: 100427.0014.0001.0001.0011

Stellungnahme der TÜV Rheinland Energy GmbH vom 7. März 2017

Figure 101: Notification published in BAnz AT 31.07.2017 B12, chapter II 30th Notification

# 9. Annexes

**Appendix 1** **Measured and calculated values**

Annex 1: Zero level and detection limit

Annex 2: Flow rate accuracy

Annex 3: Temperature dependence of the zero point and sensitivity

Annex 4: Independence of supply voltage

Annex 5: Measured values from the field test sites PM_ENVIRO_0011

Annex 6: Ambient condition at the field test locations

**Appendix 2:** **Methods used for filter weighing**

**Appendix 3** **Operation manuals**

**Annex 1** **Zero level and Detection limit ($PM_{10}$)** **Page 1 of 2**

| | |
|---|---|
| Manufacturer | PALAS |
| Type | Fidas® 200 |
| Serial-No. | SN 0111 / SN 0112 |
| Standards | ZP — Measured values with zero filter |

| No. | Date | Measured values [µg/m³] SN 0111 | Date | Measured values [µg/m³] SN 0112 |
|---|---|---|---|---|
| 1 | 4/5/2012 | 0.0000000 | 4/5/2012 | 0.0000000 |
| 2 | 4/6/2012 | 0.0000000 | 4/6/2012 | 0.0000005 |
| 3 | 4/7/2012 | 0.0000000 | 4/7/2012 | 0.0000000 |
| 4 | 4/8/2012 | 0.0000000 | 4/8/2012 | 0.0000000 |
| 5 | 4/9/2012 | 0.0000000 | 4/9/2012 | 0.0000000 |
| 6 | 4/10/2012 | 0.0000008 | 4/10/2012 | 0.0000000 |
| 7 | 4/11/2012 | 0.0000000 | 4/11/2012 | 0.0000008 |
| 8 | 4/12/2012 | 0.0000008 | 4/12/2012 | 0.0000003 |
| 9 | 4/13/2012 | 0.0000000 | 4/13/2012 | 0.0000006 |
| 10 | 4/14/2012 | 0.0000000 | 4/14/2012 | 0.0000000 |
| 11 | 4/15/2012 | 0.0000177 | 4/15/2012 | 0.0000008 |
| 12 | 4/16/2012 | 0.0012831 | 4/16/2012 | 0.0000000 |
| 13 | 4/17/2012 | 0.0010071 | 4/17/2012 | 0.0000000 |
| 14 | 4/18/2012 | 0.0001465 | 4/18/2012 | 0.0000000 |
| 15 | 4/19/2012 | 0.0004303 | 4/19/2012 | 0.0000000 |
| | No. of values | 15 | No. of values | 15 |
| | Mean (Zero level) | 0.0001924 | Mean (Zero level) | 0.0000002 |
| | Standard deviation $s_{x0}$ | 0.0004064 | Standard deviation $s_{x0}$ | 0.0000003 |
| | Detection limit x | 1.34E-03 | Detection limit x | 1.01E-06 |

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

**Annex 1** **Zero level and Detection limit ($PM_{2.5}$)** **Page 2 of 2**

| | | | | |
|---|---|---|---|---|
| Manufacturer | PALAS | | | |
| Type | Fidas® 200 | Standards | ZP | Measured values with zero filter |
| Serial-No. | SN 0111 / SN 0112 | | | |

| No. | Date | Measured values [µg/m³] SN 0111 | Date | Measured values [µg/m³] SN 0112 |
|---|---|---|---|---|
| 1 | 4/5/2012 | 0.0000003 | 4/5/2012 | 0.0000000 |
| 2 | 4/6/2012 | 0.0000000 | 4/6/2012 | 0.0000005 |
| 3 | 4/7/2012 | 0.0000000 | 4/7/2012 | 0.0000000 |
| 4 | 4/8/2012 | 0.0000000 | 4/8/2012 | 0.0000000 |
| 5 | 4/9/2012 | 0.0000000 | 4/9/2012 | 0.0000000 |
| 6 | 4/10/2012 | 0.0000000 | 4/10/2012 | 0.0000000 |
| 7 | 4/11/2012 | 0.0000008 | 4/11/2012 | 0.0000008 |
| 8 | 4/12/2012 | 0.0000000 | 4/12/2012 | 0.0000003 |
| 9 | 4/13/2012 | 0.0000008 | 4/13/2012 | 0.0000006 |
| 10 | 4/14/2012 | 0.0000000 | 4/14/2012 | 0.0000000 |
| 11 | 4/15/2012 | 0.0000000 | 4/15/2012 | 0.0000008 |
| 12 | 4/16/2012 | 0.0000177 | 4/16/2012 | 0.0000000 |
| 13 | 4/17/2012 | 0.0012831 | 4/17/2012 | 0.0000000 |
| 14 | 4/18/2012 | 0.0010071 | 4/18/2012 | 0.0000000 |
| 15 | 4/19/2012 | 0.0001465 | 4/19/2012 | 0.0000000 |
| | No. of values | 15 | No. of values | 15 |
| | Mean (Zero level) | 0.0001638 | Mean (Zero level) | 0.0000002 |
| | Standard deviation $s_{x0}$ | 0.0004036 | Standard deviation $s_{x0}$ | 0.0000003 |
| | Detection limit x | 1.33E-03 | Detection limit x | 1.01E-06 |

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x}_0)^2}$$

**Annex 2** **Flow rate accuracy** **Page 1 of 2**

Manufacturer: PALAS

Type: Fidas® 200 S

Serial-No.: SN 7146 / SN 7147

Nominal flow rate [l/min]: 4.8

Test period: 28.04.2016 ff

| | | SN 7146 | | SN 7147 | |
|---|---|---|---|---|---|
| Temperature 1 | -20°C | No. | Measured value [l/min] | No. | Measured value [l/min] |
| | | 1 | 4.82 | 1 | 4.86 |
| | | 2 | 4.81 | 2 | 4.86 |
| | | 3 | 4.81 | 3 | 4.86 |
| | | 4 | 4.82 | 4 | 4.86 |
| | | 5 | 4.83 | 5 | 4.86 |
| | | 6 | 4.83 | 6 | 4.86 |
| | | 7 | 4.83 | 7 | 4.86 |
| | | 8 | 4.83 | 8 | 4.87 |
| | | 9 | 4.82 | 9 | 4.86 |
| | | 10 | 4.82 | 10 | 4.86 |
| | | Mean | **4.82** | Mean | **4.86** |

| | | SN 7146 | | SN 7147 | |
|---|---|---|---|---|---|
| Temperature 2 | 50°C | No. | Measured value [l/min] | No. | Measured value [l/min] |
| | | 1 | 4.78 | 1 | 4.70 |
| | | 2 | 4.79 | 2 | 4.71 |
| | | 3 | 4.79 | 3 | 4.69 |
| | | 4 | 4.78 | 4 | 4.71 |
| | | 5 | 4.78 | 5 | 4.70 |
| | | 6 | 4.78 | 6 | 4.71 |
| | | 7 | 4.79 | 7 | 4.71 |
| | | 8 | 4.78 | 8 | 4.71 |
| | | 9 | 4.79 | 9 | 4.71 |
| | | 10 | 4.78 | 10 | 4.70 |
| | | Mean | **4.78** | Mean | **4.70** |

**Annex 2** **Flow rate accuracy** **Page 2 of 2**

Manufacturer PALAS

Nominal flow rate [l/min] 4.8

Type Fidas® 200

Serial-No. SN 7146 / SN 7147

Test period 28.04.2016 ff

| | | SN 7146 | | SN 7147 | |
|---|---|---|---|---|---|
| Temperature 1 | 5°C | No. | Measured value [l/min] | No. | Measured value [l/min] |
| | | 1 | 4.77 | 1 | 4.84 |
| | | 2 | 4.77 | 2 | 4.84 |
| | | 3 | 4.78 | 3 | 4.85 |
| | | 4 | 4.77 | 4 | 4.84 |
| | | 5 | 4.79 | 5 | 4.83 |
| | | 6 | 4.77 | 6 | 4.85 |
| | | 7 | 4.78 | 7 | 4.84 |
| | | 8 | 4.77 | 8 | 4.84 |
| | | 9 | 4.76 | 9 | 4.84 |
| | | 10 | 4.77 | 10 | 4.95 |
| | | Mean | **4.77** | Mean | **4.85** |

| | | SN 7146 | | SN 7147 | |
|---|---|---|---|---|---|
| Temperature 2 | 40°C | No. | Measured value [l/min] | No. | Measured value [l/min] |
| | | 1 | 4.79 | 1 | 4.78 |
| | | 2 | 4.80 | 2 | 4.78 |
| | | 3 | 4.80 | 3 | 4.78 |
| | | 4 | 4.79 | 4 | 4.77 |
| | | 5 | 4.79 | 5 | 4.78 |
| | | 6 | 4.79 | 6 | 4.78 |
| | | 7 | 4.80 | 7 | 4.77 |
| | | 8 | 4.78 | 8 | 4.78 |
| | | 9 | 4.79 | 9 | 4.77 |
| | | 10 | 4.79 | 10 | 4.77 |
| | | Mean | **4.79** | Mean | **4.78** |

**Annex 3** **Dependence of zero point on surrounding temperature ($PM_{10}$)** **Page 1 of 12**

Manufacturer PALAS

Type Fidas® 200S

Serial-No. SN 0111 / SN 0112

Test period 05.09.12 - 07.10.12

| | | | Measurement 1 | Measurement 2 | Measurement 3 | | |
|---|---|---|---|---|---|---|---|
| SN 0111 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Zero | 1 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000001 |
| | 2 | -20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 3 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 4 | 50 | 0.0000005 | 0.0000016 | 0.0000014 | 0.0000012 | |
| | 5 | 20 | 0.0000000 | 0.0000008 | 0.0000000 | 0.0000003 | |
| SN 0112 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Zero | 1 | 20 | 0.0000003 | 0.0000000 | 0.0000332 | 0.0000112 | 0.0000043 |
| | 2 | -20 | 0.0000000 | 0.0000017 | 0.0000000 | 0.0000006 | |
| | 3 | 20 | 0.0000000 | 0.0000001 | 0.0000040 | 0.0000014 | |
| | 4 | 50 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 5 | 20 | 0.0000006 | 0.0000000 | 0.0000000 | 0.0000002 | |

**Annex 3** **Dependence of zero point on surrounding temperature ($PM_{2.5}$)** **Page 2 of 12**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Manufacturer | PALAS | | | | | | |
| Type | Fidas® 200S | | | | | | |
| Serial-No. | SN 0111 / SN 0112 | | | | | | |
| Test period | 05.09.12 - 07.10.12 | | Measurement 1 | Measurement 2 | Measurement 3 | | |
| SN 0111 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Zero | 1 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000001 |
| | 2 | -20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 3 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 4 | 50 | 0.0000005 | 0.0000016 | 0.0000014 | 0.0000012 | |
| | 5 | 20 | 0.0000000 | 0.0000008 | 0.0000000 | 0.0000003 | |
| SN 0112 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Zero | 1 | 20 | 0.0000003 | 0.0000000 | 0.0000332 | 0.0000112 | 0.0000043 |
| | 2 | -20 | 0.0000000 | 0.0000017 | 0.0000000 | 0.0000006 | |
| | 3 | 20 | 0.0000000 | 0.0000001 | 0.0000040 | 0.0000014 | |
| | 4 | 50 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 5 | 20 | 0.0000006 | 0.0000000 | 0.0000000 | 0.0000002 | |

**Annex 3** **Dependence of zero point on surrounding temperature ($PM_{10}$)** **Page 3 of 12**

Manufacturer PALAS

Type Fidas® 200

Serial-No. SN 5048 / SN 5049

Test period 01.07.14 - 07.07.14

| SN 5048 | No. | Temperature [°C] | Measurement 1 Measured value [µg/m³] | Measurement 2 Measured value [µg/m³] | Measurement 3 Measured value [µg/m³] | Mean value [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Zero | 1 | 20 | 0.0000539 | 0.0000393 | 0.0000517 | 0.0000483 | 0.0000597 |
| | 2 | 5 | 0.0001291 | 0.0000801 | 0.0001070 | 0.0001054 | |
| | 3 | 20 | 0.0001098 | 0.0000698 | 0.0000901 | 0.0000899 | |
| | 4 | 40 | 0.0000607 | 0.0000249 | 0.0000298 | 0.0000385 | |
| | 5 | 20 | 0.0000467 | 0.0000373 | 0.0000386 | 0.0000408 | |

| SN 5049 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Zero | 1 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| | 2 | 5 | 0.0000000 | 0.0000000 | 0.0000024 | 0.0000008 | |
| | 3 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 4 | 40 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 5 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |

**Annex 3** **Dependence of zero point on surrounding temperature ($PM_{2.5}$)** 

Manufacturer PALAS

Type Fidas® 200

Serial-No. SN 5048 / SN 5049

Test period 01.07.14 - 07.07.14

| | | | Measurement 1 | Measurement 2 | Measurement 3 | | |
|---|---|---|---|---|---|---|---|
| SN 5048 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value [µg/m³] | Mean value at 20°C [µg/m³] |
| Zero | 1 | 20 | 0.0000552 | 0.0000387 | 0.0000510 | 0.0000483 | 0.0000597 |
| | 2 | 5 | 0.0001226 | 0.0000801 | 0.0001070 | 0.0001032 | |
| | 3 | 20 | 0.0001098 | 0.0000698 | 0.0000901 | 0.0000899 | |
| | 4 | 40 | 0.0000607 | 0.0000255 | 0.0000293 | 0.0000385 | |
| | 5 | 20 | 0.0000467 | 0.0000382 | 0.0000377 | 0.0000408 | |
| SN 5049 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Zero | 1 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| | 2 | 5 | 0.0000000 | 0.0000000 | 0.0000024 | 0.0000008 | |
| | 3 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 4 | 40 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |
| | 5 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |

**Annex 3** **Dependence of zero point on surrounding temperature ($PM_{10}$)** **Page 5 of 12**

Manufacturer PALAS

Type Fidas® 200 E

Serial-No. SN 6623 / SN 6624

Test period 15.09.15 - 19.09.15

| SN 6623 | No. | Temperature [°C] | Measurement 1<br>Measured value [µg/m³] | Measurement 2<br>Measured value [µg/m³] | Measurement 3<br>Measured value [µg/m³] | Mean value [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Zero | 1 | 20 | 0.0000000 | 0.0000004 | 0.0000015 | 0.0000006 | 0.0000009 |
| | 2 | 5 | 0.0000011 | 0.0000047 | 0.0000000 | 0.0000019 | |
| | 3 | 20 | 0.0000060 | 0.0000000 | 0.0000000 | 0.0000020 | |
| | 4 | 40 | 0.0000010 | 0.0000000 | 0.0000000 | 0.0000003 | |
| | 5 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |

| SN 6624 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Zero | 1 | 20 | 0.0000000 | 0.0000000 | 0.0000010 | 0.0000003 | 0.0000008 |
| | 2 | 5 | 0.0000040 | 0.0000051 | 0.0000000 | 0.0000030 | |
| | 3 | 20 | 0.0000061 | 0.0000000 | 0.0000000 | 0.0000020 | |
| | 4 | 40 | 0.0000024 | 0.0000000 | 0.0000000 | 0.0000008 | |
| | 5 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |

**Annex 3** **Dependence of zero point on surrounding temperature ($PM_{2.5}$)** **Page 6 of 12**

Manufacturer PALAS

Type Fidas® 200 E

Serial-No. SN 6623 / SN 6624

Test period 15.09.15 - 19.09.15

| SN 6623 | No. | Temperature [°C] | Measurement 1<br>Measured value [µg/m³] | Measurement 2<br>Measured value [µg/m³] | Measurement 3<br>Measured value [µg/m³] | Mean value [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Zero | 1 | 20 | 0.0000000 | 0.0000004 | 0.0000015 | 0.0000006 | 0.0000009 |
| | 2 | 5 | 0.0000011 | 0.0000047 | 0.0000000 | 0.0000019 | |
| | 3 | 20 | 0.0000060 | 0.0000000 | 0.0000000 | 0.0000020 | |
| | 4 | 40 | 0.0000010 | 0.0000000 | 0.0000000 | 0.0000003 | |
| | 5 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |

| SN 6624 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Zero | 1 | 20 | 0.0000000 | 0.0000000 | 0.0000010 | 0.0000003 | 0.0000008 |
| | 2 | 5 | 0.0000040 | 0.0000051 | 0.0000000 | 0.0000030 | |
| | 3 | 20 | 0.0000061 | 0.0000000 | 0.0000000 | 0.0000020 | |
| | 4 | 40 | 0.0000024 | 0.0000000 | 0.0000000 | 0.0000008 | |
| | 5 | 20 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | |

**Annex 3** **Dependence of span on surrounding temperature ($PM_{10}$)** 

Manufacturer PALAS

Used test standard CalDust 1100

Type Fidas® 200 S

Serial-No. SN 0111 / SN 0112

Test period 16.09.13 - 18.09.13

| | | | Measurement 1 | Measurement 2 | Meaurement 3 | | |
|---|---|---|---|---|---|---|---|
| SN 0111 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Span | 1 | 20 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 |
| | 2 | -20 | 38.2 | 38.2 | 38.2 | 38.2 | |
| | 3 | 20 | 39.9 | 39.9 | 40.0 | 39.9 | |
| | 4 | 50 | 39.4 | 39.4 | 39.7 | 39.5 | |
| | 5 | 20 | 40.0 | 40.1 | 40.0 | 40.0 | |
| SN 0112 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Span | 1 | 20 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 |
| | 2 | -20 | 41.8 | 41.8 | 41.8 | 41.8 | |
| | 3 | 20 | 40.0 | 40.0 | 40.1 | 40.0 | |
| | 4 | 50 | 39.9 | 40.1 | 40.1 | 40.0 | |
| | 5 | 20 | 40.0 | 40.1 | 40.1 | 40.1 | |

