TÜV RHEINLAND
ENERGIE UND UMWELT GMBH

Report on type approval testing of the F-701-20 measuring system with $PM_{2.5}$-pre-separator manufactured by DURAG GmbH for the component suspended particulate matter $PM_{2.5}$

TÜV-report: 936/21220478/A
Cologne, 17th March 2014

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- 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;
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according to EN ISO/IEC 17025.

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Report on type approval testing of the F-701-20 measuring system with $PM_{2.5}$-pre-separator manufactured by DURAG GmbH for the component suspended particulate matter $PM_{2.5}$

Instrument tested:	F-701-20 with $PM_{2.5}$-pre-separator
Manufacturer:	DURAG GmbH Kollaustraße 105 22453 Hamburg Germany
Test period:	December 2012 until March 2014
Date of report:	17th March 2014
Report number:	936/21220478/A
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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" [4] 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:

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

as well as for the calculations according to the Guide [4]

	$PM_{2.5}$
Limit value	30 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} (for comparison)**
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.

DURAG GmbH has commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out a type approval test of the F-701-20 measuring system for the component suspended particulate matter $PM_{2.5}$.

- 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]
- 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 [3]
- Guidance document “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of January 2010 [4]

The measuring system F-701-20 operates according to the principle of radiometric measurement. By means of a pump ambient air is sucked in via a $PM_{2.5}$-sampling inlet (sample flow 16.67 l/min). The dust-laden sampling air is then sucked onto a filter tape. The determination of the collected dust mass on the filter tape is carried out after each sample by the radiometric measuring principle of beta attenuation.

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

	Bonn, street crossing, winter	Bornheim, motorway parking area, summer	Cologne, parking lot, autumn	Cologne, parking lot, winter
Period	02/2013 – 05/2013	05/2013 – 07/2013	09/2013 – 12/2013	01/2014 – 03/2014
No. of paired values: candidates	61	68	85	52
Characteristics	Influenced by traffic	Rural structure + motorway	Urban background	Urban background
Level of ambient air pollution	Average to high	Low to average	Average	Average

The minimum requirements were fulfilled during type approval 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 for suspended particulate matter $PM_{2.5}$.

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:

F-701-20 with $PM_{2.5}$-pre-separator for suspended particulate matter $PM_{2.5}$

Manufacturer:

DURAG GmbH, Hamburg

Field of application:

Continuous measurement of the $PM_{2.5}$ fraction in ambient air (stationary operation).

Measuring ranges during type approval testing:

Component	Certification range	Unit
$PM_{2,5}$	0 – 1.000	µg/m³

Software version:

3.10

Restrictions:

None

Notes:

1. The requirements according to the guide “Demonstration of Equivalence of Ambient Air Monitoring Methods” are met for the measured component $PM_{2.5}$.
2. During the type approval testing, the cycle time was 1 h and the sample count was 24, i.e. an automatic filter change was carried out every hour, at which each filter spot has been sampled upon up to maximum 24times.
3. The measuring system shall be operated with an actively ventilated sampling system without sample tube heater.
4. The measuring system shall be operated in a lockable measuring cabinet.
5. The measuring system shall be calibrated on site with the gravimetric $PM_{2.5}$ reference method as per EN 14907 on a regular basis.
6. This report on the type approval testing can be viewed on the internet at www.qal1.de.

Test report:

TÜV Rheinland Energie und Umwelt GmbH, Cologne

Report no.: 936/21220478/A of 17th March 2014

1.3 Summary of test results

Performance criterion	Specification	Test result	Ful-filled	Page
4 Requirements on instrument design				
4.1 General requirements				
4.1.1 Measured value display	Shall be available.	The measuring system has got a measured value display.	yes	57
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	60
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	63
4.1.4 Setup times and warm-up times	Shall be specified in the instruction manual.	Setup and warm-up times were determined.	yes	65
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	66
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. In addition, the AMS shall be locked up in a measuring cabinet.	yes	67
4.1.7 Data output	The output signals shall be provided digitally and/or as analogue signals	The test signals are provided analogue (in mA) and digitally (via RS232).	yes	68

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	70
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	71
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.	A measuring range of 0 – 1000 µg/m³ is set as standard. Other measuring ranges are possible. The upper limit of the measuring range of the measuring system is greater than the respective upper limit of the certification range.	yes	72
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 are output correctly via corresponding data outputs.	yes	73
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 start point of the next measurement cycle (during the type approval test after reaching the next full hour).	yes	74
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 from an external PC via modem or router.	yes	75
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.	The switch-over between measurement and functional check (here: internal zero point and reference point measurement) can be initiated telemetrically or manually.	yes	77
5.2.7 Maintenance interval	If possible 3 months, minimum 2 weeks.	The maintenance interval is determined by the necessary maintenance work and is 4 weeks.	yes	78

Performance criterion	Specification	Test result	Fulfilled	Page
5.2.8 Availability	Minimum 95 %.	The availability was 100 % for SN 1512361 and 99.7 % for SN 1512401 without test-related downtimes. Including test-related downtimes it was 92.0 % for SN 1512361 and 92.0 % for SN 1512401.	yes	79
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 shown on the display. The test institute is informed on any changes in the instrument software.	yes	81
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	83
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 0.66 µg/m³ for System 1 (SN 1512361) and 0.75 µg/m³ for System 2 (SN 1512401).	yes	85
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.	-	87

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 $PM_{2.5}$ shall be tested according to performance criterion 5.4.10 "Calculation of expanded uncertainty between systems under test".	-	88
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.	-	89
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.	-	90
5.3.7 Sensitivity coefficient of surrounding temperature	The sensitivity coefficient of the surrounding temperature at zero and reference point shall not exceed the specifications of Table 2 of VDI Standard 4202, Sheet 1 (September 2010). For PM: Zero point value for ΔTu of 15 K between +5 °C and +20 °C or 20 K between +20 °C and +40 °C shall not exceed B_0. The measurement value in the range of B_1 shall not exceed ± 5 % for ΔTu of 15 K between +5 °C and +20 °C or for 20 K between +20 °C and +40 °C	The maximum dependence of ambient temperature in the range of +5 °C to +40 °C at zero was -1.0 µg/m³. At reference point, no deviations > 3.0 % in relation to the default value at the temperature of 20 °C were observed.	yes	91

Performance criterion	Specification	Test result	Fulfilled	Page
5.3.8 Sensitivity coefficient of supply voltage	The sensitivity coefficient of the electric voltage at reference point shall not exceed the specifications made in Table 2 of VDI Standard 4202, Sheet 1 (September 2010). For PM: Change in measured value at B_1 maximum B_0 within the voltage interval (230 +15/-20) V.	No deviations > -1.4 % for $PM_{2.5}$ in relation to the default value at the mains voltage 230 V due to changes in supply voltage were detected.	yes	94
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.	-	96
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.	-	97
5.3.11 Standard deviation from paired measurements	The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test. It shall not exceed the specifications stated in Table 2 of VDI Standard 4202, Sheet 1 (September 2010). For PM: RD $\geq$ 10 related to B_1.	In the field test, the reproducibility for the full dataset was 21 for $PM_{2.5}$.	yes	98

Performance criterion	Specification	Test result	Fulfilled	Page
5.3.12 Long-term drift	The long-term drift at zero point and reference point shall not exceed the requirements of Table 2 in the field test of VDI Standard 4202, Sheet 1 (September 2010) in the field test. For PM: Zero point: within 24 h and within the maintenance interval a maximum of B0. As reference point: within 24 h and within the maintenance interval a maximum 5 % of B1.	The maximum deviation at zero point was 1.5 µg/m³ in relation to the previous value and 1.7 µg/m³ in relation to the start value. The sensitivity drift values that were determined during testing are max. -2.7 % for $PM_{2.5}$ in relation to the respective start value.	yes	100
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.	-	106
5.3.14 Response time	The response time (rise) of the measuring systems shall not exceed 180 s. The response time (fall) of the measuring systems shall not exceed 180 s. The difference between the response time (rise) and response time (fall) of the measuring system shall not exceed 10 % of response time (rise) or 10 s, whatever value is larger.	Not applicable.	-	107

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.	-	108
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.	-	109
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.	-	110
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.	-	111
5.4 Requirements on measuring systems for particulate air pollutants				
5.4.1 General	Test according to the minimum requirement stated in Table 5 of VDI Standard 4202, Sheet 1. Furthermore, the particle mass concentration shall be related to a defined volume.	The test was carried out according to the minimum requirements set out in Table 5 of VDI Standard 4202, Sheet 1 (September 2010). The determined mass is related to a defined and actively controlled sample volume and thus the particulate mass concentration is determined.	yes	112

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.	Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.10 in this report.	-	113
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].	Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.9 in this report.	-	114
5.4.4 Calibration	The systems under test 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	115
5.4.5 Cross sensitivity	Shall not exceed 10 % of the limit value.	No deviation of the measured signal from the nominal value > -0.6 µg/m³ caused by interference due to moisture in the sample could be observed for $PM_{2.5}$. No negative influence on the measured values at varying relative humidity was detected during the field test. The comparability of the candidates with the reference method according to the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" [4] is ensured even for days with a relative humidity of > 70 %.	yes	117
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.	With the described instrument configuration and a measurement cycle of 1 h with a sample count of 24, the measuring system allows the formation of daily mean values based on 24 measurement cycles.	yes	120

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	122
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. 10 l/h) proved to be an appropriate parameter for monitoring instrument tightness. The detected maximum leak rate of 1 l/h is less than 1 % of the nominal flow rate of 1000 l/h (16.67 l/min).	yes	125
5.4.9	Determination of uncertainty between systems under test 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 $PM_{2.5}$ does not exceed the required value of 2.5 µg/m³.	yes	128
5.4.10	Calculation of expanded uncertainty between systems under test	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 WCM for all datasets under consideration lie below the defined expanded relative uncertainty Wdqo of 25 % for suspended particulate matter without application of correction factors.	yes	135
5.4.11	Application of correction factors and terms	If the maximum expanded uncertainty of the systems under test exceeds the data quality objectives according to the European Directive on ambient air quality [7], 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".	The candidates meet the requirements on data quality of ambient air quality measurements already without application of correction factors. A correction of the slope and the intercept nevertheless leads to a further significant improvement of the expanded measurement uncertainties of the full data set.	yes	149
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.	Not applicable.	-	155

2. Task definition

2.1 Nature of test

DURAG GmbH has commissioned TÜV Rheinland Energie und Umwelt GmbH to carry out type approval testing of the F-701-20 measuring system with $PM_{2.5}$-pre-separator. The test was performed as a complete type approval test.

2.2 Objective

The measuring system shall determine the concentration of suspended particulate matter $PM_{2.5}$ within a concentration range of 0 to 1.000 µg/m³.

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 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 [3]
- Guidance document “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English Version: January 2010 [4]

3. Description of the AMS tested

3.1 Measuring principle

The ambient air measuring system F-701-20 is based on the measuring principle of beta attenuation.

The air volume is sucked through a glass fiber tape (GF), which separates out the dust particles onto the filter. The volumetric flow is controlled and recorded by a microcontroller. After the intake time, the mass collected on the filter is measured radiometrically. A measuring setup consisting of a Beta radiation source (C-14) and a Geiger Mueller counter tube (GM) is used to do this.
The measuring principle for determining the dust mass is based on the fact that Beta rays are weakened as they pass through a material. The intensity of the radiation (pulses/ measuring time) is initially assessed after the rays pass through the unused filter paper. Once it has collected the dust, the intensity of the radiation is measured again. The ratio of the two intensity values is a measure of the quantity of dust collected on the filter spot (assuming homogeneous distribution on the filter surface) and, with a constant cross-sectional area of the loaded filter spot, a measure of the absolute dust mass. The absolute dust mass divided by the quantity of air taken in then gives the dust concentration.
The radiometric measuring method is universally applicable, as it determines the mass of the dust within wide limits irrespective of the chemical and physical properties of the dust and the carrier gas.
With homogeneous distribution of dust precipitation of the mass m on a filter area A_F, up to 5 mg/cm² the relationship is approximately linear:

$$\ln (n_0/n) = (\mu/\rho) * d$$

where:

$d = m/A_F$	in µg/cm² is the dust surface density with dust precipitation in µg on the constant precipitation area in cm²
μ/ρ	in cm² /g is the mass attenuation coefficient
μ	in cm^{-1} is the linear attenuation coefficient of the Beta radiation used
ρ	in g/cm³ is the density of the absorber material
n_0 and n	are the Beta particles detected by the counter per minute, without or with the dust, registered electronically as voltage pulses. The pulse rate is a measure of the radiation intensity.

The mass attenuation coefficient μ/ρ of the Beta radiation used depends on the electron density of the absorber and is thus proportional to the ratio (Z/A).

where: Z Chemical atomic number
A Mass number

However, as the ratio (Z/A) = 0.45 … 0.5 is approximately constant for most dusts that occur, in practical terms the Beta radiation attenuation is independent of the chemical composition and particle size distribution of the dust.

If the filter area remains constant, because (µ/ρ) = constant the dust mass precipitated on the filter A can be calculated from the radiation attenuation using the following equation:

$$m = A_F * (\rho/\mu) * \ln (n_0/n)$$

where: m Absolute dust mass in g

A_F Filter area in cm²

As the mass attenuation coefficient (µ/ρ) increases as the maximum Beta energy decreases, determination of mass by Beta absorption measurement is more sensitive the weaker the energy of the Beta radiation used.

The dust concentration is calculated from the absolute mass divided by the air volume taken in:

$$c = m / Q$$

where: c Dust concentration in g/m³

Q Intake air volume in m³

3.2 Principle of operation

The ambient air measuring system F-701-20 is based on the measuring principle of beta attenuation.

The particulate sample passes the $PM_{2.5}$ sampling inlet with a sample flow rate of 1 m³/h (=16.67 l/min) and reaches the measuring device F-701-20 via the sampling tube.

Within the scope of the type approval test, the measuring systems were operated with an actively ventilated sample inlet tube and without sample tube heating. When using the actively ventilated sampling inlet tube, ambient air is carried continuously through the outer sheath tube via a fan unit, so that the sample inlet tube itself inside is kept at the ambient air temperature level up to the measuring part in the device. The power supply of the fan unit is carried out by the device itself. An additional passive insulation of the outer tube can be helpful in case of extreme differences between ambient temperature and temperature at the installation site of the device.

The measuring system itself is constructed in a compact way (refer to Figure 1). Except for the sampling tube (sample inlet tube, sampling head), the meteorological sensor for the measurement of the ambient pressure and the ambient temperature and the set-up of the active ventilation of the sample inlet tube, all components are installed in one housing.

The measuring device is controlled by a microcontroller board.

The filter tape is transported from the supply reel to the take-up reel by a stepper motor. The Geiger Mueller counter tube uses the attenuation of the radiation intensity emitted by the C-14 radiation source to determine the increase in mass on the filter paper. The air is taken in by the pump, and the volumetric flow is measured by the volume sensor and regulated to a constant 1000 l/h by adjusting the bypass valve to the appropriate position. Electronics control the measuring processes, allowing user-friendly operation on a graphical touchscreen, and store the measured values.

As an option, the device can protect the measured dust samples against smearing and loss with a cover film to allow subsequent laboratory investigation of dust constituents. This option was not included in the type approval test.