## Annex 3 Dependence of span on surrounding temperature ($PM_{2.5}$) Page 8 of 12

Manufacturer PALAS

Used test standard CalDust 1100

Type Fidas® 200 S

Serial-No. SN 0111 / SN 0112

Test period 16.09.13 - 18.09.13

| | | | Measurement 1 | Measurement 2 | Meaurement 3 | | |
|---|---|---|---|---|---|---|---|
| SN 0111 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Span | 1 | 20 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| | 2 | -20 | 23.9 | 23.9 | 23.9 | 23.9 | |
| | 3 | 20 | 24.9 | 24.9 | 25.0 | 25.0 | |
| | 4 | 50 | 24.6 | 24.6 | 24.8 | 24.7 | |
| | 5 | 20 | 25.0 | 25.1 | 25.0 | 25.0 | |
| SN 0112 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Span | 1 | 20 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| | 2 | -20 | 26.2 | 26.2 | 26.2 | 26.2 | |
| | 3 | 20 | 25.0 | 25.0 | 25.1 | 25.0 | |
| | 4 | 50 | 24.9 | 25.1 | 25.1 | 25.0 | |
| | 5 | 20 | 25.0 | 25.1 | 25.1 | 25.0 | |

## Annex 3 — Dependence of span on surrounding temperature ($PM_{10}$) — Page 9 of 12

Manufacturer: PALAS

Type: Fidas® 200

Serial-No.: SN 5048 / SN 5049

Test period: 07.07.2014 - 11.07.2014

Used test standard: CalDust 1100

| SN 5048 | No. | Temperature [°C] | Measurement 1 Measured value [µg/m³] | Measurement 2 Measured value [µg/m³] | Meaurement 3 Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Span | 1 | 20 | 40.0 | 40.0 | 40.0 | 40.0 | 39.9 |
| | 2 | 5 | 39.2 | 39.1 | 39.1 | 39.1 | |
| | 3 | 20 | 39.4 | 39.7 | 39.9 | 39.7 | |
| | 4 | 40 | 40.4 | 40.4 | 40.4 | 40.4 | |
| | 5 | 20 | 39.9 | 40.0 | 40.0 | 40.0 | |
| **SN 5049** | **No.** | **Temperature [°C]** | **Measured value [µg/m³]** | **Measured value [µg/m³]** | **Measured value [µg/m³]** | **Mean value of 3 measurements [µg/m³]** | **Mean value at 20°C [µg/m³]** |
| Span | 1 | 20 | 40.0 | 40.0 | 40.0 | 40.0 | 39.9 |
| | 2 | 5 | 39.2 | 39.2 | 39.3 | 39.2 | |
| | 3 | 20 | 39.8 | 39.8 | 39.9 | 39.8 | |
| | 4 | 40 | 40.2 | 40.3 | 40.3 | 40.3 | |
| | 5 | 20 | 39.7 | 40.0 | 39.8 | 39.8 | |

## Annex 3 Dependence of span on surrounding temperature ($PM_{2.5}$) Page 10 of 12

Manufacturer PALAS

Used test standard CalDust 1100

Type Fidas® 200

Serial-No. SN 5048 / SN 5049

Test period 07.07.14 - 11.07.14

| | | | Measurement 1 | Measurement 2 | Meaurement 3 | | |
|---|---|---|---|---|---|---|---|
| SN 5048 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Span | 1 | 20 | 25.0 | 25.0 | 25.0 | 25.0 | 24.9 |
| | 2 | 5 | 24.5 | 24.4 | 24.4 | 24.4 | |
| | 3 | 20 | 24.6 | 24.8 | 24.9 | 24.8 | |
| | 4 | 40 | 25.3 | 25.3 | 25.3 | 25.3 | |
| | 5 | 20 | 24.9 | 25.0 | 25.0 | 25.0 | |
| SN 5049 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
| Span | 1 | 20 | 25.0 | 25.0 | 25.0 | 25.0 | 24.9 |
| | 2 | 5 | 24.5 | 24.5 | 24.6 | 24.5 | |
| | 3 | 20 | 24.9 | 24.9 | 24.9 | 24.9 | |
| | 4 | 40 | 25.1 | 25.2 | 25.2 | 25.2 | |
| | 5 | 20 | 24.8 | 25.0 | 24.9 | 24.9 | |

**Annex 3** **Dependence of span on surrounding temperature ($PM_{10}$)** **Page 11 of 12**

Manufacturer PALAS

Used test standard MonoDust 1500

Type Fidas® 200 E

Serial-No. SN 6623 / SN 6624

Test period 28.09.15 - 30.09.15

| SN 6623 | No. | Temperature [°C] | Measurement 1<br>Measured value [µg/m³] | Measurement 2<br>Measured value [µg/m³] | Meaurement 3<br>Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Span | 1 | 20 | 40.7 | 40.7 | 40.7 | 40.7 | 40.4 |
| | 2 | 5 | 41.0 | 41.0 | 41.0 | 41.0 | |
| | 3 | 20 | 40.3 | 40.3 | 40.3 | 40.3 | |
| | 4 | 40 | 38.5 | 38.5 | 38.5 | 38.5 | |
| | 5 | 20 | 40.3 | 40.3 | 40.3 | 40.3 | |

| SN 6624 | No. | Temperature [°C] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Span | 1 | 20 | 40.5 | 40.5 | 40.5 | 40.5 | 40.2 |
| | 2 | 5 | 39.8 | 39.8 | 39.8 | 39.8 | |
| | 3 | 20 | 40.1 | 40.1 | 40.1 | 40.1 | |
| | 4 | 40 | 40.4 | 40.4 | 40.4 | 40.4 | |
| | 5 | 20 | 40.0 | 40.0 | 40.0 | 40.0 | |

## Annex 3 — Dependence of span on surrounding temperature ($PM_{2.5}$) — Page 12 of 12

Manufacturer: PALAS

Used test standard: MonoDust 1500

Type: Fidas® 200 E

Serial-No.: SN 6623 / SN 6624

Test period: 28.09.15 - 30.09.15

| SN 6623 | No. | Temperature [°C] | Measurement 1 Measured value [µg/m³] | Measurement 2 Measured value [µg/m³] | Meaurement 3 Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] | Mean value at 20°C [µg/m³] |
|---|---|---|---|---|---|---|---|
| Span | 1 | 20 | 25.5 | 25.5 | 25.5 | 25.5 | 25.3 |
| | 2 | 5 | 25.7 | 25.7 | 25.7 | 25.7 | |
| | 3 | 20 | 25.2 | 25.2 | 25.2 | 25.2 | |
| | 4 | 40 | 24.1 | 24.1 | 24.1 | 24.1 | |
| | 5 | 20 | 25.2 | 25.2 | 25.2 | 25.2 | |
| **SN 6624** | **No.** | **Temperature [°C]** | **Measured value [µg/m³]** | **Measured value [µg/m³]** | **Measured value [µg/m³]** | **Mean value of 3 measurements [µg/m³]** | **Mean value at 20°C [µg/m³]** |
| Span | 1 | 20 | 25.3 | 25.3 | 25.3 | 25.3 | 25.1 |
| | 2 | 5 | 24.9 | 24.9 | 24.9 | 24.9 | |
| | 3 | 20 | 25.1 | 25.1 | 25.1 | 25.1 | |
| | 4 | 40 | 25.3 | 25.3 | 25.3 | 25.3 | |
| | 5 | 20 | 25.0 | 25.0 | 25.0 | 25.0 | |

**Annex 4** **Dependence of span on supply voltage ($PM_{10}$)** **Page 1 of 2**

Manufacturer PALAS

Used test standard MonoDust 1500

Type Fidas® 200 S

Serial-No. SN 6486 / SN 7147

Test period 7/18/2017

| | | | Measurement 1 | Measurement 2 | Measurement 3 | |
|---|---|---|---|---|---|---|
| SN 6486 | No. | Mains voltage [V] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] |
| Span | 1 | 230 | 40.0 | 40.1 | 39.9 | 40.00 |
| | 2 | 195 | 39.9 | 39.9 | 39.9 | 39.90 |
| | 3 | 230 | 39.9 | 39.9 | 40.0 | 39.93 |
| | 4 | 253 | 39.9 | 39.9 | 39.9 | 39.90 |
| | 5 | 230 | 39.8 | 39.9 | 39.9 | 39.87 |
| SN 7147 | No. | Mains voltage [V] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] |
| Span | 1 | 230 | 40.0 | 39.9 | 39.9 | 39.93 |
| | 2 | 195 | 40.0 | 39.9 | 39.9 | 39.93 |
| | 3 | 230 | 39.9 | 40.0 | 40.0 | 39.97 |
| | 4 | 253 | 40.0 | 40.0 | 39.9 | 39.97 |
| | 5 | 230 | 40.0 | 40.0 | 40.0 | 40.00 |

## Annex 4 Dependence of span on supply voltage ($PM_{2.5}$) Page 2 of 2

Manufacturer PALAS

Used test standard MonoDust 1500

Type Fidas® 200 S

Serial-No. SN 6486 / SN 7147

Test period 7/18/2017

| SN 6486 | No. | Mains voltage [V] | Measurement 1<br>Measured value [µg/m³] | Measurement 2<br>Measured value [µg/m³] | Measurement 3<br>Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] |
|---|---|---|---|---|---|---|
| Span | 1 | 230 | 25.0 | 25.1 | 24.9 | 25.0 |
| | 2 | 195 | 24.9 | 24.9 | 24.9 | 24.9 |
| | 3 | 230 | 24.9 | 24.9 | 25.0 | 24.9 |
| | 4 | 253 | 24.9 | 24.9 | 24.9 | 24.9 |
| | 5 | 230 | 24.9 | 24.9 | 24.9 | 24.9 |

| SN 7147 | No. | Mains voltage [V] | Measured value [µg/m³] | Measured value [µg/m³] | Measured value [µg/m³] | Mean value of 3 measurements [µg/m³] |
|---|---|---|---|---|---|---|
| Span | 1 | 230 | 25.0 | 24.9 | 24.9 | 24.9 |
| | 2 | 195 | 25.0 | 24.9 | 24.9 | 24.9 |
| | 3 | 230 | 24.9 | 25.0 | 25.0 | 25.0 |
| | 4 | 253 | 25.0 | 25.0 | 24.9 | 25.0 |
| | 5 | 230 | 25.0 | 25.0 | 25.0 | 25.0 |

**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 PM2,5 [µg/m³] | SN 0112 PM2,5 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5/14/2012 | | | | | | 12.9 | 13.0 | 20.1 | 20.3 | | Cologne, summer |
| 2 | 5/15/2012 | 6.8 | 7.2 | 11.7 | 10.0 | 64.1 | 7.0 | 7.0 | 10.5 | 10.5 | | |
| 3 | 5/16/2012 | 6.4 | 8.2 | 13.8 | 13.1 | 54.4 | 7.0 | 7.0 | 12.0 | 11.9 | | |
| 4 | 5/17/2012 | 6.5 | 7.6 | 12.4 | 11.6 | 58.9 | 6.8 | 6.9 | 11.1 | 11.1 | | |
| 5 | 5/18/2012 | | | 14.4 | 11.7 | | 8.8 | 9.0 | 13.8 | 13.9 | Outlier Ref. PM2,5 | |
| 6 | 5/19/2012 | | | | | | 9.2 | 9.4 | 13.5 | 13.5 | | |
| 7 | 5/20/2012 | 12.0 | 12.8 | 19.1 | 16.8 | 69.0 | 13.3 | 13.4 | 19.1 | 19.2 | | |
| 8 | 5/21/2012 | 27.7 | 28.6 | | | | 32.1 | 32.2 | 43.8 | 43.6 | Outlier Ref. PM10 | |
| 9 | 5/22/2012 | | | | | | 58.8 | 58.2 | 74.5 | 73.3 | | |
| 10 | 5/23/2012 | | | 45.2 | 43.3 | | 32.2 | 32.0 | 42.6 | 42.0 | Outlier Ref. PM2,5 | |
| 11 | 5/24/2012 | 10.7 | 9.1 | 19.7 | 17.0 | 54.1 | 11.1 | 11.2 | 22.1 | 22.4 | | |
| 12 | 5/25/2012 | 6.8 | 6.6 | 16.6 | 14.8 | 42.6 | 6.1 | 6.2 | 17.3 | 17.2 | | |
| 13 | 5/26/2012 | | | | | | 8.8 | 9.0 | 18.7 | 19.0 | | |
| 14 | 5/27/2012 | | | | | | 9.2 | 9.4 | 14.6 | 14.9 | | |
| 15 | 5/28/2012 | 12.2 | 12.3 | 20.6 | 19.8 | 60.5 | 15.1 | 15.2 | 22.8 | 23.0 | | |
| 16 | 5/29/2012 | 11.3 | 11.9 | 26.8 | 25.2 | 44.5 | | 15.5 | | 26.8 | SN 0111 accidentally switched off via remote control | |
| 17 | 5/30/2012 | 17.6 | 17.8 | 34.8 | 32.4 | 52.8 | 22.3 | 22.6 | 32.2 | 33.0 | | |
| 18 | 5/31/2012 | 11.6 | 12.0 | 22.6 | 21.2 | 53.8 | 15.8 | 15.7 | 23.1 | 22.8 | | |
| 19 | 6/1/2012 | 9.5 | 9.3 | 16.6 | 15.2 | 59.1 | 12.1 | 12.1 | 15.9 | 16.0 | | |
| 20 | 6/2/2012 | | | | | | 10.6 | 10.6 | 13.9 | 14.1 | | |
| 21 | 6/3/2012 | 10.7 | 10.6 | 16.7 | 16.0 | 65.0 | 14.6 | 14.5 | 16.9 | 16.9 | | |
| 22 | 6/4/2012 | 4.1 | 4.8 | 11.5 | 11.2 | 39.4 | 6.7 | 6.7 | 11.2 | 11.4 | | |
| 23 | 6/5/2012 | 5.7 | 4.8 | 14.2 | 13.2 | 38.2 | 7.1 | 7.2 | 11.4 | 11.6 | | |
| 24 | 6/6/2012 | | | | | | 6.7 | 6.8 | 10.1 | 10.1 | | |
| 25 | 6/7/2012 | 4.9 | 4.0 | 8.5 | 7.0 | 57.7 | 5.3 | 5.4 | 9.1 | 9.2 | | |
| 26 | 6/8/2012 | | | | | | 3.9 | 3.9 | 8.3 | 8.3 | | |
| 27 | 6/9/2012 | | | | | | 4.6 | 4.7 | 8.8 | 8.8 | | |
| 28 | 6/10/2012 | | | | | | | | | | Power failure | |
| 29 | 6/11/2012 | 4.2 | 8.1 | 9.4 | 8.2 | 70.2 | 5.7 | 5.7 | 10.0 | 9.8 | | |
| 30 | 6/12/2012 | 13.2 | 12.3 | 19.5 | 19.7 | 65.1 | 14.1 | 14.0 | 18.0 | 17.7 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 2 of 15**

| Manufacturer | PALAS | |
|---|---|---|
| Type of instrument | FIDAS 200 S | PM10 and PM2.5<br>Measured values in µg/m³ (ACT) |
| Serial-No. | SN 0111 / SN 0112 | |

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 6/13/2012 | 9.7 | 10.0 | 21.2 | 20.7 | 47.0 | 12.4 | 12.3 | 17.7 | 17.8 | | Cologne, summer |
| 32 | 6/14/2012 | 11.7 | 13.0 | 22.9 | 21.4 | 55.9 | 14.8 | 14.9 | 19.8 | 19.8 | | |
| 33 | 6/15/2012 | | | | | | | | | | Inlet -> Zero filter | |
| 34 | 6/16/2012 | | | | | | | | | | Zero filter | |
| 35 | 6/17/2012 | | | | | | | | | | Zero filter | |
| 36 | 6/18/2012 | 11.2 | 10.9 | 17.1 | 15.8 | 67.3 | 10.8 | 10.8 | 15.4 | 15.5 | | |
| 37 | 6/19/2012 | 19.5 | 19.1 | 29.2 | 28.7 | 66.7 | 23.1 | 22.8 | 27.0 | 26.6 | | |
| 38 | 6/20/2012 | 13.5 | 13.0 | 18.8 | 18.3 | 71.5 | 15.5 | 15.3 | 18.9 | 18.5 | | |
| 39 | 6/21/2012 | 3.6 | 3.8 | 9.6 | 8.7 | 40.4 | 5.0 | 5.1 | 10.2 | 10.0 | | |
| 40 | 6/22/2012 | 5.3 | 7.1 | 13.4 | 13.4 | 46.2 | 6.5 | 6.5 | 11.6 | 11.6 | | |
| 41 | 6/23/2012 | | | | | | 6.9 | 7.0 | 10.5 | 10.6 | | |
| 42 | 6/24/2012 | 6.0 | 5.0 | 8.9 | 10.8 | 55.7 | 5.4 | 5.4 | 9.0 | 8.9 | | |
| 43 | 6/25/2012 | 10.0 | 11.3 | 15.2 | 16.5 | 67.1 | 9.6 | 9.5 | 14.7 | 14.4 | | |
| 44 | 6/26/2012 | 13.4 | 13.7 | | 19.8 | | 12.0 | 12.2 | 16.4 | 16.5 | | |
| 45 | 6/27/2012 | 11.8 | 11.8 | 17.6 | 18.7 | 64.9 | 12.4 | 12.1 | 18.2 | 17.7 | | |
| 46 | 6/28/2012 | 8.0 | 10.3 | 17.7 | 17.1 | 52.7 | 9.3 | 9.3 | 20.7 | 20.2 | | |
| 47 | 6/29/2012 | 10.4 | 10.8 | 22.9 | 23.5 | 45.8 | 12.6 | 12.7 | 26.6 | 25.8 | | |
| 48 | 6/30/2012 | | | | | | 8.3 | 8.3 | 17.8 | 17.3 | | |
| 49 | 7/1/2012 | 6.3 | 7.3 | 12.4 | 12.1 | 55.8 | 5.8 | 5.8 | 10.9 | 10.7 | | |
| 50 | 7/2/2012 | 6.7 | 8.5 | 11.5 | 12.3 | 64.2 | 6.9 | 6.9 | 10.8 | 10.6 | | |
| 51 | 7/3/2012 | 8.7 | 9.5 | 17.1 | 15.1 | 56.6 | 7.8 | 7.9 | 13.3 | 13.7 | | |
| 52 | 7/4/2012 | 9.9 | 10.6 | 15.8 | 16.8 | 62.9 | 10.4 | 10.4 | 16.0 | 15.7 | | |
| 53 | 7/5/2012 | 8.8 | 8.6 | 13.2 | 13.8 | 64.3 | 9.5 | 9.4 | 14.6 | 14.2 | | |
| 54 | 7/6/2012 | 7.0 | 5.8 | 10.8 | 10.4 | 60.0 | 5.3 | 5.3 | 9.8 | 9.8 | | |
| 55 | 7/7/2012 | | | | | | 4.6 | 4.6 | 8.0 | 7.9 | | |
| 56 | 7/8/2012 | 3.4 | 4.1 | 6.4 | 6.7 | 57.6 | 3.1 | 3.2 | 6.3 | 6.3 | | |
| 57 | 7/9/2012 | 7.2 | 7.7 | 12.4 | 12.1 | 60.4 | 8.0 | 8.0 | 12.2 | 12.1 | | |
| 58 | 7/10/2012 | 7.1 | 7.1 | 12.8 | 11.5 | 58.4 | 8.0 | 8.0 | 12.4 | 12.4 | | |
| 59 | 7/11/2012 | 3.7 | 2.9 | 7.0 | 8.1 | 43.9 | 3.3 | 3.4 | 6.7 | 6.6 | | |
| 60 | 7/12/2012 | 3.6 | 3.6 | 8.2 | 7.0 | 46.7 | 3.3 | 3.3 | 7.2 | 7.2 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 3 of 15**

| | | | |
|---|---|---|---|
| Manufacturer | PALAS | | |
| Type of instrument | FIDAS 200 S | | PM10 and PM2.5<br>Measured values in µg/m³ (ACT) |
| Serial-No. | SN 0111 / SN 0112 | | |

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 7/13/2012 | 3.2 | 3.1 | 6.6 | 6.5 | 47.9 | 3.2 | 3.2 | 6.4 | 6.4 | | Cologne, summer |
| 62 | 7/14/2012 | | | | | | 3.8 | 3.9 | 6.6 | 6.5 | | |
| 63 | 7/15/2012 | 6.0 | 7.1 | 12.0 | 11.3 | 56.6 | 6.3 | 6.5 | 10.2 | 10.2 | | |
| 64 | 7/16/2012 | 3.7 | 4.3 | 9.1 | 7.3 | 48.6 | 3.7 | 3.8 | 7.2 | 7.1 | | |
| 65 | 7/17/2012 | 5.4 | 5.7 | 12.6 | 13.1 | 43.0 | 7.7 | 7.7 | 12.2 | 12.0 | | |
| 66 | 7/18/2012 | 5.1 | 5.6 | 10.6 | 9.3 | 53.6 | 5.2 | 5.2 | 10.2 | 10.3 | | |
| 67 | 7/19/2012 | 5.4 | 5.6 | 14.5 | 13.8 | 39.2 | 6.5 | 6.5 | 12.6 | 12.3 | | |
| 68 | 7/20/2012 | | | | | | | | | | Zero filter | |
| 69 | 7/21/2012 | | | | | | | | | | Zero filter | |
| 70 | 7/22/2012 | | | | | | | | | | Zero filter | |
| 71 | 7/23/2012 | 8.1 | 6.3 | 13.0 | 12.6 | 56.5 | 6.4 | 6.5 | 11.0 | 11.3 | | |
| 72 | 7/24/2012 | 17.1 | 16.6 | 24.5 | 22.7 | 71.5 | 12.9 | 12.9 | 20.3 | 20.5 | | |
| 73 | 7/25/2012 | 27.6 | 28.0 | 39.0 | 37.6 | 72.6 | 26.4 | 26.3 | 37.8 | 37.0 | | |
| 74 | 7/26/2012 | 26.0 | 26.1 | 35.7 | 35.1 | 73.7 | 28.5 | 28.2 | 38.6 | 37.9 | | |
| 75 | 7/27/2012 | 22.3 | 22.7 | 31.6 | 31.4 | 71.4 | 23.0 | 22.5 | 32.5 | 31.6 | | |
| 76 | 7/28/2012 | | | | | | 18.6 | 18.2 | 24.3 | 23.8 | | |
| 77 | 7/29/2012 | 4.9 | 4.7 | 9.9 | 8.7 | 51.7 | 4.2 | 4.2 | 7.7 | 7.8 | | |
| 78 | 7/30/2012 | 5.8 | 6.1 | 12.3 | 12.8 | 47.4 | 5.0 | 5.0 | 9.1 | 9.0 | | |
| 79 | 7/31/2012 | 8.0 | 7.9 | 14.4 | 14.6 | 55.0 | 6.4 | 6.5 | 11.1 | 11.3 | | |
| 80 | 8/1/2012 | 10.2 | 10.4 | 16.5 | 17.1 | 61.3 | 8.2 | 8.1 | 15.4 | 15.0 | | |
| 81 | 8/2/2012 | 6.4 | 6.7 | 13.2 | 13.4 | 49.2 | 5.3 | 5.3 | 11.3 | 11.4 | | |
| 82 | 8/3/2012 | 6.7 | 7.0 | 14.4 | 15.5 | 45.9 | 6.6 | 6.6 | 12.2 | 12.3 | | |
| 83 | 8/4/2012 | | | | | | 7.6 | 7.6 | 10.9 | 10.8 | | |
| 84 | 8/5/2012 | 4.2 | 5.4 | 8.4 | 8.9 | 54.9 | 4.9 | 4.9 | 8.0 | 7.8 | | |
| 85 | 8/6/2012 | 4.0 | 4.0 | 8.1 | 9.6 | 44.9 | 3.6 | 3.6 | 7.4 | 7.1 | | |
| 86 | 8/7/2012 | 6.8 | 5.5 | 13.5 | 12.8 | 46.8 | 5.3 | 5.3 | 10.3 | 10.2 | | |
| 87 | 8/8/2012 | 10.4 | 9.0 | 16.2 | 16.6 | 59.2 | 8.7 | 8.6 | 12.8 | 12.7 | | |
| 88 | 8/9/2012 | 7.7 | 7.6 | 12.3 | 12.7 | 61.1 | 8.1 | 8.0 | 11.7 | 11.6 | | |
| 89 | 8/10/2012 | 8.6 | 8.7 | 13.3 | 14.3 | 62.7 | 6.9 | 6.9 | 10.6 | 10.6 | | |
| 90 | 8/11/2012 | | | | | | 6.0 | 5.9 | 8.9 | 8.7 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 4 of 15**

Manufacturer PALAS
Type of instrument FIDAS 200 S
Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91 | 8/12/2012 | 6.2 | 5.6 | 10.0 | 10.0 | 59.1 | 5.4 | 5.4 | 9.7 | 9.7 | | Cologne, summer |
| 92 | 8/13/2012 | 9.7 | 9.2 | 15.4 | 16.8 | 58.6 | 8.2 | 8.2 | 15.0 | 14.8 | | |
| 93 | 8/14/2012 | 10.3 | 10.1 | 17.2 | 16.6 | 60.4 | 8.9 | 8.8 | 14.6 | 14.3 | | |
| 94 | 8/15/2012 | 10.1 | 10.4 | 19.5 | 20.0 | 51.7 | 9.8 | 9.7 | 20.2 | 19.4 | | |
| 95 | 8/16/2012 | 7.6 | 7.9 | 18.0 | 19.5 | 41.5 | 6.7 | 6.6 | 12.8 | 12.4 | | |
| 96 | 8/17/2012 | | | | | | | | | | Zero filter | |
| 97 | 8/18/2012 | | | | | | | | | | Zero filter | |
| 98 | 8/19/2012 | | | | | | | | | | Zero filter | |
| 99 | 8/20/2012 | 17.1 | 17.9 | 28.6 | 29.0 | 60.8 | 15.8 | 15.3 | 26.9 | 25.6 | | |
| 100 | 8/21/2012 | 18.3 | 19.8 | 29.3 | 29.3 | 65.1 | 19.3 | 18.7 | 29.6 | 28.3 | | |
| 101 | 8/22/2012 | 8.7 | 9.9 | 20.7 | 19.9 | 45.7 | 8.9 | 8.9 | 17.5 | 17.1 | | |
| 102 | 8/23/2012 | 7.6 | 8.3 | 14.5 | 13.8 | 56.1 | 5.9 | 5.8 | 11.7 | 11.3 | | |
| 103 | 8/24/2012 | 9.0 | 10.3 | 15.2 | 15.0 | 64.0 | 8.8 | 8.6 | 13.8 | 13.1 | | |
| 104 | 8/25/2012 | | | | | | 3.2 | 3.1 | 6.3 | 6.0 | | |
| 105 | 8/26/2012 | 6.6 | 7.3 | 12.0 | 11.1 | 60.0 | 7.6 | 7.4 | 10.3 | 10.1 | | |
| 106 | 8/27/2012 | 5.4 | 6.5 | 10.7 | 10.7 | 55.2 | 5.0 | 4.9 | 8.7 | 8.5 | | |
| 107 | 8/28/2012 | 8.2 | 7.9 | 14.7 | 16.9 | 50.9 | 6.5 | 6.4 | 12.9 | 12.3 | | |
| 108 | 8/29/2012 | 8.4 | 8.9 | 16.5 | 16.5 | 52.5 | 6.9 | 6.8 | 13.7 | 13.6 | | |
| 109 | 8/30/2012 | 5.6 | 6.1 | 14.2 | 14.4 | 40.8 | 6.6 | 6.5 | 12.3 | 12.0 | | |
| 110 | 8/31/2012 | 4.4 | 5.0 | 10.7 | 10.9 | 43.4 | 5.7 | 5.6 | 9.9 | 9.8 | | |
| 111 | 9/1/2012 | | | | | | 8.7 | 8.4 | 12.6 | 12.0 | | |
| 112 | 9/2/2012 | 10.3 | 11.9 | 18.7 | 17.9 | 60.7 | 9.3 | 9.1 | 13.6 | 13.0 | | |
| 113 | 11/19/2012 | | | | | | | | | | Zero filter | Cologne, winter |
| 114 | 11/20/2012 | | | | | | | | | | Zero filter | |
| 115 | 11/21/2012 | | | | | | | | | | | |
| 116 | 11/22/2012 | | | | | | 11.4 | 11.3 | 14.2 | 13.8 | | |
| 117 | 11/23/2012 | 15.3 | 15.1 | 19.6 | 19.6 | 77.8 | 16.8 | 16.3 | 20.4 | 19.7 | | |
| 118 | 11/24/2012 | | | | | | 15.0 | 14.8 | 19.2 | 19.0 | | |
| 119 | 11/25/2012 | 5.1 | 5.8 | 10.8 | 10.4 | 51.1 | 6.0 | 6.0 | 10.1 | 9.9 | | |
| 120 | 11/26/2012 | 6.1 | 6.9 | 11.0 | 11.6 | 57.4 | 7.2 | 7.2 | 11.0 | 10.8 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 5 of 15**

| | |
|---|---|
| Manufacturer | PALAS |
| Type of instrument | FIDAS 200 S |
| Serial-No. | SN 0111 / SN 0112 |

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 121 | 11/27/2012 | 10.9 | 11.5 | 18.5 | 17.6 | 62.0 | 11.2 | 11.2 | 15.8 | 15.8 | | Cologne, winter |
| 122 | 11/28/2012 | 23.3 | 23.5 | 29.0 | 29.1 | 80.5 | 26.0 | 25.7 | 30.5 | 30.0 | | |
| 123 | 11/29/2012 | 9.0 | 9.3 | 14.2 | 14.4 | 64.0 | 10.3 | 10.2 | 14.7 | 14.6 | | |
| 124 | 11/30/2012 | 17.8 | 19.3 | 24.5 | 24.3 | 76.0 | 19.5 | 19.0 | 23.4 | 22.7 | | |
| 125 | 12/1/2012 | | | | | | 14.4 | 14.0 | 15.9 | 15.5 | | |
| 126 | 12/2/2012 | 10.0 | 11.0 | 14.8 | 14.6 | 71.2 | 11.8 | 11.6 | 14.6 | 14.3 | | |
| 127 | 12/3/2012 | 8.8 | 9.0 | 14.1 | 14.4 | 62.2 | 10.6 | 10.3 | 13.5 | 13.0 | | |
| 128 | 12/4/2012 | 8.3 | 7.6 | 11.6 | 11.6 | 68.3 | 9.1 | | 11.8 | | SN 0112 Fuse for heater burned | |
| 129 | 12/5/2012 | 8.7 | 8.5 | 12.1 | 12.5 | 69.8 | | 9.6 | | 12.1 | SN 0111 Fuse for heater burned | |
| 130 | 12/6/2012 | 9.5 | 10.3 | 16.5 | 16.1 | 60.7 | 12.5 | 12.2 | 16.7 | 16.0 | | |
| 131 | 12/7/2012 | 13.0 | 12.8 | 15.4 | 15.4 | 83.8 | 13.2 | 12.7 | 15.5 | 14.7 | | |
| 132 | 12/8/2012 | | | | | | 29.0 | | 31.5 | | SN 0112 Fuse for heater burned | |
| 133 | 12/9/2012 | 5.5 | 5.8 | 10.1 | 8.9 | 59.5 | 7.2 | | 9.8 | | SN 0112 Fuse for heater burned | |
| 134 | 12/10/2012 | 10.6 | 11.2 | 14.5 | 13.5 | 77.5 | 13.3 | 12.6 | 15.9 | 14.8 | | |
| 135 | 12/11/2012 | 17.3 | 17.7 | 23.6 | 22.8 | 75.4 | 19.2 | 18.3 | 23.7 | 22.6 | | |
| 136 | 12/12/2012 | 18.2 | 18.5 | 24.7 | 24.2 | 75.1 | 18.2 | 17.4 | 22.9 | 22.0 | | |
| 137 | 12/13/2012 | 23.4 | 23.7 | 29.3 | 28.2 | 82.0 | 24.3 | 23.0 | 27.8 | 26.4 | | |
| 138 | 12/14/2012 | 7.3 | 6.7 | 8.9 | 8.8 | 79.5 | 7.7 | 7.3 | 9.2 | 8.9 | | |
| 139 | 12/15/2012 | | | | | | 4.5 | 4.3 | 6.5 | 6.1 | | |
| 140 | 12/16/2012 | 5.4 | 5.9 | 9.7 | 9.5 | 58.9 | 6.9 | 6.6 | 9.2 | 8.7 | | |
| 141 | 12/17/2012 | 6.8 | 7.2 | 13.7 | 13.4 | 51.9 | 9.1 | 8.8 | 13.4 | 12.7 | | |
| 142 | 12/18/2012 | 12.9 | 13.3 | 20.1 | 20.5 | 64.5 | 15.0 | 14.3 | 19.0 | 18.1 | | |
| 143 | 12/19/2012 | 13.4 | 13.3 | 18.3 | 18.0 | 73.7 | 15.4 | 14.6 | 18.1 | 17.3 | | |
| 144 | 12/20/2012 | 11.6 | 11.6 | 14.1 | 13.6 | 83.8 | 12.3 | 11.7 | 13.8 | 13.2 | | |
| 145 | 12/21/2012 | 11.7 | 10.8 | 18.1 | 17.8 | 62.7 | 13.7 | 12.9 | 17.2 | 16.2 | | |
| 146 | 12/22/2012 | | | | | | 4.4 | 4.2 | 6.4 | 6.0 | | |
| 147 | 12/23/2012 | | | | | | 4.0 | 3.9 | 6.3 | 6.0 | | |
| 148 | 12/24/2012 | | | | | | 7.8 | 7.8 | 14.6 | 14.2 | | |
| 149 | 12/25/2012 | | | | | | 2.5 | 2.4 | 3.9 | 3.8 | | |
| 150 | 12/26/2012 | | | | | | 5.5 | 5.4 | 9.3 | 8.9 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 6 of 15**