During normal measurement, an unloaded filter spot is transported between the C-14 source and the GM counter tube at the beginning of the measurement. The beam intensity is then measured for 300 seconds, i.e. the pulses generated by the GM counter tube are evaluated as a measure of the detected beta radiation.
The filter adapter is then opened and the filter tape is transported until this evaluated filter area is in the extraction position. The filter adapter is then closed again. The extraction process begins. The extraction time corresponds to the programmed cycle time (minus the measuring times). After completion of sampling, the filter adapter is opened again and the filter paper is moved back to its original position below the counter tube. The filter adapter closes and the beam intensity is measured for another 300 seconds.

The measured count rates are used to determine the dust mass collected on the filter. The dust concentration is calculated using the amount of air extracted, as shown in chapter 3.1.

The sampling time corresponds to the respective programmed cycle time and the programmed sample count minus the measuring time respectively the time for filter tape movements. With the help of the sample count, a multiple sampling on a filter spot can be set. It can be set between 1 (=for each cycle a new filter spot) and 24 (=one filter spot is sampled upon for 24times).

The sampling time is thus:

For cycle time 60 min and sample count 1:

60 min – (2 x 300 s measuring time + 120 s for filter tape movements) = 48 min

In case of a sample count >1, the measurement after sampling serves for the calculation of the measured value of the finished cycle as well as a start measurement for the following cycle, i.e. only one radiometric measurement is necessary per cycle.

During the type approval test a cycle time of 60 min with a sample count of 24 was set. The sampling time is then:

Cycle 1: 60 min – (2 x 300 s measuring time + 120 s for filter tape movements) = 48 min

Cycle 2-24: 60 min – (1 x 300 s measuring time + 120 s for filter tape movements) = 53 min

The measuring results are shown in the display and are also available as a 4-20mA analogue output signal and via the RS232 data interface (e.g. using Bavaria-Hessen protocol / Gesytec). All measured values from the last 9 months are stored and can be viewed on the display or via the serial interface. A download of the measured values, the error messages as well as the system parameters via this interface is easily possible with a terminal software As an option, you can print on the filter paper to identify the collected dust sample (e.g. for dust content analysis). The latter option was not part in the type approval test.

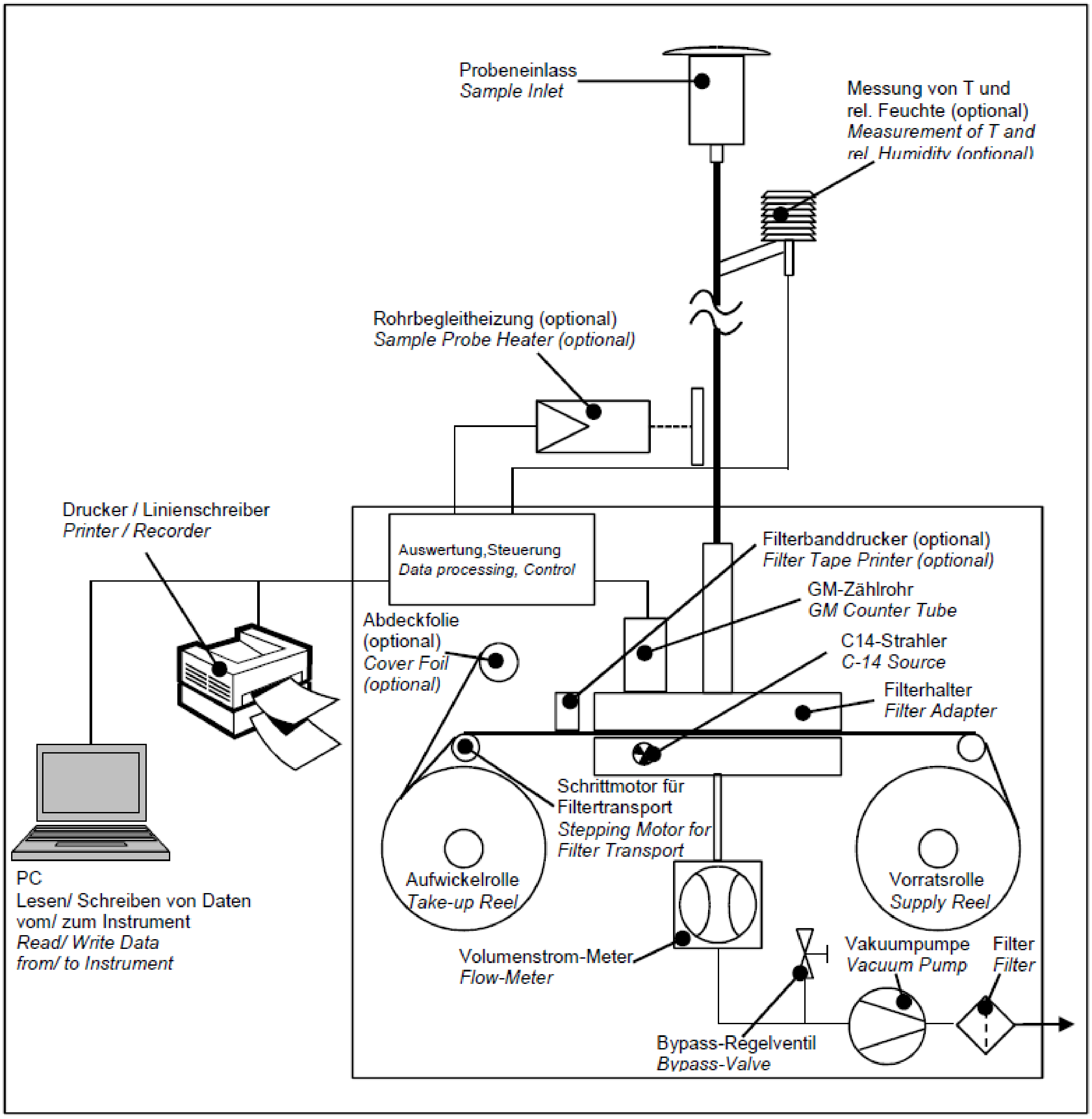


Figure 1: Schematic overview – Set-up of the measuring system F-701-20, here without actively ventilated sampling inlet tube

3.3 AMS scope and setup

The measuring system consists of a $PM_{2.5}$-sampling inlet, the meteorological sensor, the sample inlet tube with active ventilation, the respective measuring F-701-2 incl. the glass fiber filter tape, the corresponding lines and cables as well as adapters, the roof penetration incl. flanges as well as the manual in German / English language.

Figure 2 gives an overview on the measuring system F-701-20.