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 151 | 12/27/2012 | | | | | | 12.3 | 12.1 | 16.3 | 16.1 | | Cologne, winter |
| 152 | 12/28/2012 | | | | | | 5.1 | 5.0 | 7.0 | 6.7 | | |
| 153 | 12/29/2012 | | | | | | 4.1 | 4.0 | 5.9 | 5.7 | | |
| 154 | 12/30/2012 | | | | | | 5.7 | 5.5 | 8.7 | 8.4 | | |
| 155 | 12/31/2012 | | | | | | | | | | Power failure | |
| 156 | 1/1/2013 | | | | | | | | | | Power failure | |
| 157 | 1/2/2013 | 9.7 | 9.3 | 16.1 | 15.0 | 60.9 | 12.2 | 11.7 | 15.7 | 14.9 | | |
| 158 | 1/3/2013 | 11.9 | 13.1 | 19.4 | 18.6 | 65.6 | 15.7 | 15.3 | 21.4 | 20.5 | | |
| 159 | 1/4/2013 | 9.5 | 9.9 | 13.8 | 13.0 | 72.5 | 11.6 | 11.3 | 14.3 | 13.9 | | |
| 160 | 1/5/2013 | | | | | | 18.7 | 18.5 | 21.2 | 20.8 | | |
| 161 | 1/6/2013 | 26.7 | 26.6 | 37.5 | 37.4 | 71.3 | 31.6 | 30.9 | 35.4 | 34.5 | | |
| 162 | 1/7/2013 | 17.6 | 19.4 | 24.6 | 25.0 | 74.5 | 20.2 | 19.8 | 23.8 | 23.3 | | |
| 163 | 1/8/2013 | 13.6 | 14.7 | 19.6 | 20.1 | 71.4 | 17.1 | 16.8 | 20.7 | 20.3 | | |
| 164 | 1/9/2013 | 11.6 | 13.3 | 18.9 | 19.7 | 64.5 | 15.3 | 15.0 | 19.6 | 18.9 | | |
| 165 | 1/10/2013 | 13.6 | 14.7 | 21.9 | 21.5 | 65.1 | 15.8 | 15.5 | 19.5 | 19.2 | | |
| 166 | 1/11/2013 | | | | | | | | | | Zero filter | |
| 167 | 1/12/2013 | | | | | | | | | | Zero filter | |
| 168 | 1/13/2013 | | | | | | | | | | Zero filter | |
| 169 | 1/14/2013 | 24.9 | 24.8 | 28.4 | 29.4 | 86.0 | 24.6 | 23.9 | 27.5 | 26.6 | | |
| 170 | 1/15/2013 | 33.4 | 33.8 | 36.3 | 37.1 | 91.5 | 31.6 | 30.1 | 34.1 | 32.5 | | |
| 171 | 1/16/2013 | 58.5 | 58.4 | 63.7 | 63.3 | 92.0 | 61.4 | 59.4 | 66.9 | 64.4 | | |
| 172 | 1/17/2013 | 55.4 | 56.2 | 60.2 | 59.8 | 93.0 | 57.1 | 55.4 | 61.0 | 59.1 | | |
| 173 | 1/18/2013 | 17.4 | 17.5 | 19.0 | 18.6 | 92.7 | 18.2 | 17.6 | 20.1 | 19.6 | | |
| 174 | 1/19/2013 | 21.1 | 21.1 | 22.6 | 23.0 | 92.4 | 23.2 | 22.6 | 24.5 | 23.8 | | |
| 175 | 1/20/2013 | 29.7 | 30.0 | 30.9 | 31.2 | 96.2 | 32.7 | 31.6 | 35.0 | 33.6 | | |
| 176 | 1/21/2013 | 44.9 | 42.8 | 45.4 | 44.8 | 97.2 | 46.7 | 45.0 | 49.7 | 47.8 | | |
| 177 | 1/22/2013 | 53.5 | 54.9 | 61.5 | 58.2 | 90.5 | 60.5 | 58.2 | 63.6 | 61.1 | Outlier Ref. PM10 - not discarded | |
| 178 | 1/23/2013 | 62.1 | 63.2 | 69.2 | 68.8 | 90.8 | 69.0 | 66.4 | 74.0 | 71.3 | | |
| 179 | 1/24/2013 | 23.6 | 24.5 | 27.8 | 28.1 | 86.1 | 24.5 | 23.5 | 27.3 | 26.1 | | |
| 180 | 1/25/2013 | 19.6 | 19.3 | 21.2 | 20.4 | 93.3 | 18.9 | 18.1 | 20.5 | 19.5 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 7 of 15**

| | | |
|---|---|---|
| Manufacturer | PALAS | |
| Type of instrument | FIDAS 200 S | PM10 and PM2.5<br>Measured values in µg/m³ (ACT) |
| Serial-No. | SN 0111 / SN 0112 | |

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 181 | 1/26/2013 | 26.6 | 25.9 | 28.3 | 28.4 | 92.5 | 26.3 | 25.1 | 27.8 | 26.5 | | Cologne, winter |
| 182 | 1/27/2013 | 9.1 | 9.2 | 15.0 | 15.0 | 61.1 | 10.6 | 10.2 | 14.8 | 14.2 | | |
| 183 | 1/28/2013 | 5.7 | 5.9 | 8.9 | 7.9 | 68.6 | 6.2 | 5.9 | 8.4 | 8.0 | | |
| 184 | 1/29/2013 | 3.4 | 3.9 | 5.5 | 4.5 | 72.0 | 4.1 | 3.7 | 5.5 | 5.1 | | |
| 185 | 1/30/2013 | 6.4 | 6.8 | 15.2 | 14.8 | 43.8 | 7.4 | 7.2 | 13.5 | 12.7 | | |
| 186 | 1/31/2013 | 8.0 | 8.5 | 20.3 | 19.2 | 41.6 | 10.1 | 9.8 | 17.2 | 16.4 | | |
| 187 | 2/1/2013 | 9.2 | 9.4 | 11.9 | 10.9 | 81.4 | 9.3 | 8.8 | 10.9 | 10.4 | | |
| 188 | 2/2/2013 | | | | | | 6.9 | 6.7 | 11.9 | 11.3 | | |
| 189 | 2/3/2013 | | | | | | 8.7 | 8.2 | 10.6 | 10.0 | | |
| 190 | 2/4/2013 | | | | | | 9.4 | 9.0 | 14.5 | 13.7 | | |
| 191 | 2/5/2013 | | | | | | | | | | Zero filter | |
| 192 | 2/6/2013 | | | | | | | | | | Zero filter | |
| 193 | 2/27/2013 | | | | | | | | | | Zero filter | Bonn, winter |
| 194 | 2/28/2013 | | | | | | | | | | Zero filter | |
| 195 | 3/1/2013 | 24.9 | 23.0 | 36.3 | 36.7 | 65.6 | 29.4 | 29.4 | 38.5 | 38.1 | | |
| 196 | 3/2/2013 | | | | | | 34.3 | 34.1 | 43.3 | 42.7 | | |
| 197 | 3/3/2013 | 22.1 | 23.2 | 29.3 | 29.8 | 76.6 | 24.7 | 24.5 | 28.6 | 28.4 | | |
| 198 | 3/4/2013 | 19.6 | 20.5 | 28.2 | 28.7 | 70.2 | 21.6 | 21.6 | 29.6 | 29.5 | | |
| 199 | 3/5/2013 | 28.4 | 27.7 | 40.2 | 39.9 | 70.1 | 31.0 | 30.9 | 41.6 | 41.1 | | |
| 200 | 3/6/2013 | 25.8 | 24.5 | 39.3 | 39.7 | 63.8 | 26.5 | 26.2 | 39.6 | 38.9 | | |
| 201 | 3/7/2013 | 28.0 | 28.3 | 39.5 | 39.5 | 71.2 | 30.9 | 30.1 | 40.9 | 40.0 | | |
| 202 | 3/8/2013 | 28.8 | 27.0 | 35.4 | 34.8 | 79.5 | 32.4 | 31.4 | 39.4 | 38.5 | | |
| 203 | 3/9/2013 | | | | | | 12.1 | 11.8 | 15.6 | 15.1 | | |
| 204 | 3/10/2013 | 21.8 | 22.0 | 23.1 | 22.3 | 96.5 | 25.6 | 25.0 | 26.7 | 26.0 | | |
| 205 | 3/11/2013 | 27.6 | 28.1 | 31.2 | 30.3 | 90.6 | 31.5 | 30.7 | 34.1 | 33.4 | | |
| 206 | 3/12/2013 | 15.6 | 15.6 | 17.8 | 17.7 | 87.9 | 16.1 | 15.3 | 19.4 | 18.5 | | |
| 207 | 3/13/2013 | 36.7 | 36.7 | 50.8 | 50.0 | 72.9 | 33.4 | 32.5 | 45.9 | 44.5 | | |
| 208 | 3/14/2013 | 19.6 | 19.2 | 27.5 | 27.6 | 70.3 | 19.2 | 18.7 | 29.6 | 28.8 | | |
| 209 | 3/15/2013 | 22.0 | 21.5 | 31.7 | 31.7 | 68.7 | 21.8 | 21.4 | 32.2 | 31.5 | | |
| 210 | 3/16/2013 | | | | | | 14.4 | 14.2 | 25.2 | 25.1 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** 

Manufacturer PALAS

Type of instrument FIDAS 200 S

Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 211 | 3/17/2013 | 7.0 | 7.4 | 11.0 | 10.5 | 67.2 | 9.4 | 9.1 | 12.9 | 12.8 | | Bonn, winter |
| 212 | 3/18/2013 | 7.7 | 8.2 | 17.4 | 17.2 | 45.9 | 9.0 | 8.7 | 17.4 | 16.7 | | |
| 213 | 3/19/2013 | 9.5 | 9.9 | 17.1 | 16.8 | 57.5 | 11.0 | 10.5 | 17.2 | 16.1 | | |
| 214 | 3/20/2013 | 21.3 | 20.9 | 25.2 | 24.5 | 84.7 | 23.4 | 22.1 | 25.7 | 24.3 | | |
| 215 | 3/21/2013 | 37.5 | 36.6 | 46.3 | 45.9 | 80.5 | 39.0 | 37.4 | 45.9 | 44.0 | | |
| 216 | 3/22/2013 | 21.4 | 21.6 | 26.0 | 26.3 | 82.2 | 25.5 | 24.5 | 30.4 | 29.0 | | |
| 217 | 3/23/2013 | | | | | | 25.3 | 24.4 | 28.3 | 27.5 | | |
| 218 | 3/24/2013 | 15.1 | 15.9 | 19.7 | 18.8 | 80.6 | 17.5 | 16.8 | 20.8 | 20.0 | | |
| 219 | 3/25/2013 | 20.1 | 20.6 | 26.0 | 25.6 | 78.9 | 23.2 | 22.3 | 29.2 | 28.1 | | |
| 220 | 3/26/2013 | 15.7 | 15.3 | 21.1 | 20.4 | 74.7 | 16.9 | 16.2 | 22.9 | 22.1 | | |
| 221 | 3/27/2013 | 26.6 | 25.9 | 33.3 | 32.8 | 79.5 | 27.5 | 26.3 | 34.6 | 32.9 | | |
| 222 | 3/28/2013 | | | | | | 51.4 | 48.7 | 59.1 | 55.8 | | |
| 223 | 3/29/2013 | 71.1 | 69.8 | 76.5 | 76.3 | 92.2 | 74.6 | 70.3 | 78.0 | 73.4 | | |
| 224 | 3/30/2013 | | | | | | | | | | Zero filter | |
| 225 | 3/31/2013 | | | | | | | | | | Zero filter | |
| 226 | 4/1/2013 | | | | | | | | | | Zero filter | |
| 227 | 4/2/2013 | 20.2 | 20.2 | 24.7 | 25.2 | 81.0 | 23.4 | 22.0 | 28.0 | 26.6 | | |
| 228 | 4/3/2013 | 27.2 | 26.5 | 31.4 | 30.8 | 86.3 | 31.0 | 29.0 | 35.3 | 33.2 | | |
| 229 | 4/4/2013 | 29.5 | 29.1 | 33.5 | 33.2 | 88.0 | 35.8 | 36.2 | 39.6 | 40.2 | | |
| 230 | 4/5/2013 | 25.8 | 25.4 | 30.8 | 30.0 | 84.1 | 29.7 | 30.0 | 34.1 | 34.6 | | |
| 231 | 4/6/2013 | | | | | | 25.8 | 26.0 | 30.2 | 30.3 | | |
| 232 | 4/7/2013 | 23.0 | 22.8 | 30.9 | 30.2 | 74.9 | 25.5 | 25.7 | 32.7 | 32.5 | | |
| 233 | 4/8/2013 | 26.3 | 25.1 | 31.7 | 31.7 | 81.0 | 29.3 | 29.4 | 35.2 | 35.5 | | |
| 234 | 4/9/2013 | 16.5 | 16.5 | 21.6 | 21.0 | 77.4 | 18.1 | 18.0 | 21.3 | 21.2 | | |
| 235 | 4/10/2013 | 12.2 | 12.2 | 17.9 | 17.8 | 68.4 | 12.3 | 12.1 | 16.7 | 16.2 | | |
| 236 | 4/11/2013 | 9.4 | 8.8 | 15.9 | 15.7 | 57.4 | 7.5 | 7.4 | 13.6 | 13.2 | | |
| 237 | 4/12/2013 | 6.2 | 6.3 | 10.4 | 10.4 | 60.4 | 5.1 | 4.9 | 9.5 | 8.8 | | |
| 238 | 4/13/2013 | | | | | | 6.5 | 6.4 | 10.9 | 10.4 | | |
| 239 | 4/14/2013 | 7.2 | 6.9 | 11.9 | 11.1 | 61.4 | 5.2 | 5.2 | 9.2 | 9.1 | | |
| 240 | 4/15/2013 | 18.5 | 16.8 | 31.2 | 30.2 | 57.3 | 18.1 | 17.6 | 28.7 | 27.6 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 9 of 15**

| | | |
|---|---|---|
| Manufacturer | PALAS | PM10 and PM2.5 |
| Type of instrument | FIDAS 200 S | Measured values in µg/m³ (ACT) |
| Serial-No. | SN 0111 / SN 0112 | |

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 241 | 4/16/2013 | 12.7 | 11.2 | 21.1 | 20.7 | 57.2 | 12.3 | 12.0 | 20.8 | 20.3 | | Bonn, winter |
| 242 | 4/17/2013 | 9.9 | 9.8 | 19.5 | 19.7 | 50.2 | 8.0 | 8.0 | 19.1 | 18.6 | | |
| 243 | 4/18/2013 | 9.4 | 8.7 | 21.4 | 21.5 | 42.2 | 8.3 | 8.3 | 20.7 | 20.3 | | |
| 244 | 4/19/2013 | 10.3 | 10.3 | 21.0 | 20.8 | 49.4 | 11.7 | 11.5 | 20.6 | 19.8 | | |
| 245 | 4/20/2013 | | | | | | 13.5 | 13.3 | 20.8 | 20.1 | | |
| 246 | 4/21/2013 | 24.4 | 23.0 | 36.7 | 37.6 | 63.8 | 23.4 | 22.9 | 33.4 | 32.5 | | |
| 247 | 4/22/2013 | 31.0 | 29.4 | 44.7 | 43.9 | 68.3 | 32.7 | 31.7 | 47.2 | 45.3 | | |
| 248 | 4/23/2013 | 11.0 | 10.4 | 18.2 | 18.8 | 57.6 | 9.8 | 9.4 | 19.5 | 18.6 | | |
| 249 | 4/24/2013 | 14.3 | 12.7 | 24.2 | 24.4 | 55.6 | 13.3 | 12.8 | 25.3 | 24.6 | | |
| 250 | 4/25/2013 | 13.8 | 12.1 | 23.3 | 23.6 | 55.3 | 11.9 | 11.5 | 24.7 | 23.8 | | |
| 251 | 4/26/2013 | | | | | | | | | | Zero filter | |
| 252 | 4/27/2013 | | | | | | | | | | Zero filter | |
| 253 | 4/28/2013 | | | | | | | | | | Zero filter | |
| 254 | 4/29/2013 | 14.3 | 12.9 | 20.6 | 21.4 | 64.9 | 12.7 | 12.1 | 20.5 | 19.3 | | |
| 255 | 4/30/2013 | | | | | | 16.0 | 15.2 | 24.5 | 23.1 | | |
| 256 | 5/1/2013 | 16.9 | 18.2 | 21.4 | 22.2 | 80.7 | 19.5 | 18.1 | 23.8 | 21.9 | | |
| 257 | 5/2/2013 | | | | | | 20.0 | 18.6 | 27.7 | 25.7 | | |
| 258 | 5/3/2013 | 23.2 | 23.4 | 33.7 | 34.4 | 68.5 | 27.6 | 25.8 | 38.5 | 35.7 | | |
| 259 | 5/4/2013 | 20.2 | 19.7 | 30.1 | 30.6 | 65.7 | 21.9 | 20.5 | 31.6 | 29.5 | | |
| 260 | 5/5/2013 | 9.6 | 9.3 | 14.0 | 14.8 | 65.4 | 7.9 | 7.4 | 13.2 | 12.3 | | |
| 261 | 5/14/2013 | | | | | | | | | | Zero filter | Bornheim, summer |
| 262 | 5/15/2013 | | | | | | | | | | Zero filter | |
| 263 | 5/16/2013 | 21.0 | 20.7 | 24.5 | 24.7 | 84.6 | 18.8 | 18.7 | 22.6 | 22.5 | | |
| 264 | 5/17/2013 | 16.1 | 15.5 | 18.3 | 19.4 | 83.8 | 15.3 | 15.1 | 17.3 | 17.1 | | |
| 265 | 5/18/2013 | | | | | | 9.5 | 9.7 | 12.3 | 12.3 | | |
| 266 | 5/19/2013 | | | | | | 18.9 | 18.8 | 22.6 | 22.2 | | |
| 267 | 5/20/2013 | 11.3 | 10.3 | 13.9 | 14.7 | 75.2 | 11.2 | 11.0 | 14.3 | 13.9 | | |
| 268 | 5/21/2013 | | 5.4 | 8.3 | 8.8 | | 4.9 | 4.9 | 8.2 | 8.2 | Power failure Ref. PM2,5 Device#1 | |
| 269 | 5/22/2013 | | | | | | 6.9 | 6.9 | 11.1 | 10.8 | | |
| 270 | 5/23/2013 | | | | | | 5.5 | 5.5 | 7.4 | 7.2 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 10 of 15**

Manufacturer PALAS
Type of instrument FIDAS 200 S
Serial-No. SN 0111 / SN 0112

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 271 | 5/24/2013 | | | 10.1 | 10.7 | | 5.9 | 5.8 | 8.6 | 8.3 | Power failure Ref. PM2,5 Device#1 | Bornheim, summer |
| 272 | 5/25/2013 | | | | | | 10.5 | 10.5 | 14.1 | 14.0 | | |
| 273 | 5/26/2013 | | 6.6 | 12.9 | 13.4 | | 7.9 | 7.6 | 11.1 | 10.7 | Power failure Ref. PM2,5 Device#1 | |
| 274 | 5/27/2013 | 11.7 | 11.0 | 16.9 | 17.6 | 65.7 | 10.6 | 10.5 | 16.4 | 16.0 | | |
| 275 | 5/28/2013 | 8.7 | 7.7 | 12.8 | 12.2 | 65.8 | 6.8 | 6.7 | 11.7 | 11.4 | | |
| 276 | 5/29/2013 | | | | | | 4.1 | 3.9 | 6.1 | 5.6 | | |
| 277 | 5/30/2013 | | | | | | 9.1 | 8.7 | 11.1 | 10.5 | | |
| 278 | 5/31/2013 | | | | | | 16.7 | 15.6 | 22.9 | 21.5 | | |
| 279 | 6/1/2013 | | | | | | 15.7 | 14.9 | 19.3 | 18.3 | | |
| 280 | 6/2/2013 | 5.3 | 5.0 | 10.8 | 10.7 | 47.7 | 4.9 | 4.8 | 8.9 | 8.7 | | |
| 281 | 6/3/2013 | 8.0 | 7.0 | 14.5 | 14.5 | 51.5 | 8.0 | 7.8 | 13.5 | 12.9 | | |
| 282 | 6/4/2013 | 9.5 | 9.5 | 18.2 | 18.4 | 51.9 | 11.6 | 11.0 | 17.9 | 16.8 | | |
| 283 | 6/5/2013 | 9.1 | 9.3 | 17.2 | 18.8 | 51.2 | 9.8 | 9.3 | 19.0 | 17.6 | | |
| 284 | 6/6/2013 | 10.8 | 10.2 | 17.0 | 17.5 | 60.8 | 8.5 | 8.0 | 16.9 | 15.8 | | |
| 285 | 6/7/2013 | 17.0 | 16.1 | 28.6 | 29.9 | 56.6 | 15.6 | 14.8 | 30.6 | 29.1 | | |
| 286 | 6/8/2013 | | | | | | 17.6 | 16.5 | 25.3 | 23.7 | | |
| 287 | 6/9/2013 | 14.0 | 13.6 | 20.1 | 21.3 | 66.9 | 16.6 | 15.2 | 20.7 | 19.1 | | |
| 288 | 6/10/2013 | 16.1 | 15.4 | 26.1 | 27.1 | 59.1 | 19.6 | 18.2 | 27.0 | 24.7 | | |
| 289 | 6/11/2013 | 13.0 | 12.2 | 20.8 | 20.7 | 60.7 | 18.2 | 19.4 | 25.2 | 26.3 | | |
| 290 | 6/12/2013 | 7.1 | 6.4 | 14.6 | 14.0 | 47.4 | 7.4 | 7.8 | 17.3 | 17.4 | | |
| 291 | 6/13/2013 | 5.6 | 5.4 | 13.4 | 12.7 | 42.1 | 5.1 | 5.3 | 14.5 | 14.1 | | |
| 292 | 6/14/2013 | 5.0 | 5.7 | 10.8 | 10.8 | 49.3 | 4.4 | 4.7 | 8.4 | 8.7 | | |
| 293 | 6/15/2013 | 5.1 | 5.3 | 10.6 | 10.2 | 50.0 | 4.3 | 4.5 | 8.7 | 8.7 | | |
| 294 | 6/16/2013 | 7.3 | 7.6 | 16.7 | 16.6 | 44.8 | 7.0 | 7.4 | 11.9 | 11.9 | | |
| 295 | 6/17/2013 | 12.2 | 13.3 | 21.3 | 20.9 | 60.3 | 10.1 | 10.5 | 19.0 | 18.8 | | |
| 296 | 6/18/2013 | 17.8 | 17.3 | 28.6 | 29.1 | 60.9 | 18.7 | 19.0 | 31.5 | 30.8 | | |
| 297 | 6/19/2013 | 31.9 | 32.7 | 48.7 | 48.5 | 66.5 | 36.2 | 35.9 | 51.4 | 49.7 | | |
| 298 | 6/20/2013 | 8.7 | 10.1 | 15.5 | 14.9 | 62.1 | 12.8 | 12.6 | 19.7 | 18.7 | | |
| 299 | 6/21/2013 | 4.2 | 4.5 | 7.2 | 6.8 | 62.2 | 3.7 | 3.8 | 7.5 | 7.1 | | |
| 300 | 6/22/2013 | 3.3 | 4.1 | 5.7 | 5.9 | 63.8 | | | | | Zero filter | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 11 of 15**

| | |
|---|---|
| Manufacturer | PALAS |
| Type of instrument | FIDAS 200 S |
| Serial-No. | SN 0111 / SN 0112 |

PM10 and PM2.5
Measured values in µg/m³ (ACT)

| No. | Date | Ref. 1 PM2,5 [µg/m³] | Ref. 2 PM2,5 [µg/m³] | Ref. 1 PM10 [µg/m³] | Ref 2. PM10 [µg/m³] | Ratio PM2,5/PM10 [%] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | SN 0111 PM10 [µg/m³] | SN 0112 PM10 [µg/m³] | Remark | Test site |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301 | 6/23/2013 | 3.1 | 3.0 | 4.6 | 5.5 | 59.8 | | | | | Zero filter | Bornheim, summer |
| 302 | 6/24/2013 | 8.7 | 8.0 | 13.9 | 13.2 | 61.6 | 9.8 | 9.6 | 13.5 | 13.0 | | |
| 303 | 6/25/2013 | 6.3 | 6.6 | 12.9 | 12.7 | 50.4 | 7.2 | 7.0 | 11.2 | 10.9 | | |
| 304 | 6/26/2013 | 9.1 | 9.4 | 14.6 | 14.5 | 63.4 | 9.0 | 8.8 | 13.1 | 12.4 | | |
| 305 | 6/27/2013 | 9.8 | 9.6 | 14.2 | 13.8 | 69.5 | 9.9 | 9.5 | 14.0 | 13.1 | | |
| 306 | 6/28/2013 | 8.8 | 8.7 | 14.2 | 14.7 | 60.4 | 9.4 | 8.9 | 15.5 | 14.7 | | |
| 307 | 6/29/2013 | 6.0 | 5.8 | 11.7 | 11.5 | 50.8 | 5.4 | 5.0 | 9.9 | 9.0 | | |
| 308 | 6/30/2013 | 7.4 | 6.9 | 14.6 | 14.4 | 49.3 | 6.9 | 6.5 | 13.1 | 11.9 | | |
| 309 | 7/1/2013 | 7.7 | 7.6 | 13.4 | 13.2 | 57.5 | 8.0 | 7.4 | 14.8 | 13.1 | | |
| 310 | 7/2/2013 | 7.9 | 7.9 | 12.5 | 12.0 | 64.9 | 7.8 | 7.3 | 12.9 | 11.8 | | |
| 311 | 7/3/2013 | 3.6 | 3.8 | 9.0 | 9.9 | 39.1 | 4.6 | 4.2 | 11.1 | 9.6 | | |
| 312 | 7/4/2013 | 7.5 | 7.9 | 13.5 | 13.6 | 56.8 | 8.0 | 7.2 | 13.3 | 11.9 | | |
| 313 | 7/5/2013 | 12.9 | 13.1 | 20.9 | 19.9 | 63.8 | 14.8 | 13.2 | 21.7 | 19.0 | | |
| 314 | 7/6/2013 | 13.3 | 13.1 | 18.7 | 18.5 | 71.0 | 15.2 | 13.8 | 20.3 | 18.3 | | |
| 315 | 7/7/2013 | 11.3 | 10.7 | 14.9 | 14.4 | 75.0 | 10.9 | 9.8 | 15.0 | 13.2 | | |
| 316 | 7/8/2013 | 11.3 | 10.6 | 16.3 | 16.1 | 67.7 | 10.1 | 9.0 | 16.4 | 14.4 | | |
| 317 | 7/9/2013 | 14.2 | 14.5 | 24.9 | 22.6 | 60.5 | 15.9 | 14.1 | 24.5 | 21.1 | | |
| 318 | 7/10/2013 | 9.7 | 10.2 | 19.1 | 17.5 | 54.6 | 11.8 | 10.4 | 19.9 | 17.0 | | |
| 319 | 7/11/2013 | 13.6 | 14.3 | 26.6 | 24.9 | 54.1 | 17.5 | 17.1 | 25.1 | 24.0 | | |
| 320 | 7/12/2013 | 16.5 | 16.8 | | | | 22.0 | 21.3 | 30.3 | 28.8 | Outlier Ref. PM10 | |
| 321 | 7/13/2013 | 15.3 | 15.3 | 20.4 | 20.7 | 74.5 | 18.3 | 17.5 | 23.4 | 22.1 | | |
| 322 | 7/14/2013 | 14.5 | 14.5 | 22.2 | 21.5 | 66.5 | 19.7 | 18.7 | 26.7 | 24.7 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 12 of 15**

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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 323 | 2/27/2014 | 7.0 | 7.4 | 12.7 | 12.2 | 57.4 | 6.7 | 6.7 | 10.9 | 10.6 | | Teddington, Winter |
| 324 | 2/28/2014 | 12.4 | 13.6 | 19.3 | 18.5 | 68.7 | 13.1 | 13.7 | 15.8 | 16.4 | | |
| 325 | 3/1/2014 | 13.7 | 14.0 | 19.8 | 19.7 | 70.3 | 14.2 | 14.5 | 17.8 | 18.0 | | |
| 326 | 3/2/2014 | 3.9 | 4.2 | 7.9 | 7.7 | 52.3 | 4.4 | 4.4 | 7.4 | 7.1 | | |
| 327 | 3/3/2014 | 8.9 | 9.4 | 12.5 | 13.1 | 71.4 | 8.5 | 8.7 | 10.7 | 10.8 | | |
| 328 | 3/4/2014 | 14.7 | 15.4 | 21.7 | 21.4 | 69.8 | 14.1 | 14.4 | 18.3 | 18.4 | | |
| 329 | 3/5/2014 | 9.6 | 11.3 | 21.3 | 20.9 | 49.5 | 11.3 | 10.9 | 16.4 | 15.4 | | |
| 330 | 3/6/2014 | 10.5 | 10.7 | 17.2 | 17.5 | 61.1 | 10.8 | 10.5 | 14.6 | 13.8 | | |
| 331 | 3/7/2014 | 11.3 | 11.4 | 16.5 | 16.2 | 69.3 | 10.8 | 10.4 | 14.5 | 13.7 | | |
| 332 | 3/8/2014 | 41.7 | 42.2 | 47.0 | 46.1 | 90.0 | 44.1 | 43.0 | 48.2 | 46.9 | | |
| 333 | 3/9/2014 | 28.6 | 29.1 | 34.2 | 33.5 | 85.2 | 28.5 | 27.6 | 32.9 | 31.7 | | |
| 334 | 3/10/2014 | 10.0 | 10.4 | 17.5 | 17.4 | 58.4 | 12.4 | 12.0 | 18.3 | 17.3 | | |
| 335 | 3/11/2014 | 19.2 | 20.5 | 31.1 | 30.5 | 64.5 | 19.0 | 18.6 | 26.7 | 25.7 | | |
| 336 | 3/12/2014 | 44.5 | 45.7 | 60.2 | 59.7 | 75.2 | 47.6 | 46.5 | 55.2 | 53.3 | | |
| 337 | 3/13/2014 | | | 68.0 | 67.1 | | 58.3 | 56.4 | 67.7 | 65.2 | Outlier Ref. PM2,5 | |
| 338 | 3/14/2014 | 40.1 | 40.6 | 48.7 | 47.9 | 83.7 | 42.5 | 39.7 | 49.7 | 46.0 | | |
| 339 | 3/15/2014 | 9.3 | 9.3 | 14.2 | 13.4 | 67.1 | 9.0 | 8.3 | 13.1 | 12.0 | | |
| 340 | 3/16/2014 | 11.1 | 11.5 | 14.8 | 14.3 | 77.8 | 10.8 | 10.1 | 13.8 | 12.8 | | |
| 341 | 3/17/2014 | 12.0 | 12.5 | 18.4 | 18.0 | 67.3 | 13.1 | 12.1 | 18.6 | 16.9 | | |
| 342 | 3/18/2014 | 7.3 | 7.6 | 16.0 | 15.4 | 47.4 | 8.1 | 7.5 | 13.7 | 12.2 | | |
| 343 | 3/19/2014 | 13.4 | 14.2 | 27.0 | 25.7 | 52.4 | 16.3 | 15.1 | 23.3 | 21.1 | | |
| 344 | 3/20/2014 | 6.2 | 6.9 | 13.5 | 12.7 | 50.2 | 7.9 | 7.5 | 13.0 | 12.2 | | |
| 345 | 3/21/2014 | 3.4 | 3.9 | 10.0 | 9.7 | 37.0 | 4.4 | 4.4 | 8.7 | 8.4 | | |
| 346 | 3/22/2014 | 3.9 | 4.2 | 8.0 | 7.7 | 51.7 | 4.2 | 4.4 | 7.0 | 7.1 | | |
| 347 | 3/23/2014 | 7.6 | 7.6 | 10.6 | 10.4 | 72.7 | 6.8 | 7.2 | 9.0 | 9.4 | | |
| 348 | 3/24/2014 | 8.1 | 8.2 | 11.8 | 11.6 | 69.7 | 7.5 | 7.8 | 9.7 | 10.0 | | |
| 349 | 3/25/2014 | 19.5 | 19.9 | 28.1 | 27.5 | 70.8 | 18.2 | 19.3 | 22.2 | 23.2 | | |
| 350 | 3/26/2014 | | | | | | | | | | | |
| 351 | 3/27/2014 | | | | | | | | | | | |
| 352 | 3/28/2014 | | | | | | | | | | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 13 of 15**

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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 353 | 3/29/2014 | | | | | | | | | | | Teddington, Winter |
| 354 | 3/30/2014 | | | | | | | | | | | |
| 355 | 3/31/2014 | | | | | | | | | | | |
| 356 | 4/1/2014 | 33.9 | 32.7 | 44.5 | 42.9 | 76.2 | 32.2 | 32.7 | 41.1 | 41.3 | | |
| 357 | 4/2/2014 | 58.6 | 57.7 | | | | 58.0 | 59.9 | 80.6 | 81.8 | Outlier Ref. PM10 | |
| 358 | 4/3/2014 | 35.6 | 35.6 | 51.6 | 49.9 | 70.1 | 37.7 | 39.0 | 49.8 | 50.4 | | |
| 359 | 4/4/2014 | 6.8 | 6.6 | 10.6 | 10.6 | 63.3 | 6.5 | 6.6 | 9.2 | 9.1 | | |
| 360 | 4/5/2014 | 4.2 | 4.1 | 6.1 | 6.0 | 68.9 | 4.2 | 4.4 | 5.6 | 5.8 | | |
| 361 | 4/6/2014 | 3.1 | 2.8 | 5.6 | 5.3 | 53.6 | 2.9 | 2.9 | 4.6 | 4.5 | | |
| 362 | 4/7/2014 | 3.4 | 3.2 | 7.2 | 6.7 | 47.8 | 3.9 | 3.9 | 6.7 | 6.8 | | |
| 363 | 4/8/2014 | 5.8 | 5.8 | 13.5 | 12.8 | 44.1 | 7.3 | 7.4 | 11.4 | 11.4 | | |
| 364 | 4/9/2014 | 8.4 | 8.5 | 15.5 | 14.8 | 56.0 | 8.9 | 8.8 | 13.4 | 12.9 | | |
| 365 | 4/10/2014 | 9.1 | 8.9 | 14.8 | 14.5 | 61.4 | 8.2 | 8.0 | 13.2 | 12.8 | | |
| 366 | 4/11/2014 | 14.3 | 14.3 | 19.9 | 19.3 | 73.1 | 13.2 | 13.3 | 17.6 | 17.5 | | |
| 367 | 4/12/2014 | 8.3 | 8.2 | 13.9 | 13.0 | 61.4 | 9.2 | 9.0 | 13.1 | 12.7 | | |
| 368 | 4/13/2014 | 8.0 | 7.5 | 14.5 | 13.8 | 54.8 | 7.9 | 7.7 | 12.8 | 12.1 | | |
| 369 | 4/14/2014 | 7.5 | 7.4 | 15.6 | 15.0 | 49.0 | 6.9 | 6.7 | 13.1 | 12.4 | | |
| 370 | 4/15/2014 | 9.0 | 8.4 | 21.4 | 20.5 | 41.4 | 9.4 | 9.3 | 17.8 | 17.2 | | |
| 371 | 4/16/2014 | 16.1 | 15.6 | 28.4 | 28.0 | 56.2 | 15.3 | 14.8 | 23.2 | 22.0 | | |
| 372 | 4/17/2014 | 9.6 | 9.1 | 18.1 | 17.5 | 52.5 | 10.6 | 10.1 | 17.7 | 16.5 | | |
| 373 | 4/18/2014 | 5.3 | 5.0 | 12.5 | 11.8 | 42.1 | 5.7 | 5.5 | 10.6 | 10.2 | | |
| 374 | 4/19/2014 | 18.5 | 18.5 | 26.6 | 26.2 | 70.0 | 18.9 | 18.8 | 23.3 | 22.8 | | Teddington, Summer |
| 375 | 4/20/2014 | 39.0 | 39.1 | 45.7 | 44.7 | 86.3 | 39.4 | 38.5 | 43.1 | 41.9 | | |
| 376 | 4/21/2014 | 20.7 | 20.8 | 28.0 | 26.9 | 75.5 | 22.3 | 21.0 | 26.2 | 24.3 | | |
| 377 | 4/22/2014 | 8.9 | 9.8 | 14.6 | 14.0 | 65.5 | 9.7 | 9.1 | 12.6 | 11.6 | | |
| 378 | 4/23/2014 | 7.2 | 7.4 | 10.9 | 10.4 | 68.1 | 7.6 | 7.1 | 9.7 | 8.7 | | |
| 379 | 4/24/2014 | 13.2 | 12.8 | 16.8 | 16.0 | 79.3 | 11.3 | 10.6 | 13.5 | 12.5 | | |
| 380 | 4/25/2014 | 9.0 | 9.0 | 13.5 | 12.8 | 68.8 | 9.3 | 9.1 | 11.5 | 11.4 | | |
| 381 | 4/26/2014 | 4.1 | 4.2 | 9.2 | 8.9 | 46.1 | 4.4 | 4.2 | 7.9 | 7.2 | | |
| 382 | 4/27/2014 | 17.9 | 17.6 | 25.1 | 24.4 | 71.5 | 16.4 | 15.7 | 19.6 | 18.4 | | |