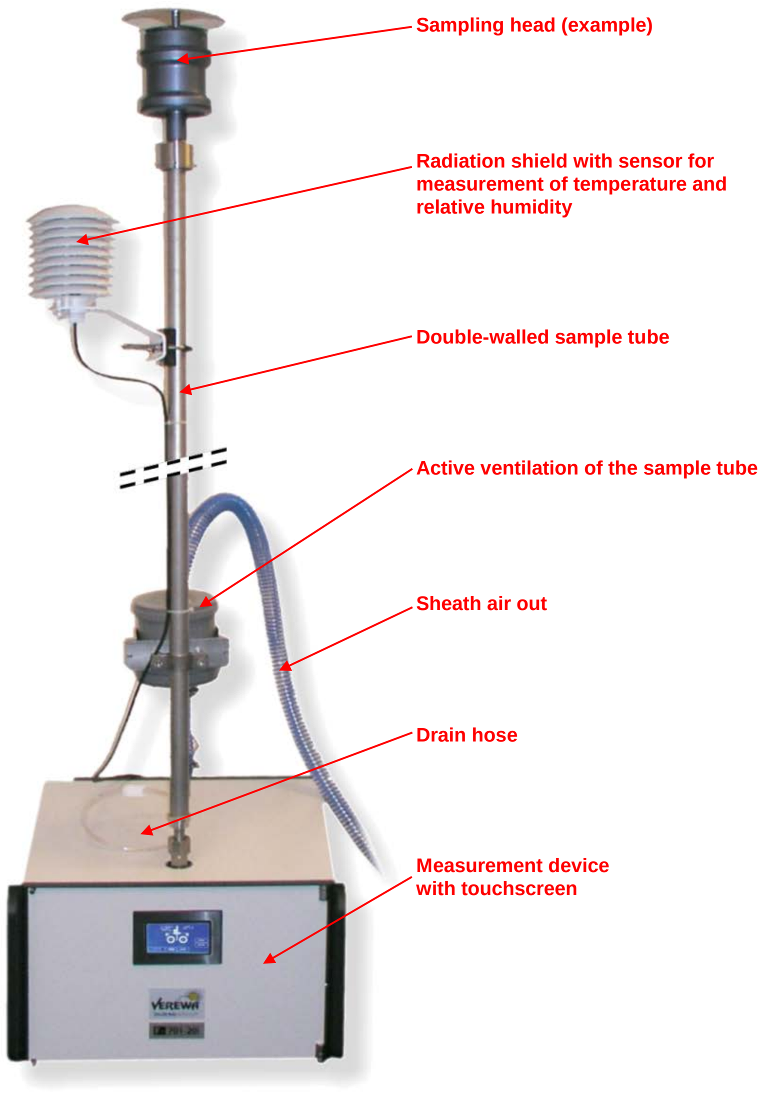


Figure 2: Overview F-701-20

As a sampling inlet, a $PM_{2,5}$ sampling inlet (manufacturer: Comde-Derenda GmbH, Stahnsdorf, Germany) is used. Alternatively also TSP- or PM_{10}-sampling inlets can be used.

Figure 3: Sampling inlet $PM_{2,5}$

The connection between sampling inlet and measuring device is carried out with an actively ventilated sampling inlet tube. When using the actively ventilated sampling inlet tube, ambient air is carried continuously through the outer sheath tube via a fan unit, so that the sample inlet tube itself inside is kept at the ambient air temperature level up to the measuring part in the device. The length of the sampling inlet tube during the type approval test was 2 m, alternatively also standard lengths of 1 m and 3 m are available.

Figure 4: Active ventilation of the sampling system during field test

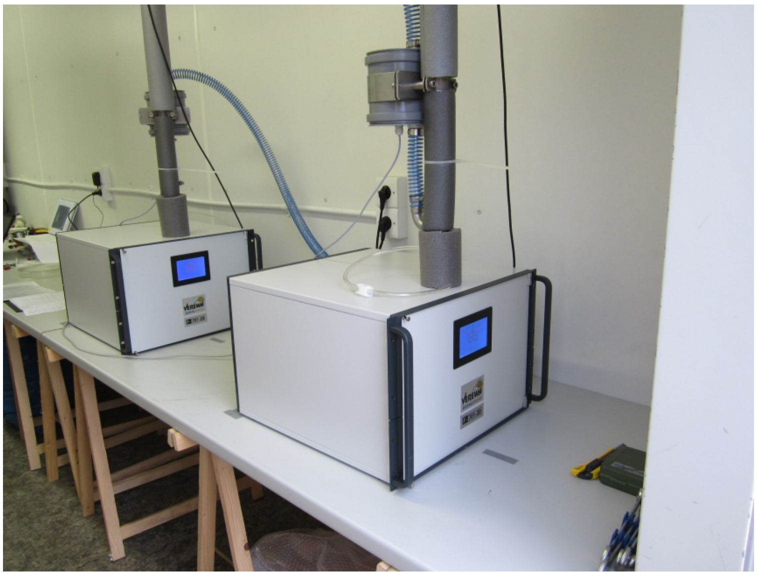


Figure 5: F-701-20 during field test

For external check of the zero point of the measuring system, a zero filter is mounted at the device inlet. The use of that filter allows the provision of particulate-free air.

Figure 6: Zero filter for provision of particulate-free air, during field test

For external check of the radiometric measurement, the instrument manufacturer provides a reference foil.

Figure 7: Reference foil

The operating of the measuring system is carried out on the front of the measuring device via a touchscreen-display. The user can obtain measured data and system information, change parameters as well as perform tests for check on proper functioning of the measuring system.

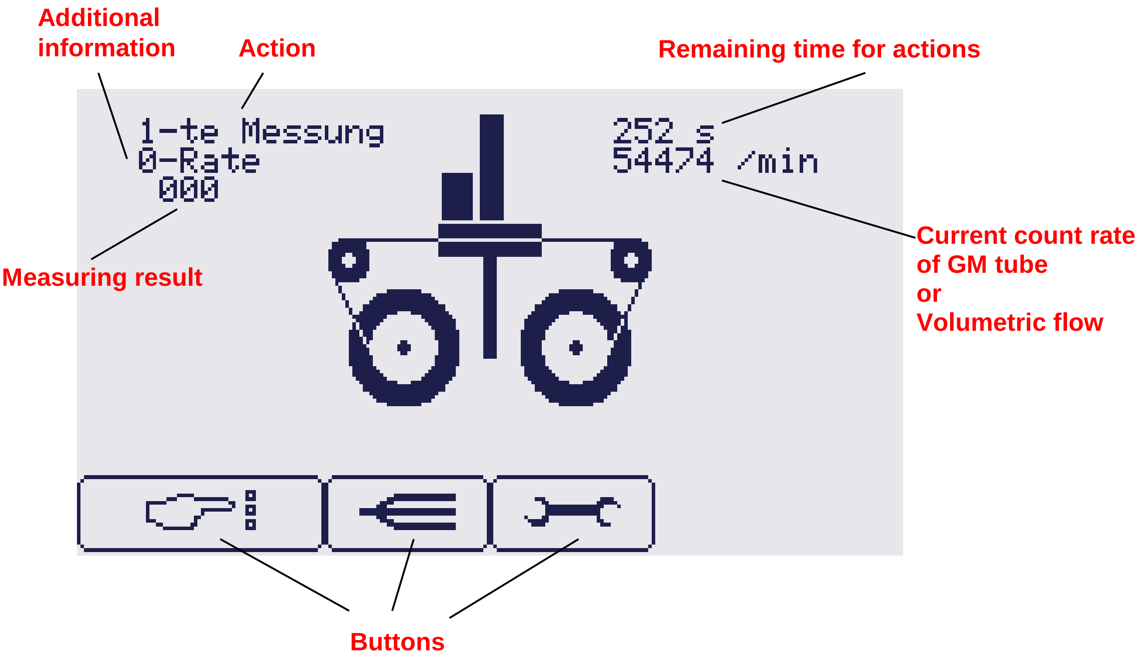
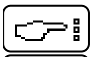


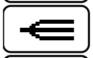
Figure 8: Main menu F-701-20

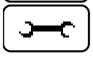
After switching on the instrument, the main menu appears. Different information is displayed here, as

- Current instrument status (measurement; n-th measurement (cycle number in case of multiple sampling); standby)
- Additional information e.g. status during current cycle (0-Rate…)

Via three keys, the following actions are available:

 Switch between measuring, data display and setup mode.

 Go to a submenu

 Open maintenance menu

Via the key  it can be switched between the following menus during normal operation:

Measuring mode: Dust measurement and display of results, display of activities, perfor mance of service actions.

Data display mode: Display the measured values in graphs or tables

Setup mode: Display and edit the parameters

In the setup mode, all parameters can be viewed and modified after password entry. Figure 9 gives an overview on the menu structure of the parameters. Single parameters are described in details in the instrument manual in chapter 7.3.3.