**Annex 5** **Measured values from field test sites, related to actual conditions** **Page 14 of 15**

| | |
|---|---|
| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 383 | 4/28/2014 | 18.7 | 18.9 | 24.3 | 23.3 | 78.8 | 18.2 | 19.2 | 22.0 | 22.8 | | Teddington, Summer |
| 384 | 4/29/2014 | 17.5 | 16.8 | 23.5 | 22.8 | 74.1 | 18.5 | 19.2 | 21.5 | 22.1 | | |
| 385 | 4/30/2014 | 12.5 | 12.1 | 15.6 | 15.3 | 79.6 | 12.0 | 12.3 | 13.8 | 14.1 | | |
| 386 | 5/1/2014 | 13.0 | 12.8 | 17.8 | 17.8 | 72.5 | 12.4 | 12.8 | 14.9 | 15.1 | | |
| 387 | 5/2/2014 | 5.4 | 5.8 | 12.3 | 12.2 | 45.4 | 6.3 | 6.5 | 11.3 | 11.5 | | |
| 388 | 5/3/2014 | 8.9 | 9.0 | 14.3 | 14.3 | 62.5 | 9.1 | 9.0 | 12.4 | 12.0 | | |
| 389 | 5/4/2014 | 13.1 | 13.4 | 20.3 | 19.7 | 66.3 | 13.1 | 12.9 | 16.4 | 15.8 | | |
| 390 | 5/5/2014 | 10.7 | 11.2 | 15.4 | 15.2 | 71.8 | 13.1 | 12.5 | 17.2 | 16.1 | | |
| 391 | 5/6/2014 | 4.2 | 4.4 | 10.8 | 10.5 | 40.6 | 5.0 | 4.8 | 9.4 | 9.0 | | |
| 392 | 5/7/2014 | 3.1 | 3.0 | 7.7 | 7.4 | 40.6 | 3.5 | 3.4 | 7.3 | 7.0 | | |
| 393 | 5/8/2014 | 3.4 | 3.1 | 7.3 | 7.1 | 45.4 | 4.4 | 4.2 | 7.9 | 7.4 | | |
| 394 | 5/9/2014 | 5.1 | 4.6 | 12.3 | 11.7 | 40.2 | 6.2 | 5.8 | 12.1 | 10.6 | | |
| 395 | 5/10/2014 | 3.8 | 3.3 | 10.6 | 10.1 | 34.3 | 5.8 | 5.5 | 11.5 | 10.4 | | |
| 396 | 5/11/2014 | 4.1 | 3.7 | 11.0 | 10.1 | 37.1 | 5.8 | 5.4 | 11.4 | 10.2 | | |
| 397 | 5/12/2014 | 4.4 | 4.6 | 8.4 | 8.0 | 54.8 | 4.5 | 4.3 | 7.7 | 7.0 | | |
| 398 | 5/13/2014 | 6.3 | 6.2 | 9.7 | 9.1 | 66.7 | 6.9 | 6.7 | 9.5 | 9.1 | | |
| 399 | 5/14/2014 | 8.7 | 9.1 | 13.5 | 12.9 | 67.8 | 8.8 | 9.4 | 12.7 | 13.3 | | |
| 400 | 5/15/2014 | 9.7 | 9.8 | 14.8 | 14.4 | 66.9 | 9.8 | 10.3 | 13.6 | 14.0 | | |
| 401 | 5/16/2014 | 15.3 | 14.8 | 22.4 | 21.7 | 68.1 | 15.6 | 16.3 | 21.6 | 22.2 | | |
| 402 | 5/17/2014 | 13.9 | 13.6 | 18.6 | 18.3 | 74.4 | 14.6 | 15.0 | 19.5 | 19.7 | | |
| 403 | 5/18/2014 | | | 25.4 | 25.4 | | 20.6 | 21.3 | 26.7 | 27.2 | Outlier Ref. PM2,5 | |
| 404 | 5/19/2014 | 11.8 | 11.3 | 17.7 | 17.1 | 66.5 | 11.0 | 11.1 | 16.4 | 16.4 | | |
| 405 | 5/20/2014 | 7.2 | 6.6 | 10.7 | 10.0 | 66.4 | 7.5 | 7.7 | 10.6 | 10.6 | | |
| 406 | 5/21/2014 | 6.7 | 6.4 | 10.6 | 10.3 | 62.3 | 6.9 | 6.8 | 10.8 | 10.7 | | |
| 407 | 5/22/2014 | 4.4 | 3.8 | 9.8 | 8.9 | 43.7 | 4.3 | 4.3 | 8.6 | 8.4 | | |
| 408 | 5/23/2014 | 5.6 | 5.3 | 9.9 | 9.1 | 57.1 | 5.0 | 5.1 | 7.5 | 7.5 | | |
| 409 | 5/24/2014 | 3.9 | 3.7 | 9.0 | 8.3 | 43.9 | 4.5 | 4.5 | 7.9 | 7.6 | | |
| 410 | 5/25/2014 | 8.1 | 7.9 | 13.1 | 12.6 | 62.1 | 7.7 | 7.6 | 10.7 | 10.3 | | |
| 411 | 5/26/2014 | 9.2 | 9.1 | 14.2 | 13.0 | 67.2 | 8.4 | 8.4 | 11.5 | 11.4 | | |
| 412 | 5/27/2014 | 6.0 | 6.2 | 8.4 | 8.0 | 74.7 | 4.9 | 4.9 | 6.8 | 6.5 | | |

**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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 413 | 5/28/2014 | 6.7 | 7.0 | 10.5 | 10.2 | 66.2 | 6.6 | 6.3 | 9.3 | 8.6 | | Teddington, Summer |
| 414 | 5/29/2014 | 8.6 | 9.1 | 13.2 | 12.9 | 67.7 | 9.6 | 9.1 | 12.4 | 11.5 | | |
| 415 | 5/30/2014 | 9.7 | 9.8 | 15.0 | 14.2 | 66.5 | 10.9 | 10.4 | 15.3 | 14.3 | | |
| 416 | 5/31/2014 | 11.3 | 11.7 | 17.0 | 16.1 | 69.4 | 13.4 | 12.2 | 17.3 | 15.5 | | |
| 417 | 6/1/2014 | 8.7 | 8.7 | 13.1 | 12.2 | 68.6 | 9.8 | 8.9 | 13.0 | 11.7 | | |
| 418 | 6/2/2014 | 5.5 | 6.0 | 9.5 | 8.3 | 64.9 | 6.7 | 6.6 | 9.3 | 9.1 | | |

**Annex 6** **Ambient conditions from field test sites** **Page 1 of 15**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5/14/2012 | Cologne, summer | 15.4 | 22.1 | 1006 | 52.7 | 0.9 | 144 | 0.9 |
| 2 | 5/15/2012 | | 9.2 | 15.7 | 1006 | 76.3 | 1.2 | 119 | 6.0 |
| 3 | 5/16/2012 | | 8.9 | 14.6 | 1016 | 65.0 | 1.1 | 138 | 1.2 |
| 4 | 5/17/2012 | | 14.4 | 18.8 | 1008 | 46.4 | 0.9 | 177 | 0.0 |
| 5 | 5/18/2012 | | 15.4 | 20.0 | 1003 | 72.3 | 0.6 | 187 | 0.0 |
| 6 | 5/19/2012 | | 19.3 | 24.9 | 1002 | 65.9 | 0.2 | 231 | 0.0 |
| 7 | 5/20/2012 | | 19.5 | 27.8 | 997 | 70.6 | 0.2 | 148 | 0.3 |
| 8 | 5/21/2012 | | 21.2 | 26.4 | 993 | 68.1 | 0.4 | 135 | 0.0 |
| 9 | 5/22/2012 | | 21.5 | 27.6 | 1005 | 72.2 | 0.5 | 110 | 0.0 |
| 10 | 5/23/2012 | | 20.3 | 26.0 | 1015 | 76.0 | 0.2 | 176 | 0.0 |
| 11 | 5/24/2012 | | 23.2 | 31.5 | 1017 | 50.4 | 0.7 | 159 | 0.0 |
| 12 | 5/25/2012 | | 21.2 | 28.6 | 1016 | 39.9 | 1.0 | 177 | 0.0 |
| 13 | 5/26/2012 | | 21.3 | 28.1 | 1013 | 46.2 | 0.6 | 187 | 0.0 |
| 14 | 5/27/2012 | | 21.4 | 28.1 | 1010 | 51.8 | 0.3 | 200 | 0.0 |
| 15 | 5/28/2012 | | 21.7 | 27.8 | 1007 | 53.4 | 0.8 | 108 | 0.0 |
| 16 | 5/29/2012 | | 20.4 | 25.4 | 1008 | 57.7 | 0.9 | 104 | 0.0 |
| 17 | 5/30/2012 | | 19.8 | 24.7 | 1011 | 61.7 | 0.7 | 140 | 0.0 |
| 18 | 5/31/2012 | | 17.1 | 24.4 | 1009 | 76.1 | 0.9 | 130 | 13.3 |
| 19 | 6/1/2012 | | 15.0 | 18.4 | 1011 | 68.6 | 0.8 | 107 | 0.0 |
| 20 | 6/2/2012 | | 15.2 | 20.2 | 1006 | 58.2 | 0.7 | 151 | 3.0 |
| 21 | 6/3/2012 | | 11.9 | 15.2 | 1002 | 87.2 | 0.3 | 154 | 6.8 |
| 22 | 6/4/2012 | | 12.2 | 20.2 | 1006 | 80.4 | 0.9 | 125 | 7.2 |
| 23 | 6/5/2012 | | 14.2 | 19.0 | 1007 | 60.8 | 0.5 | 167 | 6.5 |
| 24 | 6/6/2012 | | 16.0 | 20.0 | 1000 | 78.5 | 0.4 | 165 | 5.0 |
| 25 | 6/7/2012 | | 19.7 | 24.5 | 996 | 69.4 | 1.1 | 178 | 0.3 |
| 26 | 6/8/2012 | | 17.5 | 23.1 | 1003 | 58.9 | 2.7 | 189 | 0.3 |
| 27 | 6/9/2012 | | 15.5 | 19.9 | 1006 | 57.5 | 1.6 | 166 | 0.0 |
| 28 | 6/10/2012 | | 17.8 | 26.6 | 1000 | 56.8 | 0.3 | 184 | 0.0 |
| 29 | 6/11/2012 | | 15.5 | 19.9 | 995 | 81.8 | 0.4 | 151 | 26.6 |
| 30 | 6/12/2012 | | 16.4 | 21.1 | 1000 | 72.0 | 0.8 | 116 | 0.0 |

**Annex 6** **Ambient conditions from field test sites** **Page 2 of 15**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 31 | 6/13/2012 | Cologne, summer | 13.9 | 15.4 | 1010 | 71.0 | 0.2 | 114 | 0.0 |
| 32 | 6/14/2012 | | 16.4 | 20.9 | 1010 | 65.0 | 0.2 | 174 | 0.3 |
| 34 | 6/15/2012 | | 17.8 | 21.8 | 1007 | 79.2 | 0.4 | 152 | 11.6 |
| 34 | 6/16/2012 | | 15.7 | 18.1 | 1010 | 82.0 | 0.6 | 155 | 1.8 |
| 35 | 6/17/2012 | | 18.4 | 24.1 | 1011 | 61.8 | 0.6 | 133 | 0.0 |
| 36 | 6/18/2012 | | 18.9 | 24.9 | 1011 | 69.1 | 0.7 | 137 | 0.0 |
| 37 | 6/19/2012 | | 18.6 | 21.4 | 1010 | 73.9 | 0.1 | 149 | 7.5 |
| 38 | 6/20/2012 | | 18.6 | 23.0 | 1006 | 82.1 | 0.3 | 135 | 2.1 |
| 39 | 6/21/2012 | | 19.0 | 24.6 | 1005 | 76.2 | 0.4 | 151 | 12.7 |
| 40 | 6/22/2012 | | 17.0 | 21.9 | 1013 | 64.6 | 1.2 | 161 | 0.6 |
| 41 | 6/23/2012 | | 18.6 | 23.4 | 1014 | 59.4 | 0.7 | 138 | 0.0 |
| 42 | 6/24/2012 | | 15.7 | 20.0 | 1006 | 76.5 | 1.6 | 162 | 6.9 |
| 43 | 6/25/2012 | | 15.5 | 19.9 | 1012 | 71.5 | 0.8 | 124 | 0.6 |
| 44 | 6/26/2012 | | 19.1 | 24.2 | 1014 | 61.4 | 0.5 | 138 | 0.0 |
| 45 | 6/27/2012 | | 20.3 | 23.2 | 1009 | 82.7 | 0.3 | 136 | 0.3 |
| 46 | 6/28/2012 | | 24.9 | 32.0 | 1001 | 68.1 | 0.7 | 172 | 10.0 |
| 47 | 6/29/2012 | | 19.7 | 27.4 | 1004 | 84.5 | 0.2 | 146 | 29.5 |
| 48 | 6/30/2012 | | 21.2 | 26.0 | 1006 | 67.3 | 0.6 | 152 | 0.0 |
| 49 | 7/1/2012 | | 17.3 | 23.2 | 1012 | 64.9 | 0.4 | 150 | 0.0 |
| 50 | 7/2/2012 | | 17.5 | 21.9 | 1012 | 71.0 | 0.2 | 183 | 0.0 |
| 51 | 7/3/2012 | | 22.2 | 27.7 | 1009 | 59.9 | 0.2 | 163 | 0.0 |
| 52 | 7/4/2012 | | 24.0 | 28.8 | 1004 | 60.6 | 0.5 | 171 | 0.0 |
| 53 | 7/5/2012 | | 23.6 | 30.6 | 1002 | 68.8 | 0.4 | 189 | 0.0 |
| 54 | 7/6/2012 | | 21.0 | 27.2 | 1005 | 63.9 | 0.7 | 167 | 0.0 |
| 55 | 7/7/2012 | | 20.6 | 25.9 | 1003 | 65.6 | 0.2 | 157 | 5.9 |
| 56 | 7/8/2012 | | 18.8 | 22.6 | 1002 | 72.1 | 1.6 | 170 | 9.8 |
| 57 | 7/9/2012 | | 19.8 | 25.2 | 1006 | 65.8 | 0.5 | 144 | 0.0 |
| 58 | 7/10/2012 | | 18.4 | 24.8 | 1005 | 77.5 | 0.5 | 145 | 8.0 |
| 59 | 7/11/2012 | | 16.1 | 21.6 | 1006 | 70.2 | 1.2 | 163 | 1.5 |
| 60 | 7/12/2012 | | 17.2 | 22.2 | 1005 | 66.6 | 0.9 | 150 | 11.3 |

**Annex 6** **Ambient conditions from field test sites** **Page 3 of 15**

| 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 |

**Annex 6** **Ambient conditions from field test sites** **Page 5 of 15**

| 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 |

**Annex 6** **Ambient conditions from field test sites** **Page 7 of 15**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 181 | 1/26/2013 | Cologne, winter | -0.1 | 2.7 | 1004 | 81.5 | 0.9 | 148 | 0.6 |
| 182 | 1/27/2013 | | 3.1 | 5.2 | 999 | 85.4 | 0.9 | 160 | 10.2 |
| 183 | 1/28/2013 | | 6.9 | 10.2 | 1004 | 78.3 | 1.9 | 172 | 9.8 |
| 184 | 1/29/2013 | | 11.9 | 15.0 | 1001 | 82.4 | 2.0 | 177 | 4.2 |
| 185 | 1/30/2013 | | 10.9 | 15.8 | 1005 | 71.5 | 2.9 | 149 | 4.4 |
| 186 | 1/31/2013 | | 8.6 | 10.1 | 1004 | 72.4 | 2.4 | 155 | 5.9 |
| 187 | 2/1/2013 | | 5.0 | 7.5 | 990 | 88.1 | 0.9 | 127 | 11.7 |
| 188 | 2/2/2013 | | 3.7 | 4.9 | 1006 | 78.8 | 1.8 | 94 | 0.9 |
| 189 | 2/3/2013 | | 5.8 | 9.2 | 1006 | 82.0 | 2.0 | 144 | 3.0 |
| 190 | 2/4/2013 | | 7.5 | 10.9 | 1000 | 76.2 | 1.9 | 149 | 3.3 |
| 191 | 2/5/2013 | | 2.5 | 7.0 | 990 | 79.2 | 1.0 | 142 | 0.9 |
| 192 | 2/6/2013 | | 2.4 | 3.6 | 997 | 84.5 | 0.9 | 112 | 5.4 |
| 193 | 2/27/2013 | Bonn, winter | 2.5 | 3.6 | 1021 | 78.9 | 0.9 | 185 | 0.0 |
| 194 | 2/28/2013 | | 4.1 | 6.8 | 1017 | 71.8 | 1.2 | 250 | 0.0 |
| 195 | 3/1/2013 | | 3.5 | 4.8 | 1016 | 72.0 | 1.7 | 249 | 0.0 |
| 196 | 3/2/2013 | | 3.0 | 5.8 | 1015 | 67.4 | 1.2 | 238 | 0.0 |
| 197 | 3/3/2013 | | 3.1 | 6.0 | 1014 | 72.8 | 0.5 | 196 | 0.0 |
| 198 | 3/4/2013 | | 6.6 | 12.4 | 1007 | 57.8 | 1.4 | 140 | 0.0 |
| 199 | 3/5/2013 | | 8.5 | 14.0 | 999 | 56.5 | 1.2 | 136 | 0.0 |
| 200 | 3/6/2013 | | 11.5 | 18.7 | 993 | 48.5 | 0.4 | 143 | 0.0 |
| 201 | 3/7/2013 | | 12.3 | 16.4 | 990 | 67.5 | 0.5 | 144 | 2.1 |
| 202 | 3/8/2013 | | 13.7 | 18.3 | 990 | 72.1 | 1.4 | 138 | 1.5 |
| 203 | 3/9/2013 | | 10.6 | 13.7 | 991 | 72.2 | 1.2 | 178 | 3.6 |
| 204 | 3/10/2013 | | 1.6 | 5.7 | 993 | 81.8 | 3.6 | 273 | 2.4 |
| 205 | 3/11/2013 | | -1.4 | 0.4 | 996 | 78.7 | 1.9 | 241 | 0.0 |
| 206 | 3/12/2013 | | -3.4 | -1.2 | 995 | 83.9 | 2.0 | 276 | 0.0 |
| 207 | 3/13/2013 | | -1.2 | 0.8 | 999 | 72.8 | 1.1 | 224 | 0.3 |
| 208 | 3/14/2013 | | -1.3 | 2.0 | 1004 | 75.3 | 1.1 | 209 | 2.1 |
| 209 | 3/15/2013 | | 2.3 | 5.7 | 1006 | 58.8 | 1.0 | 132 | 2.1 |
| 210 | 3/16/2013 | | 5.3 | 7.8 | 998 | 49.0 | 3.4 | 131 | 0.0 |

**Annex 6** **Ambient conditions from field test sites** **Page 8 of 15**

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 211 | 3/17/2013 | Bonn, winter | 4.7 | 6.1 | 988 | 78.3 | 2.2 | 131 | 0.9 |
| 212 | 3/18/2013 | | 6.6 | 11.1 | 985 | 60.3 | 0.7 | 131 | 0.0 |
| 213 | 3/19/2013 | | 5.8 | 10.0 | 991 | 74.5 | 0.6 | 157 | 1.2 |
| 214 | 3/20/2013 | | 2.6 | 4.9 | 999 | 85.8 | 1.9 | 240 | 13.2 |
| 215 | 3/21/2013 | | 0.6 | 3.3 | 1010 | 78.8 | 1.0 | 229 | 0.3 |
| 216 | 3/22/2013 | | 2.9 | 7.3 | 1006 | 63.4 | 3.2 | 146 | 0.0 |
| 217 | 3/23/2013 | | 1.1 | 3.4 | 1005 | 56.8 | 4.2 | 146 | 0.0 |
| 218 | 3/24/2013 | | 1.0 | 4.7 | 1005 | 42.8 | 3.3 | 153 | 0.0 |
| 219 | 3/25/2013 | | 0.9 | 4.6 | 1004 | 49.0 | 2.6 | 153 | 0.0 |
| 220 | 3/26/2013 | | 1.6 | 6.1 | 1003 | 44.1 | 2.3 | 168 | 0.0 |
| 221 | 3/27/2013 | | 2.6 | 6.4 | 1001 | 49.5 | 2.0 | 148 | 0.0 |
| 222 | 3/28/2013 | | 3.0 | 6.7 | 999 | 58.9 | 1.2 | 243 | 0.0 |
| 223 | 3/29/2013 | | 0.4 | 3.1 | 999 | 77.8 | 1.1 | 271 | 1.5 |
| 224 | 3/30/2013 | | 1.8 | 4.4 | 1000 | 68.9 | 1.3 | 271 | 0.0 |
| 225 | 3/31/2013 | | 1.7 | 4.0 | 1003 | 68.2 | 1.1 | 269 | 0.0 |
| 226 | 4/1/2013 | | 3.2 | 7.3 | 1001 | 52.9 | 1.5 | 190 | 0.0 |
| 227 | 4/2/2013 | | 3.6 | 8.5 | 1003 | 52.2 | 1.8 | 201 | 0.0 |
| 228 | 4/3/2013 | | 3.0 | 6.6 | 1005 | 58.0 | 1.8 | 158 | 0.0 |
| 229 | 4/4/2013 | | 4.4 | 8.7 | 1001 | 60.5 | 1.8 | 166 | 0.0 |
| 230 | 4/5/2013 | | 3.8 | 4.7 | 1003 | 67.8 | 1.6 | 267 | 0.0 |
| 231 | 4/6/2013 | | 3.6 | 6.2 | 1012 | 73.9 | 1.7 | 221 | 0.3 |
| 232 | 4/7/2013 | | 6.4 | 11.4 | 1008 | 51.4 | 0.7 | 174 | 0.0 |
| 234 | 4/8/2013 | | 7.0 | 11.5 | 996 | 63.9 | 1.4 | 130 | 0.9 |
| 234 | 4/9/2013 | | 8.3 | 10.6 | 992 | 78.0 | 1.2 | 133 | 1.8 |
| 235 | 4/10/2013 | | 9.7 | 13.2 | 996 | 77.3 | 1.4 | 154 | 6.0 |
| 236 | 4/11/2013 | | 13.0 | 17.3 | 991 | 69.6 | 1.3 | 169 | 6.0 |
| 237 | 4/12/2013 | | 12.2 | 16.8 | 997 | 69.0 | 1.1 | 154 | 4.4 |
| 238 | 4/13/2013 | | 13.9 | 17.2 | 1011 | 56.8 | 1.4 | 152 | 0.6 |
| 239 | 4/14/2013 | | 18.3 | 24.1 | 1011 | 57.0 | 1.5 | 136 | 0.0 |
| 240 | 4/15/2013 | | 17.5 | 23.1 | 1011 | 67.0 | 1.5 | 214 | 2.7 |

**Annex 6** **Ambient conditions from field test sites** 

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 241 | 4/16/2013 | Bonn, winter | 18.4 | 22.8 | 1011 | 54.4 | 0.9 | 149 | 0.0 |
| 242 | 4/17/2013 | | 18.7 | 25.0 | 1009 | 54.3 | 0.6 | 141 | 0.0 |
| 243 | 4/18/2013 | | 15.6 | 19.8 | 1009 | 46.2 | 3.1 | 210 | 0.0 |
| 244 | 4/19/2013 | | 11.4 | 14.7 | 1017 | 57.7 | 3.5 | 260 | 0.0 |
| 245 | 4/20/2013 | | 10.3 | 13.9 | 1018 | 51.5 | 3.3 | 274 | 0.0 |
| 246 | 4/21/2013 | | 11.1 | 13.1 | 1009 | 57.4 | 1.1 | 253 | 0.0 |
| 247 | 4/22/2013 | | 13.2 | 17.4 | 1009 | 46.5 | 1.4 | 217 | 0.0 |
| 248 | 4/23/2013 | | 13.7 | 18.9 | 1014 | 63.6 | 1.7 | 187 | 0.0 |
| 249 | 4/24/2013 | | 17.9 | 24.6 | 1016 | 56.5 | 1.0 | 167 | 0.0 |
| 250 | 4/25/2013 | | 20.0 | 26.6 | 1010 | 51.5 | 0.4 | 146 | 0.0 |
| 251 | 4/26/2013 | | 11.9 | 20.3 | 1000 | 77.3 | 2.2 | 230 | 9.9 |
| 252 | 4/27/2013 | | 7.8 | 9.8 | 1003 | 70.3 | 3.2 | 293 | 0.0 |
| 253 | 4/28/2013 | | 9.2 | 12.2 | 1007 | 68.3 | 0.7 | 169 | 0.0 |
| 254 | 4/29/2013 | | 12.0 | 16.9 | 1010 | 56.1 | 1.9 | 209 | 0.0 |
| 255 | 4/30/2013 | | 11.8 | 15.1 | 1014 | 57.9 | 1.0 | 214 | 0.0 |
| 256 | 5/1/2013 | | 14.6 | 18.3 | 1011 | 62.8 | 0.9 | 173 | 0.3 |
| 257 | 5/2/2013 | | 16.5 | 21.6 | 1009 | 60.4 | 1.1 | 200 | 0.0 |
| 258 | 5/3/2013 | | 16.0 | 20.6 | 1007 | 60.0 | 1.5 | 253 | 0.0 |
| 259 | 5/4/2013 | | 15.7 | 21.0 | 1011 | 54.5 | 2.4 | 238 | 0.0 |
| 260 | 5/5/2013 | | 16.4 | 22.1 | 1013 | 55.9 | 1.3 | 190 | 0.0 |
| 261 | 5/14/2013 | Bornheim, summer | No weather data available | | | | | | |
| 262 | 5/15/2013 | | | | | | | | |
| 263 | 5/16/2013 | | 12.6 | 16.7 | 989 | 85.5 | 0.7 | 263 | 8.6 |
| 264 | 5/17/2013 | | 10.0 | 10.6 | 995 | 89.1 | 0.8 | 265 | 2.4 |
| 265 | 5/18/2013 | | 12.0 | 17.8 | 1000 | 77.7 | 0.4 | 216 | 0.0 |
| 266 | 5/19/2013 | | 16.7 | 22.4 | 998 | 66.5 | 2.7 | 273 | 7.4 |
| 267 | 5/20/2013 | | 11.9 | 15.0 | 1000 | 83,,1 | 0.3 | 175 | 6.2 |
| 268 | 5/21/2013 | | 12.9 | 18.2 | 1001 | 78.8 | 1.8 | 239 | 13.1 |
| 269 | 5/22/2013 | | 8.8 | 11.1 | 1004 | 82.4 | 2.4 | 258 | 7.4 |
| 270 | 5/23/2013 | | 6.4 | 10.6 | 1000 | 81.9 | 1.8 | 255 | 2.4 |

**Annex 6** **Ambient conditions from field test sites** 

| No. | Date | Test site | Amb. temperature (AVG) [°C] | Amb. temperature (MAX) [°C] | Amb. pressure [hPa] | Rel. humidity [%] | Wind velocity [m/s] | Wind direction [°] | Precipitation [mm] |
|---|---|---|---|---|---|---|---|---|---|
| 271 | 5/24/2013 | Bornheim, summer | 8.3 | 14.6 | 1003 | 69.9 | 0.7 | 192 | 0.9 |
| 272 | 5/25/2013 | | 10.5 | 15.0 | 1005 | 70.9 | 2.8 | 270 | 3.0 |
| 273 | 5/26/2013 | | 9.8 | 11.8 | 1002 | 79.9 | 3.2 | 271 | 5.7 |
| 274 | 5/27/2013 | | 14.0 | 20.5 | 1000 | 61.4 | 1.6 | 244 | 0.0 |
| 275 | 5/28/2013 | | 17.2 | 23.9 | 993 | 60.4 | 2.0 | 179 | 1.2 |
| 276 | 5/29/2013 | | 9.7 | 11.1 | 995 | 88.4 | 0.6 | 207 | 15.0 |
| 277 | 5/30/2013 | | 13.5 | 16.6 | 999 | 69.6 | 1.7 | 237 | 2.4 |
| 278 | 5/31/2013 | | 16.1 | 22.0 | 1001 | 73.0 | 4.7 | 299 | 0.9 |
| 279 | 6/1/2013 | | 11.9 | 14.7 | 1009 | 79.4 | 4.4 | 290 | 0.3 |
| 280 | 6/2/2013 | | 13.3 | 18.6 | 1016 | 57.6 | 4.0 | 288 | 0.0 |
| 281 | 6/3/2013 | | 12.9 | 17.9 | 1017 | 61.6 | 3.6 | 269 | 0.0 |
| 282 | 6/4/2013 | | 15.6 | 21.6 | 1012 | 64.5 | 1.7 | 237 | 0.0 |
| 283 | 6/5/2013 | | 19.9 | 26.6 | 1009 | 54.2 | 0.6 | 197 | 0.0 |
| 284 | 6/6/2013 | | 20.9 | 28.3 | 1010 | 52.6 | 0.8 | 168 | 0.0 |
| 285 | 6/7/2013 | | 21.7 | 29.1 | 1010 | 55.5 | 1.0 | 211 | 0.0 |
| 286 | 6/8/2013 | | 21.1 | 26.8 | 1005 | 62.3 | 2.1 | 243 | 0.0 |
| 287 | 6/9/2013 | | 15.6 | 19.2 | 1001 | 78.7 | 1.8 | 273 | 4.5 |
| 288 | 6/10/2013 | | 14.4 | 18.1 | 1005 | 75.9 | 1.2 | 253 | 0.6 |
| 289 | 6/11/2013 | | 18.8 | 23.8 | 1008 | 61.5 | 0.6 | 198 | 0.0 |
| 290 | 6/12/2013 | | 21.1 | 23.7 | 1008 | 67.1 | 1.0 | 181 | 0.0 |
| 291 | 6/13/2013 | | 17.0 | 27.6 | 1007 | 77.9 | 1.3 | 209 | 22.5 |
| 292 | 6/14/2013 | | 16.1 | 21.2 | 1009 | 65.4 | 0.6 | 181 | 0.0 |
| 293 | 6/15/2013 | | 17.2 | 22.6 | 1005 | 63.1 | 1.4 | 209 | 0.0 |
| 294 | 6/16/2013 | | 17.7 | 23.7 | 1007 | 63.9 | 0.7 | 226 | 0.0 |
| 295 | 6/17/2013 | | 23.3 | 29.7 | 1004 | 64.7 | 0.9 | 185 | 0.0 |
| 296 | 6/18/2013 | | 27.2 | 34.8 | 1005 | 61.3 | 0.4 | 178 | 0.0 |
| 297 | 6/19/2013 | | 26.9 | 35.0 | 1003 | 67.8 | 1.9 | 244 | 0.0 |
| 298 | 6/20/2013 | | 20.5 | 25.1 | 1003 | 78.5 | 1.0 | 187 | 34.6 |
| 299 | 6/21/2013 | | 19.0 | 23.4 | 1005 | 69.8 | 1.6 | 196 | 0.3 |
| 300 | 6/22/2013 | | 19.0 | 23.7 | 1004 | 67.8 | 1.8 | 198 | 1.5 |

**Annex 6** **Ambient conditions from field test sites** **Page 11 of 15**

| 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 6** **Ambient conditions from field test sites** **Page 12 of 15**

| 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] |
|---|---|---|---|---|---|---|---|---|---|
| 323 | 2/27/2014 | Teddington, Winter | 6.4 | 12.6 | 984 | 80.6 | 0.2 | 109 | 2.5 |
| 324 | 2/28/2014 | | 4.8 | 9.6 | 984 | 89.3 | 0.8 | 8 | 5.1 |
| 325 | 3/1/2014 | | 4.9 | 10.6 | 983 | 83.7 | 0.1 | 189 | 0.0 |
| 326 | 3/2/2014 | | 6.9 | 11.4 | 969 | 88.1 | 1.1 | 162 | 10.2 |
| 327 | 3/3/2014 | | 4.4 | 8.9 | 976 | 92.1 | 0.1 | 116 | 10.2 |
| 328 | 3/4/2014 | | 4.8 | 12.2 | 992 | 85.6 | 0.0 | 188 | 0.0 |
| 329 | 3/5/2014 | | 8.5 | 15.1 | 1005 | 76.0 | 0.1 | 199 | 0.0 |
| 330 | 3/6/2014 | | 9.2 | 14.4 | 1004 | 80.5 | 0.4 | 177 | 0.0 |
| 331 | 3/7/2014 | | 11.0 | 17.1 | 1007 | 77.5 | 0.4 | 131 | 0.0 |
| 332 | 3/8/2014 | | 11.5 | 16.7 | 1004 | 64.2 | 0.5 | 156 | 0.0 |
| 333 | 3/9/2014 | | 10.7 | 19.5 | 1005 | 68.2 | 0.4 | 155 | 0.0 |
| 334 | 3/10/2014 | | 9.1 | 14.4 | 1013 | 75.6 | 2.3 | 14 | 0.0 |
| 335 | 3/11/2014 | | 7.4 | 12.4 | 1015 | 84.2 | 1.0 | 27 | 0.0 |
| 336 | 3/12/2014 | | 9.4 | 17.5 | 1012 | 76.7 | 0.3 | 40 | 0.0 |
| 337 | 3/13/2014 | | 9.8 | 19.6 | 1011 | 74.5 | 0.2 | 21 | 0.0 |
| 338 | 3/14/2014 | | 11.4 | 18.9 | 1007 | 71.5 | 0.0 | 266 | 0.0 |
| 339 | 3/15/2014 | | 11.4 | 18.9 | 1006 | 69.7 | 0.2 | 307 | 0.0 |
| 340 | 3/16/2014 | | 12.2 | 20.6 | 1004 | 69.2 | 0.2 | 294 | 0.0 |
| 341 | 3/17/2014 | | 10.4 | 15.9 | 1000 | 73.7 | 0.1 | 250 | 0.0 |
| 342 | 3/18/2014 | | 10.3 | 14.4 | 1000 | 74.6 | 0.2 | 239 | 0.0 |
| 343 | 3/19/2014 | | 10.9 | 18.5 | 1000 | 75.7 | 0.3 | 188 | 0.0 |
| 344 | 3/20/2014 | | 10.1 | 14.4 | 987 | 79.5 | 0.5 | 200 | 2.5 |
| 345 | 3/21/2014 | | 8.3 | 13.8 | 984 | 73.2 | 0.6 | 187 | 7.6 |
| 346 | 3/22/2014 | | 6.2 | 12.8 | 984 | 76.6 | 0.2 | 224 | 0.0 |
| 347 | 3/23/2014 | | 5.5 | 11.1 | 994 | 72.3 | 0.7 | 309 | 0.0 |
| 348 | 3/24/2014 | | 7.9 | 12.0 | 991 | 70.6 | 1.3 | 139 | 5.1 |
| 349 | 3/25/2014 | | 6.2 | 9.4 | 996 | 81.3 | 0.6 | 40 | 0.0 |
| 350 | 3/26/2014 | | 8.8 | 10.2 | 999 | 59.6 | 1.7 | 359 | 0.0 |
| 351 | 3/27/2014 | | | | | | | | |
| 352 | 3/28/2014 | | | | | | | | |