Password	Password entry
Measurement	Display the measured / saved values
Parameter	Display and enter the main parameters
Sub parameter	Display and enter the secondary parameters
Adjust	Correct the input and output signals
Interface	Set the interface parameters
Date/Time	Set the date and time
Service	Basic operating functions, troubleshooting

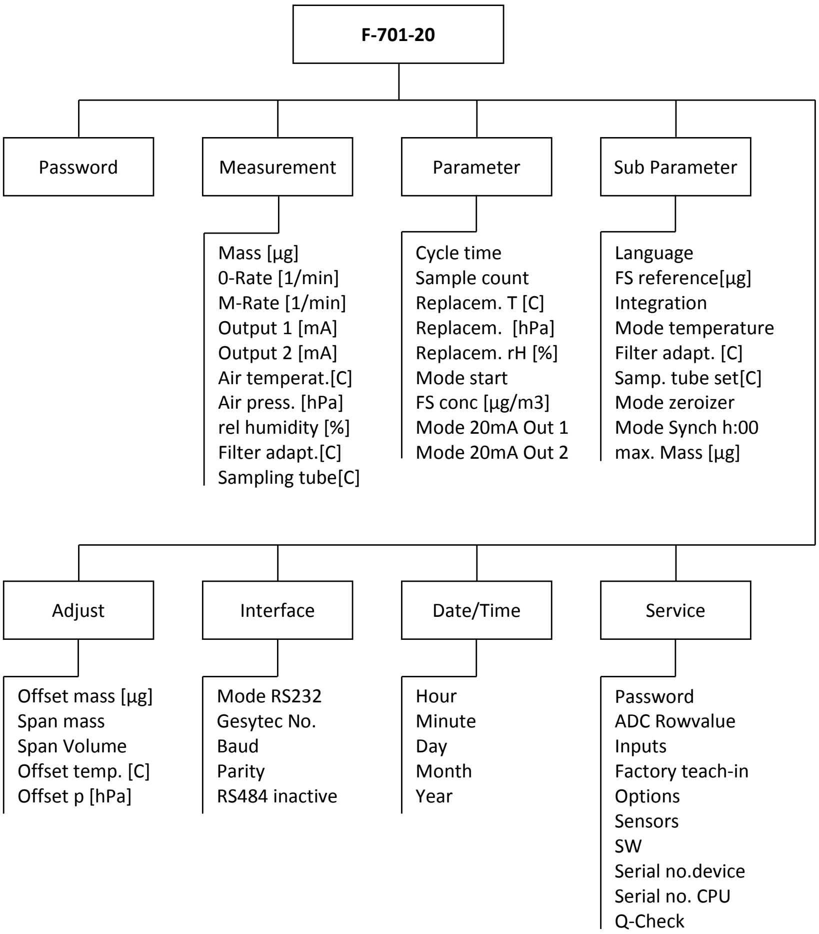
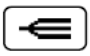
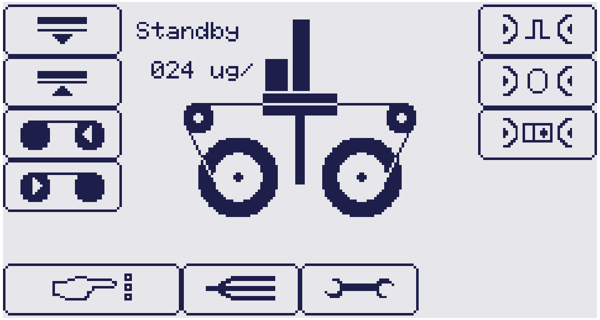


Figure 9: Flow scheme – menu structure for parameters

By pushing the key  , additional information can be obtained, e.g. during measuring mode additional information like standardized volume flow, ambient temperature, rel. humidity and ambient pressure.

By pushing the key [wrench key], the maintenance menu is activated after entry of the respective password. The following actions can be carried out:



	Open filter housing
	Close filter housing
	Filter tape forwards
	Filter tape backwards
	Start reference measurement
	Start zero measurement
	Start reference foil measurement

In manual mode, also:

- Start measurement

Besides the direct communication via touchscreen-display, it is also possible to communicate with the measuring system via RS232. During the type approval test work, the measuring systems have been accessed especially for download of internally saved data via RS232 and the terminal software HyperTerminal.

Figure 10 gives an overview on the parameters of the candidates during the type approval test (with example of device SN 1512361).

```
                                  P_1512361.TXT
Parameter Ausdruck  15.10.13 14:33
-------------------------  Stammdaten:  ---------------------------------------
Beta Staubmeter  F 701-20
Serien Nr.Geraet  1512361  Serien Nr.CPU     1227716
Silicon Serial Number      8A-70-00-00-00-0C-E9-68
SW 3.10

-------------------------  Parameter:  ----------------------------------------
Zykluszeit             1 h  Belegzahl             24  Ersatzwert T [C]      20
Ersatzwert [hPa]      1013  Ersatzwert rF[%]      50  Modus Start       60 Min
MBE/20mA [ug/m3]       200  Modus 20mA Ausg1    conc  Modus 20mA Ausg2    mass

Sprache            Deutsch  MBE Ref/20mA[ug]    1000  Integral               1
Modus Temperatur humidity  Filterh.Soll [C]       3  Rohr    Soll [C]       3
Modus Nullrueck. inactive  Modus Synch h:00      10  Max. Masse [ug]      250

Offset Masse[ug]         0  Span   Masse           1  Span Volumen       0.982
Offset Temp. [C]         1  Offset Druck hPa      -8

Modus RS232       terminal  Gesytec Nr.          123  Baud              9600bd
Parity/Bit          no   8  RS485 inactive

-------------------------  Fertigungseinstellungen:  --------------------------
Offset sc1  [ug]         0  Offset sc2-n[ug]       0  Span Service           1
Offs Fi-Ha[0.1C]         0  Filter adapt.100    4258  Filter adapt.120    9001
Tube heater 100       4240  Tube heater 120     9019  Temperature 100     4271
Temperature 120       9022  Volumesensor 1 V    3278  Volumesensor 5 V   15613
Pressure   4 mA       4024  Pressure 20 mA     15679  Reserve   4 mA      4000
Reserve 20 mA        15000  b 20 mA Out1       0.998  c 20 mA Out1       0.016
b 20 mA Out2         1.001  c 20 mA Out2       0.021

Meldung debounce         0  Beta Sensor      GM tube  Geraetetyp      F701- 20
Filter Motor         micro  Abstand Qu./Rohr    1600  Abstand Flecken     1600
Intell. Korr.     Active 1  ICC Wert            0.39  Vol. GM Quelle       780
Filter Drucker    inactive

Sensor Luft T      meteor.  Sensor Luft p     4/20mA  Druck b            31.25
Druck c                675  Sensor Luft rF   meteor.
```

Figure 10: Overview print out of parameters F-701-20

Table 2 contains a list of important technical specifications of the ambient air measuring system F-701-20.

Table 2: Technical specifications F-701-20 (manufacturer´s information)

Dimensions / Weight	**F-701-20**
Measuring device	482 x 530 x 320 mm / 31 kg
Sampling tube	Single- or double-walled sampling tube, length 1 , 2 m or 3 m
Sampling inlet	According to manufacturer, during type approval test Comde-Derenda GmbH, sampling inlet PM2,5 1,0m³/h for tube connection 16 mm
Power supply	Analyser: 230 V / 50 Hz or 115 V / 60 Hz
Power consumption	approx. 400 W
Ambient conditions	
Temperature	+5 to +40 °C (during type approval test)
Humidity	Non-condensing
Sample flow rate (Inlet)	16.67 l/min = 1 m³/h
Radiometry **Source**	^{14}C-surface emitting source, <450 kBq (< 12,5 µCi)
Detector	Geiger-Müller-end window counter tube
Parameter filter change	
Filtertape	Glass fiber filter, 30 m or 45 m
Measuring cycle (cycle time)	15 min - 24 h During type approval test: 1 h (24 changes per day)
Sample count (Multiple sampling)	1 – 24 During type approval test: 24 (max. 24 cycles per filter spot)
Max. dust mass per filter spot	Dependent on dust constitution, selectable, during type approval test 400 µg
Parameter sample conditioning	
Conditioning of sampling inlet tube	Active ventilation
Buffer capacity Data (internal)	Dependent on size of SD-card, access via menu directly at device on data over the last 9 months

	F-701-20
Instrument input and -output	Output: Analogue: 4-20 mA Digital RS232
Protocols	Communication with PC via RS232 Bayern-Hessen, Gesytec
Status signals / Error messages	available, overview refer to chapter 6 table 3 (status signals) respectively chapter 11 table 7 (error messages) of the user´s manual

4. Test programme

4.1 General

The type approval test was carried out with two identical devices with the serial numbers SN 1512361 and SN 1512401.