**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] |
|---|---|---|---|---|---|---|---|---|---|
| 353 | 3/29/2014 | Teddington, Winter | | | | | | | |
| 354 | 3/30/2014 | | 14.1 | 15.0 | 994 | 67.3 | 0.8 | 119 | 0.0 |
| 355 | 3/31/2014 | | 15.5 | 17.3 | 993 | 60.3 | 0.7 | 127 | 0.0 |
| 356 | 4/1/2014 | | 14.5 | 21.1 | 988 | 71.7 | 0.3 | 26 | 0.0 |
| 357 | 4/2/2014 | | 14.7 | 19.6 | 982 | 73.4 | 0.9 | 49 | 0.0 |
| 358 | 4/3/2014 | | 13.8 | 18.9 | 983 | 77.1 | 0.5 | 112 | 0.0 |
| 359 | 4/4/2014 | | 10.8 | 17.2 | 993 | 77.6 | 0.1 | 157 | 0.0 |
| 360 | 4/5/2014 | | 13.7 | 16.1 | 994 | 86.5 | 0.6 | 173 | 2.5 |
| 361 | 4/6/2014 | | 13.7 | 15.6 | 993 | 88.0 | 0.6 | 178 | 0.0 |
| 362 | 4/7/2014 | | 10.3 | 15.0 | 991 | 86.5 | 0.2 | 194 | 2.5 |
| 363 | 4/8/2014 | | 9.2 | 16.2 | 1005 | 70.7 | 0.3 | 299 | 0.0 |
| 364 | 4/9/2014 | | 12.0 | 20.0 | 1005 | 69.0 | 0.0 | 222 | 0.0 |
| 365 | 4/10/2014 | | 13.5 | 18.2 | 1002 | 56.2 | 0.3 | 329 | 0.0 |
| 366 | 4/11/2014 | | 11.1 | 17.6 | 1002 | 63.8 | 0.3 | 351 | 0.0 |
| 367 | 4/12/2014 | | 11.3 | 16.1 | 1001 | 70.3 | 0.2 | 275 | 0.0 |
| 368 | 4/13/2014 | | 11.6 | 18.0 | 1003 | 64.8 | 0.5 | 312 | 0.0 |
| 369 | 4/14/2014 | | 10.9 | 17.7 | 1009 | 59.0 | 0.8 | 354 | 0.0 |
| 370 | 4/15/2014 | | 9.8 | 16.6 | 1011 | 60.2 | 0.5 | 75 | 0.0 |
| 371 | 4/16/2014 | | 10.9 | 19.4 | 1005 | 59.7 | 0.3 | 123 | 0.0 |
| 372 | 4/17/2014 | | 12.3 | 19.4 | 1000 | 60.1 | 1.0 | 332 | 0.0 |
| 373 | 4/18/2014 | | 9.3 | 13.8 | 1002 | 57.5 | 1.4 | 13 | 0.0 |
| 374 | 4/19/2014 | Teddington, Summer | 10.7 | 15.1 | 995 | 68.0 | 1.5 | 34 | 0.0 |
| 375 | 4/20/2014 | | 9.9 | 17.8 | 986 | 90.0 | 0.4 | 38 | 7.6 |
| 376 | 4/21/2014 | | 13.8 | 20.8 | 986 | 80.0 | 0.2 | 348 | 22.9 |
| 377 | 4/22/2014 | | 11.7 | 16.7 | 994 | 81.9 | 0.3 | 165 | 0.0 |
| 378 | 4/23/2014 | | 12.8 | 17.4 | 1000 | 81.2 | 0.3 | 164 | 2.5 |
| 379 | 4/24/2014 | | 13.4 | 19.4 | 996 | 71.8 | 0.4 | 16 | 0.0 |
| 380 | 4/25/2014 | | 10.2 | 14.3 | 989 | 93.3 | 0.5 | 138 | 5.1 |
| 381 | 4/26/2014 | | 12.2 | 16.7 | 984 | 70.4 | 1.4 | 138 | 0.0 |
| 382 | 4/27/2014 | | 12.3 | 15.4 | 987 | 77.1 | 0.8 | 58 | 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] |
|---|---|---|---|---|---|---|---|---|---|
| 383 | 4/28/2014 | Teddington, Summer | 13.0 | 18.4 | 993 | 75.8 | 0.6 | 49 | 0.0 |
| 384 | 4/29/2014 | | 11.6 | 17.7 | 994 | 79.4 | 0.4 | 59 | 0.0 |
| 385 | 4/30/2014 | | 13.6 | 21.6 | 992 | 74.4 | 0.3 | 180 | 5.1 |
| 386 | 5/1/2014 | | 11.5 | 13.9 | 995 | 90.2 | 0.7 | 358 | 12.7 |
| 387 | 5/2/2014 | | 8.5 | 13.1 | 1009 | 69.6 | 1.0 | 16 | 0.0 |
| 388 | 5/3/2014 | | 10.6 | 17.0 | 1008 | 58.7 | 0.3 | 16 | 0.0 |
| 389 | 5/4/2014 | | 11.9 | 19.4 | 1000 | 66.3 | 0.3 | 161 | 0.0 |
| 390 | 5/5/2014 | | 15.3 | 19.1 | 988 | 61.6 | 0.6 | 158 | 0.0 |
| 391 | 5/6/2014 | | 15.0 | 21.7 | 987 | 63.2 | 0.2 | 201 | 0.0 |
| 392 | 5/7/2014 | | 13.4 | 17.2 | 991 | 69.4 | 0.2 | 208 | 2.5 |
| 393 | 5/8/2014 | | 13.5 | 16.4 | 988 | 83.9 | 0.2 | 211 | 2.5 |
| 394 | 5/9/2014 | | 14.2 | 18.9 | 991 | 68.0 | 0.3 | 209 | 2.5 |
| 395 | 5/10/2014 | | 12.1 | 18.5 | 983 | 71.6 | 0.5 | 198 | 2.5 |
| 396 | 5/11/2014 | | 11.9 | 16.1 | 988 | 66.8 | 0.2 | 242 | 0.0 |
| 397 | 5/12/2014 | | 12.0 | 19.4 | 994 | 74.9 | 0.2 | 309 | 5.1 |
| 398 | 5/13/2014 | | 11.6 | 17.2 | 1006 | 76.2 | 0.4 | 331 | 0.0 |
| 399 | 5/14/2014 | | 14.2 | 20.4 | 1014 | 62.1 | 0.6 | 346 | 0.0 |
| 400 | 5/15/2014 | | 15.3 | 22.6 | 1015 | 65.2 | 0.1 | 59 | 0.0 |
| 401 | 5/16/2014 | | 17.1 | 24.4 | 1008 | 64.4 | 0.1 | 55 | 0.0 |
| 402 | 5/17/2014 | | 18.5 | 26.5 | 999 | 67.4 | 0.2 | 150 | 0.0 |
| 403 | 5/18/2014 | | 18.7 | 24.5 | 987 | 57.2 | 0.7 | 142 | 0.0 |
| 404 | 5/19/2014 | | 20.0 | 25.3 | 983 | 56.9 | 1.3 | 124 | 0.0 |
| 405 | 5/20/2014 | | 14.9 | 20.3 | 990 | 75.0 | 0.3 | 158 | 0.0 |
| 406 | 5/21/2014 | | 16.0 | 20.1 | 984 | 71.4 | 0.7 | 49 | 7.6 |
| 407 | 5/22/2014 | | 14.6 | 18.3 | 983 | 70.7 | 1.4 | 138 | 5.1 |
| 408 | 5/23/2014 | | 13.7 | 17.6 | 988 | 74.1 | 0.7 | 145 | 10.2 |
| 409 | 5/24/2014 | | 12.7 | 17.1 | 994 | 75.1 | 0.6 | 163 | 0.0 |
| 410 | 5/25/2014 | | 13.1 | 19.6 | 1000 | 69.9 | 0.3 | 161 | 5.1 |
| 411 | 5/26/2014 | | 11.9 | 13.3 | 997 | 93.2 | 0.5 | 324 | 2.5 |
| 412 | 5/27/2014 | | 11.2 | 13.4 | 994 | 94.4 | 0.8 | 318 | 15.2 |

**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] |
|---|---|---|---|---|---|---|---|---|---|
| 413 | 5/28/2014 | Teddington, Summer | 13.9 | 16.8 | 993 | 89.4 | 0.1 | 46 | 0.0 |
| 414 | 5/29/2014 | | 15.6 | 19.3 | 999 | 76.3 | 0.8 | 54 | 0.0 |
| 415 | 5/30/2014 | | 13.2 | 19.3 | 1006 | 71.0 | 0.5 | 40 | 0.0 |
| 416 | 5/31/2014 | | 16.1 | 20.7 | 1004 | 65.3 | 0.3 | 333 | 0.0 |
| 417 | 6/1/2014 | | 18.1 | 24.9 | 1000 | 60.5 | 0.1 | 351 | 0.0 |
| 418 | 6/2/2014 | | 16.4 | 23.2 | 996 | 74.3 | 0.1 | 174 | 0.0 |

# Annex 2:

# Methods used for filter weighing

## A.1 Performance of weighing

Weighing takes place in an air-conditioned weighing chamber. Conditions are as follows: 20 °C ±1 °C and 50% ±5% rel. humidity and thus meet the requirements of EN 14907.

Filters for the field test are weighed manually. For further processing, filters incl. the control filters are placed sieves to avoid cross-loading.
Conditions for initial and back weighing had previously been defined and are in line with the standard.

| Before sampling = initial weighing | After sampling = back weighing |
|---|---|
| Processing 48 hours + 2 hours | Processing 48 hours + 2 hours |
| Filter weighing | Filter weighing |
| additional processing 24 hours + 2 hours | additional processing 24 hours + 2 hours |
| Filter weighing and immediate packaging | Filter weighing |

The balance is available ready for operation at all times. The balance is calibrated before every weighing series. If everything turns out to be okay, the reference with is weighed against the calibration weight of 200 mg and peripheral parameters are recorded. Deviations from the previous weighing meet the standard's requirements and do not exceed 20 µg (see Figure 102). The six control filters are weighed this way. For control filters deviating by more than 40 µg a warning is displayed on the evaluation page. This filters are not used for back weighing. The first three flawless control filters are used for back weighing, remaining filters remain safely stored in their can to be used in the event the first three filters are damaged or experience excessive deviations. Figure 103 presents the exemplary trend over a period of four weeks.

Filters, for which there is a difference or more than 40 µg between the first and the second weighing, are not used for initial weighing. For back weighing, filters with differences exceeding 60 µg are removed from the evaluation as required by the standard.

Weighed filters are separately kept in polystyrene boxes for transports to and from the measurement site and for storage. The box is not opened until the filter is inserted in the filter cartridge. Virgin filters can be stored in the weighing chamber up to 28 days until sampling. Should this period be exceeded, initial weighing will be repeated.

Deposited filters can be stored for a maximum of 15 days at temperatures up to 23°C. Filters are stored in a fridge at 7°C.

## A2 Evaluation of the filters

Filters are evaluated using a correction term. The purpose of this corrective calculation is to minimise changes in the mass as a result of conditions in the weighing chamber.

Equation:

$$Dust = MF_{rück} - ( M_{Tara} \times ( MKon_{rück} / MKon_{hin} ) ) \qquad (F1)$$

$MKon_{hin}$ = mean mass of the 3 control filters determined on 48 h and 72h initial weighing

$MKon_{rück}$ = mean mass of the 3 control filters determined on 48 h and 72 h back weighing

$M_{Tara}$ = mean mass of the filter determined on 48 h and 72 h initial weighing

$MF_{rück}$ =mean mass of the filter determined on 48 h and 72 h back weighing

Dust = corrected dust load on the filter

The corrective calculation proved to render the method independent of the conditions in the weighing chamber. This way, the influence of water contents on the filter mass comparing virgin and deposited filters can be controlled and does not influence the dust concentrations deposited on the used filters. This is sufficient to meet the requirements of EN 14907, chapter 9.3.2.5.

The exemplary trend for the calibration weight for Nov 2008 to Feb 2009 shows that the permissible difference of 20 µg compared to the previous measurement is not exceeded.

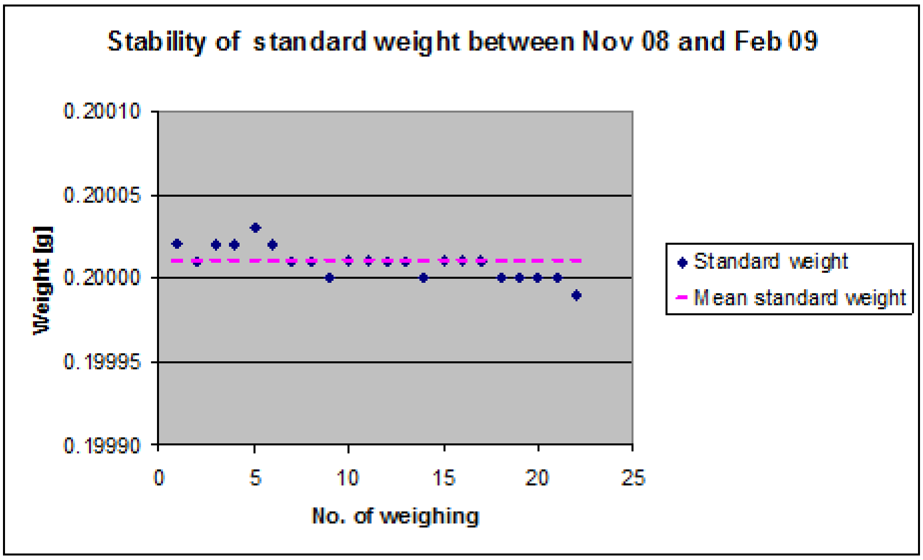



Figure 102: Stability calibration weight

Table 52: Stability calibration weight

| Date | Weighing no. | Standard weight | Difference compared to previous weighing |
|---|---|---|---|
| | | g | µg |
| 12.11.2008 | 1 | 0.20002 | |
| 13.11.2008 | 2 | 0.20001 | -10 |
| 10.12.2008 | 3 | 0.20002 | 10 |
| 11.12.2008 | 4 | 0.20002 | 0 |
| 17.12.2008 | 5 | 0.20003 | 10 |
| 18.12.2008 | 6 | 0.20002 | -10 |
| 07.01.2009 | 7 | 0.20001 | -10 |
| 08.01.2009 | 8 | 0.20001 | 0 |
| 14.01.2009 | 9 | 0.20000 | -10 |
| 15.01.2009 | 10 | 0.20001 | 10 |
| 21.01.2009 | 11 | 0.20001 | 0 |
| 22.01.2009 | 12 | 0.20001 | 0 |
| 29.01.2009 | 13 | 0.20001 | 0 |
| 30.01.2009 | 14 | 0.20000 | -10 |
| 04.02.2008 | 15 | 0.20001 | 10 |
| 05.02.2009 | 16 | 0.20001 | 0 |
| 11.02.2009 | 17 | 0.20001 | 0 |
| 12.02.2009 | 18 | 0.20000 | -10 |
| 18.02.2009 | 19 | 0.20000 | 0 |
| 19.02.2009 | 20 | 0.20000 | 0 |
| 26.02.2009 | 21 | 0.20000 | 0 |
| 27.02.2009 | 22 | 0.19999 | -10 |

Marked yellow = mean
Marked green = lowest value
Marked blue = highest value

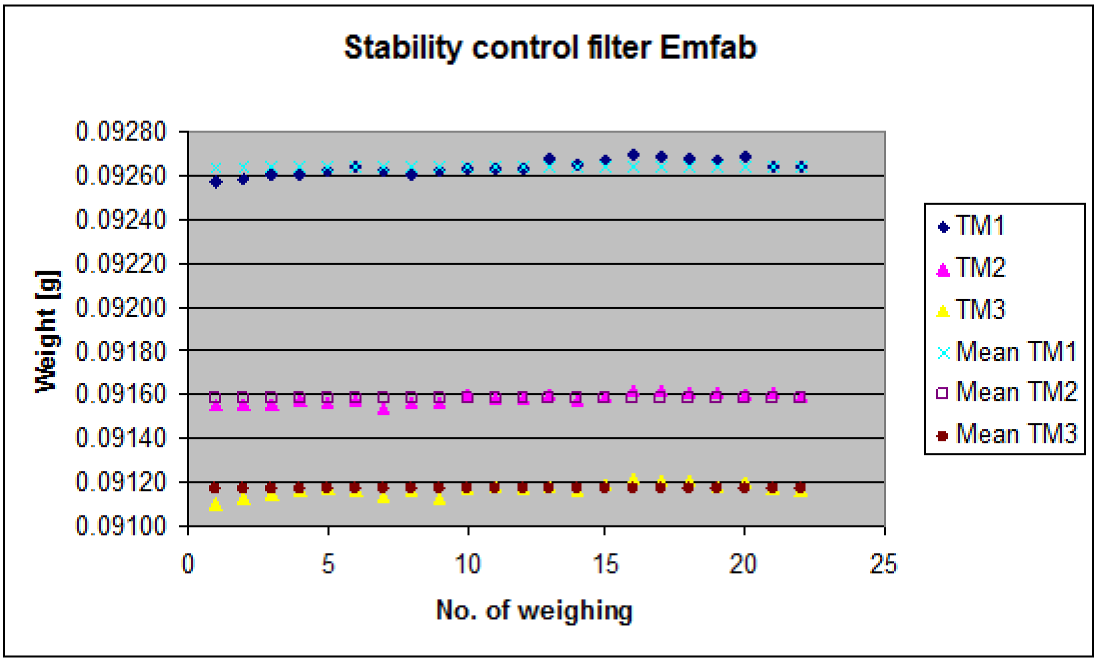



Figure 103: Stability of the control filter

Table 53: Stability of the control filter

| | Control filter no. | | |
|---|---|---|---|
| Weighing no. | TM1 | TM2 | TM3 |
| 1 | 0.09257 | 0.09155 | 0.09110 |
| 2 | 0.09258 | 0.09155 | 0.09113 |
| 3 | 0.09260 | 0.09155 | 0.09115 |
| 4 | 0.09260 | 0.09157 | 0.09116 |
| 5 | 0.09262 | 0.09156 | 0.09117 |
| 6 | 0.09264 | 0.09157 | 0.09116 |
| 7 | 0.09262 | 0.09154 | 0.09114 |
| 8 | 0.09260 | 0.09156 | 0.09116 |
| 9 | 0.09262 | 0.09156 | 0.09113 |
| 10 | 0.09263 | 0.09160 | 0.09117 |
| 11 | 0.09263 | 0.09158 | 0.09118 |
| 12 | 0.09263 | 0.09158 | 0.09117 |
| 13 | 0.09267 | 0.09160 | 0.09118 |
| 14 | 0.09265 | 0.09157 | 0.09116 |
| 15 | 0.09266 | 0.09159 | 0.09119 |
| 16 | 0.09269 | 0.09162 | 0.09122 |
| 17 | 0.09268 | 0.09162 | 0.09121 |
| 18 | 0.09267 | 0.09161 | 0.09121 |
| 19 | 0.09266 | 0.09161 | 0.09118 |
| 20 | 0.09268 | 0.09160 | 0.09120 |
| 21 | 0.09264 | 0.09161 | 0.09117 |
| 22 | 0.09264 | 0.09159 | 0.09116 |
| | | | |
| | | | |
| Average | 0.09264 | 0.09158 | 0.09117 |
| Standard dev. | 3.2911E-05 | 2.4937E-05 | 2.8558E-05 |
| rel. Standard dev. | 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 yellow = mean
Marked green = lowest value
Marked blue = highest value

# Appendix 3

## Manuals