The test was started in December 2012 with the software version 3.07. Within the frame work of the software maintenance process, the software was in the meanwhile developed and optimised up to version 3.10. The manufacturing site of the instrument manufacturer DURAG GmbH in Hamburg, Germany is part of the regular surveillance according to Standard EN 15267-2 since 2010. Since 2013 also the measuring system F-701-20 is covered in the audit scope. According to the requirements of the Standard EN 15267-2, the applied modifications of the software have been described, assessed, the type of modification classified and the information submitted to the test house.

The following modifications to the software between version 3.07 and 3.10 have been applied in detail:

Table 3: Overview on software versions during the type approval test

Version	Description of modifications	Type of modification	Assessment test house
3.07	Start version	-	-
3.10	A software dongle was implemented to hinder copying of hardware.	Functional extension	No impact
	The time, shown on the display, can also be shown with seconds.	Functional extension	No impact
	For the parameter „Cycle time“, the value „1/2 h“ was not permanently saved (all other settings worked flawless). Instead the cycle time was 1 h after switching on. The error was corrected.	Bug elimination	No impact
	Renaming parameter „Modus Start h:00“ to „Modus Synch h:00“	Cosmetic	No impact
	Parameter „Steps sens./tube“ and „Pitch dust spot“ moved from menu point „Sub Parameter“ to „Service/Options“.	Cosmetic	No impact

3.10	The parameter Q-Check is not delivered anymore when reading out the parameters via the serial interface	Cosmetic	No impact
	During the „switch-on“-message on the display, the date of the software version is not displayed anymore (it could cause confusion with the current date)	Cosmetic	No impact

The applied modifications are for functional extensions, bug elimination and for cosmetic maintenance. They don´t have any impact on the measuring system.

With the start of the third of in total four comparison campaigns, the software version was upgraded from 3.07 to 3.10 and the instruments were operated with this software for the comparison campaigns Cologne, autumn and Cologne, winter.

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).

In the following report, the performance criteria according to the considered standards [1, 2, 3, 4] 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 F-701-20 with the serial numbers SN 1512361 and SN 1512401. 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

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
- Reference foils

The recording of measurement values was performed within the device. The recorded data were read out via RS232 interface with the help of HyperTerminal.

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 1512361
System 2: SN 1512401

The following performance criteria were tested in the field:

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

The following auxiliary devices were used during the field test:

- TÜV Rheinland measuring cabinet, air conditioned to approx. 20 °C
- Weather station (WS 500 of ELV Elektronik AG) 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 $PM_{2.5}$ as per item 5
- 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
- Reference foils

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

During the testing, the impaction plates of the $PM_{2.5}$ sampling inlets 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 $PM_{2.5}$ sampling inlets of the candidates were cleaned approx. every 4 weeks. The sampling inlet 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 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 4: Field test sites

No.	Test site	Period	Characterisation
1	Bonn, road junction, winter	02/2013 – 05/2013	Influence of traffic
2	Bornheim, summer	05/2013 – 07/2013	Rural structure + influence of traffic
3	Cologne, autumn	09/2013 – 12/2013	Urban background
4	Cologne, winter	01/2014 – 03/2014	Urban background

Figure 11 to Figure 14 show the course of PM concentrations at the measuring locations in the field as recorded by the reference measuring systems.

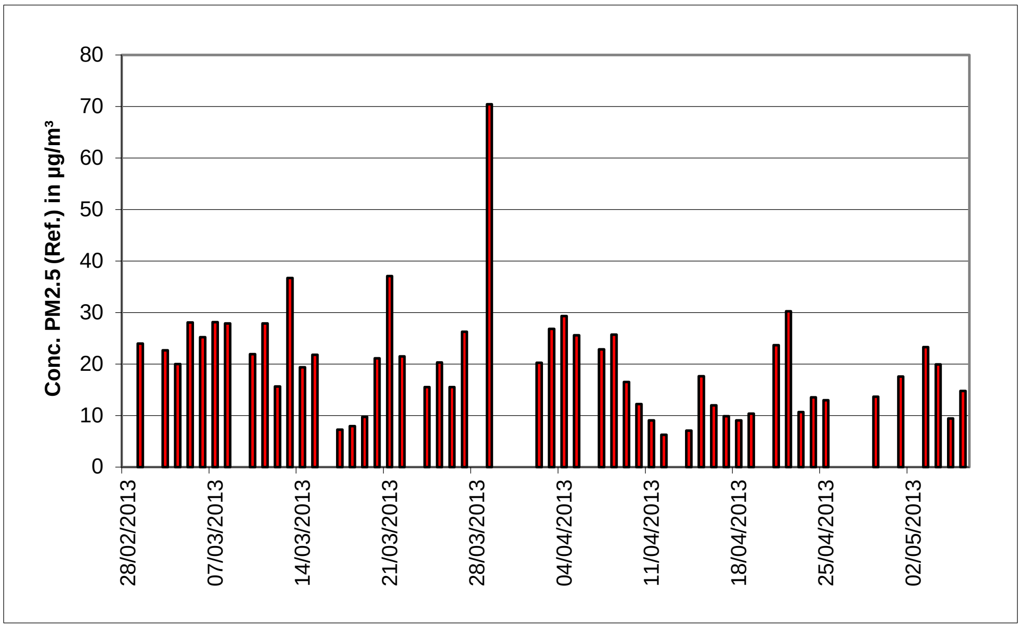


Figure 11: Course of $PM_{2.5}$ concentrations (reference) at test site "Bonn, road junction, winter"

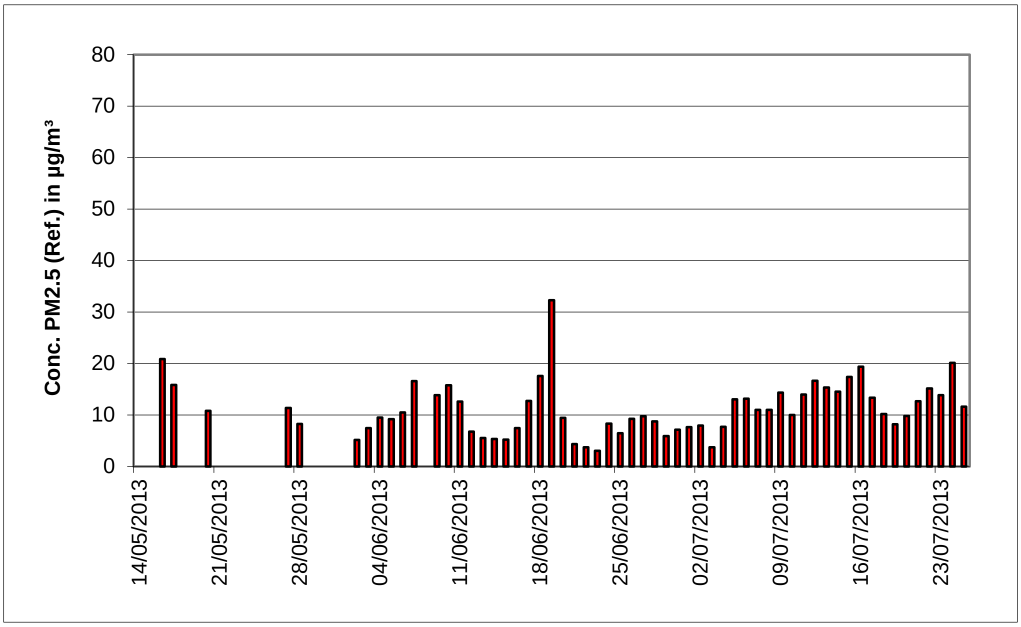


Figure 12: Course of $PM_{2.5}$ concentrations (reference) at test site "Bornheim, summer"

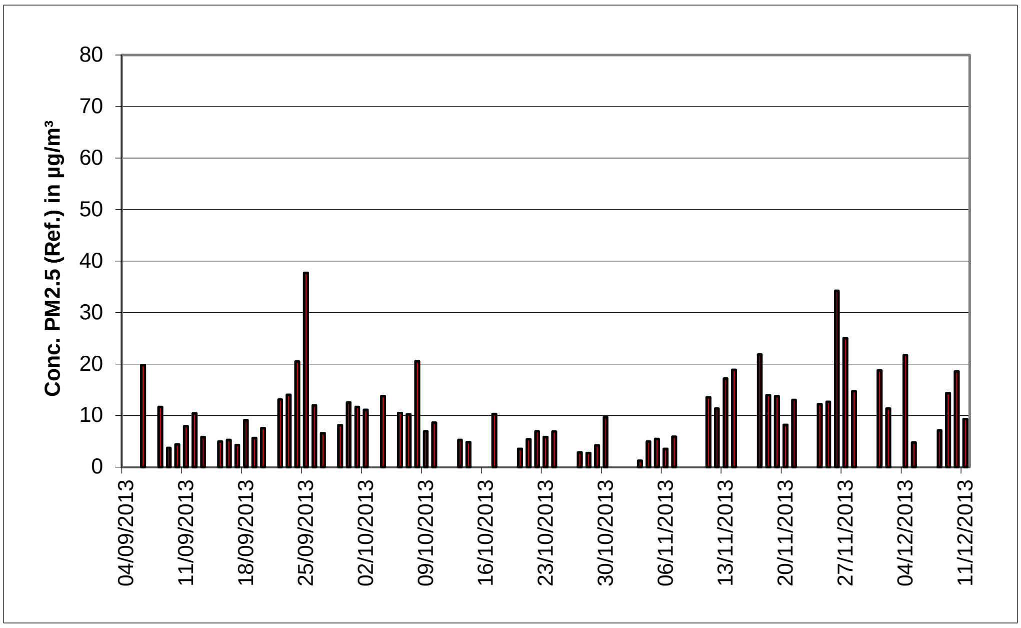


Figure 13: Course of $PM_{2.5}$ concentrations (reference) at test site "Cologne, autumn"

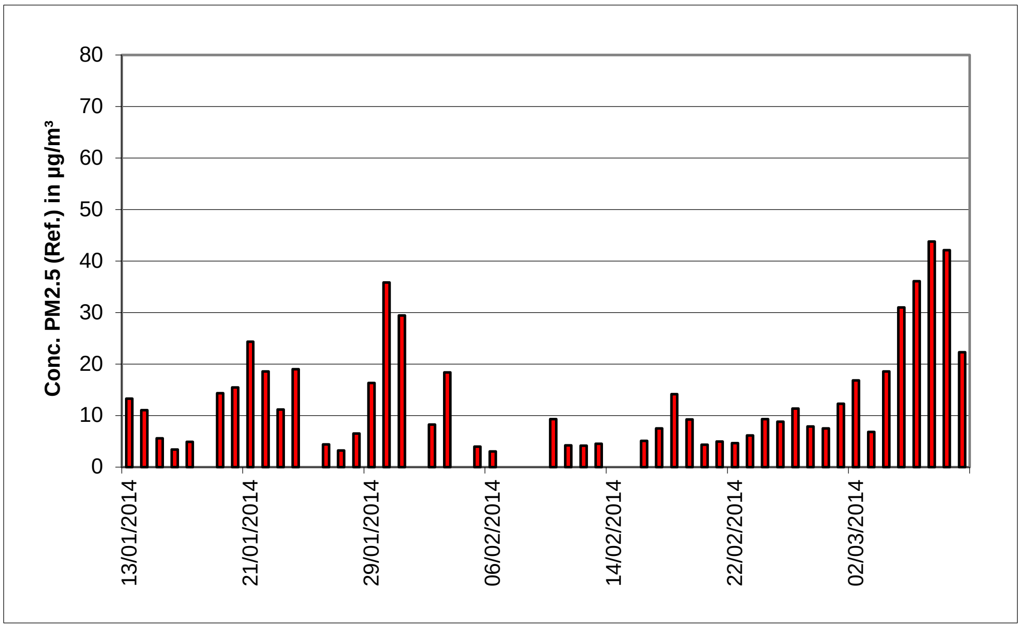


Figure 14: Course of $PM_{2.5}$ concentrations (reference) at test site "Cologne, winter"

The following figures show the measuring cabinet at the field test sites Bonn (road junction), Bornheim (motorway parking lot) and Cologne (parking lot).

Figure 15: Field test site Bonn, road junction, winter

Figure 16: Field test site Bornheim, summer

Figure 17: Field test site Cologne, autumn & winter

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:

- Height of cabinet roof: 2.50 m
- Sampling height for tested system 0.50 m / 0.51 m above cabinet roof
- Sampling height for reference system 3.00 / 3.01 m above ground
- Height of wind vane: 4.5 m above ground

The following Table 5 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.

Table 5: Ambient conditions at the field test sites, daily mean values

	Bonn, winter	Bornheim, summer	Cologne, autumn	Cologne, winter
Number of value pairs Reference $PM_{2.5}$	51	58	68	47
$PM_{2.5}$ ratio in PM_{10} [%]				
Range	42.2 – 96.5	39.1 – 84.6	28.6 – 90.7	32.0 – 90.9
Mean value	70.5	60.5	61.7	68.8
Ambient temperature [°C]				
Range	-3.4 – 20.0	6.4 – 27.6	1.1 – 25.5	2.5 – 13.1
Mean value	8.0	17.7	10.9	6.5
Ambient pressure [hPa]				
Range	985 – 1018	989 – 1020	986 – 1027	984 – 1022
Mean value	1004	1008	1008	1000
Rel. humidity [%]				
Range	42.8 – 85.8	52.2 – 89.1	56.3 – 89.8	46.8 – 87.2
Mean value	63.0	69.2	79.5	74.4
Wind velocity [m/s]				
Range	0.4 – 4.2	0.2 – 4.7	0.0 – 2.5	0.0 – 3.0
Mean value	1.6	1.4	0.4	0.7
Amount of precipitation [mm/d]				
Range	0.0 – 13.2	0.0 – 34.6	0.0 – 35.8	0.0 – 18.9
Mean value	0.9	3.3	3.4	1.7

Sampling duration

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) 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 [4] 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.

The statistical outlier test according to Grubbs (99 %) did not identify any significant outlier for paired measurements for all test sites. Thus no paired measurements have been discarded for the $PM_{2.5}$ reference measurement.

Filter handling– mass determination

The following filters were used in the type approval test:

Table 6: Used filter materials

Measuring system	Filter material, type	Manufacturer
Reference systems LVS3	Emfab™, ∅ 47 mm	Pall

The filters were handled in compliance with Standard EN 14907.

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

5. Reference method

In accordance with Standard EN 14907, the following devices were used in the testing:

1. 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 and 2010
$PM_{2.5}$ sampling head

During the testing, two reference systems for $PM_{2.5}$ 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.

The sampling head of the small filter device LVS3 sucks in the sample air 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 $PM_{2.5}$ 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

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 has got a measured value display. It shows the respective concentration value of the last cycle. Furthermore in the data display mode, the stored measured values can be easily displayed in either a table display or a bar chart display.

6.5 Assessment

The measuring system has got a measured value display.

Performance criterion met? yes

6.6 Detailed presentation of test results

Figure 18 shows the display with the current concentration value of the respective last cycle. Figure 19 and Figure 20 show the display of the stored measured values as table and as bar chart.

Figure 18: Measurement display for concentration values

Figure 19: Data display – measured values as table

Figure 20: Data display – measured values as bar chart

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 on the device itself or online via RS232-interface and Gesytec-Protocol.
2. The sampling inlet 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 4 weeks).
3. Check of the filter tape stock –
   A filter tape with 45 m length is lasting theoretically for 30,000 measurement cycles in case of a cycle time of 1 h and a sample count of 24 (setting during type approval test), which equals to 1,250 days. As - because of a possible exceedance of the maximum allowed mass per filter spot of 400 µg, which is dependent on the PM concentration level under practical conditions - a new filter spot might be used earlier than by reaching the 24times sampling, the time for consumption of the filter tape might be reduced accordingly.
   In case of a cycle time of 1 h and a minimum sample count of 1 (i.e. for each cycle a new filter spot is used), there are 1,250 measurement cycles possible, which equals 52 days. Thus it is recommended to check the filter tape stock during each visit of the measuring system for regular maintenance (e.g. in the framework of cleaning the sampling inlet).
4. According to the manufacturer. the pump needs maintenance approx. every 6 weeks after one year of operation, i.e. the filters must be blown out and the blade height has to be checked and the blades to be replaced if necessary.
5. According to CEN/TS 16450 [8], a check of the sensors for ambient temperature and ambient pressure should be done every 3 months.
6. According to CEN/TS 16450 [8], a check of the sampling flow rate should be done every 3 months.
7. Within the framework of the check of the sampling flow rate, the tightness should also be checked every 3 months.
8. The filter adapter, the transport reel and the pressure rollers have to be cleaned every 6 months.
9. The waste air filter and the hose connections have to be checked and if necessary blown out every 6 months.
10. The pump filter and seals shall be replaced once a year.

11. Once per year, the meteorological sensor has to be sent to the manufacturer for recalibration. Furthermore it is recommended to check the radiometric measurement with the help of the reference foil once a year.
12. During the annual maintenance, the cleaning of the sampling tube needs also to be considered.

Maintenance work shall be carried out according to the instructions provided in the manual (chapter 5.3 and 10). 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. The replacement of the filter tape, the maintenance work at the pump as well as the operations described in item 7ff shall only be performed when the device is on standstill. These operations incur every 6 weeks (pump), every 6 months (cleaning) respectively dependent on the set cycle time and sample count (change of filter tape). 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, reference foil.

6.3 Method

The system status is monitored continuously and problems are indicated by a series of different status messages. Parameters, which are important for the correct performance (e.g. flow rate), can be viewed directly on the instrument display and/or recorded continuously during data recording.

The measuring system offers for the purpose of a functional check, the possibility of an internal check of zero- and reference point. Both tests can be accessed directly via the maintenance menu. A telemetric control is also possible.

During the internal check of the zero point ("zero measurement"), the functionality of the source and the Geiger-Müller-tube is checked. Without filter tape transport, a 0-rate and a M-rate is measured and the corresponding determined mass is calculated. The result shall not exceed a measured value of ≤ 10 µg as absolute value.

During the internal check of the reference point ("reference measurement"), also a 0-rate and a M-rate is measured without filter tape transport. The M-rate is evaluated 1/6 weaker, which corresponds to a mass of 444 µg (if the parameter "offset" is set to 0 and the parameter "span" is set to 1 in the device). This measured value should be obtained with a tolerance of ± 20 µg. If the offset- and span parameters differ from 0 respectively 1, this has to be considered accordingly.

Furthermore 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.

For the external check of the radiometric measurement, the instrument manufacturer supplies a reference foil. By using the reference foil, only mass values can be determined.

In the course of the testing, an external check of the stability via reference foil was performed regularly over the entire field test period.

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.

For functional check, the measuring system offers the possibility of an internal check of zero- and reference point. Both tests can be accessed directly via the maintenance menu or telemetrically.

The internal checks of zero and reference point have been explicitly checked again on March 15, 2014 with the following results:

Table 7: Results of the internal checks of zero- and reference point

15.03.2014	SN 1512361		SN 1512401	
	Nominal	Actual	Nominal	Actual
Zero measurement	≤ 10 µg	1 µg	≤ 10 µg	4 µg
Reference measurement	444 µg ± 20 µg	446 µg	444 µg ± 20 µg	444 µg

For both devices the determined deviations were within the permissible limits stated by the manufacturer.

An external check of the zero point is possible at any time with the help of a zero filter. An external check of the radiometric measurement with the help of the reference foil is also possible at any time.

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. For functional check, the measuring system offers the possibility of an internal check of the zero and the reference point. Both tests can be accessed directly via the maintenance menu or telemetrically.

The results of the external zero point checks by means of zero filter that were carried out during the field tests as well as checks of the stability of the radiometric measurement, 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 measuring system must be installed not subject to weather conditions, e.g. in an air-conditioned cabinet. Additionally the installation of the actively ventilated sampling system through the roof requires extensive structural measures at the installation site. A non-stationary application is therefore only to be undertaken together with the associated peripheral devices.

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

- Unpacking and Installation of the AMS (in a rack or on a table)
- Installation of the double-walled, actively ventilated sampling system and the $PM_{2.5}$-sampling inlet
- Installation of meteorological sensor (in close proximity to the sampling inlet)
- Connection of all supply and control lines
- Power connection
- Optional connection of peripheral recording- and control systems (data logger, PC) to the respective interfaces
- Power-up of AMS
- Insertion of filter tape

The execution of these operations and thus the set-up time takes approx. 1 h.

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.

After switching on the system, the system is in waiting position until the set start time for the next measurement cycle is reached.

The following actions are necessary for the initial start-up:

- Check of system settings, e.g. cycle time, sample count, start mode, temperature mode, mode Synch h:00 as well as date and time
- Check and, if required, adjustment of the meteorological sensor and the ambient pressure measurement
- Leak test
- Check and, if required, adjustment of the flow rate
- If necessary, external check of the radiometric mass determination with the reference foil

Duration: approx. 1 hour

In case of restarting operation after a short downtime, e.g. after a power outage, the above mentioned steps can be omitted with exception of a check of the system parameters, a plausibility test of the sensor values and an inspection of possible status/error messages.

If required, potential changes in the basic parameter setting of the measuring instrument can likewise be performed in just a few minutes by staff familiarised with the instruments.

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 1 h. The warm-up time amounts to approx. 1 h in case of initial start-up respectively the waiting time until the start for the next measurement cycle in case of re-start after short downtime.

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 shall be installed in horizontal position (e.g. on a table or in a rack), not subject to weather conditions. The temperature at the installation site must be in the range of 5°C to 40°C. Direct sunlight respectively a direct exposure to heater or air conditioner shall be omitted.

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 400 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 via touch screen display on the front site of the AMS.

A change of parameters or the adjustment of sensors is only possible by typing in several key sequences.

The measuring system also has a password protection. There are three different passwords available:

Password1: For changing parameters (→Parameter mode)

Password2: For performing service actions

Password3: System password

Without knowledge of password1, instrument parameters can be viewed, but not changed.

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

6.4 Evaluation

Unintended and unauthorised adjustment of instrument parameters can be avoided by password protection. 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. In addition, the AMS shall be locked up in a measuring cabinet.

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

Data logger Yokogawa (for analogue signal), PC with “Hyper-Terminal” software

6.3 Method

The test was carried out using a data logger of the type Yokogawa (analogue output, only exemplary test in lab) and a PC with “Hyper-Terminal” software (via RS232-interface).

During the type approval test, the measuring system was connected to a PC via RS232 and the data was downloaded on the PC.

The AMS also offers the possibility to output analogue signals – the functionality was checked exemplarily during the laboratory test

.

6.4 Evaluation

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

Analogue:	4-20 mA	concentration range selectable
Digital:	RS 232-interface	

6.5 Assessment

The test signals are provided analogue (in mA) and digitally (via RS232).

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

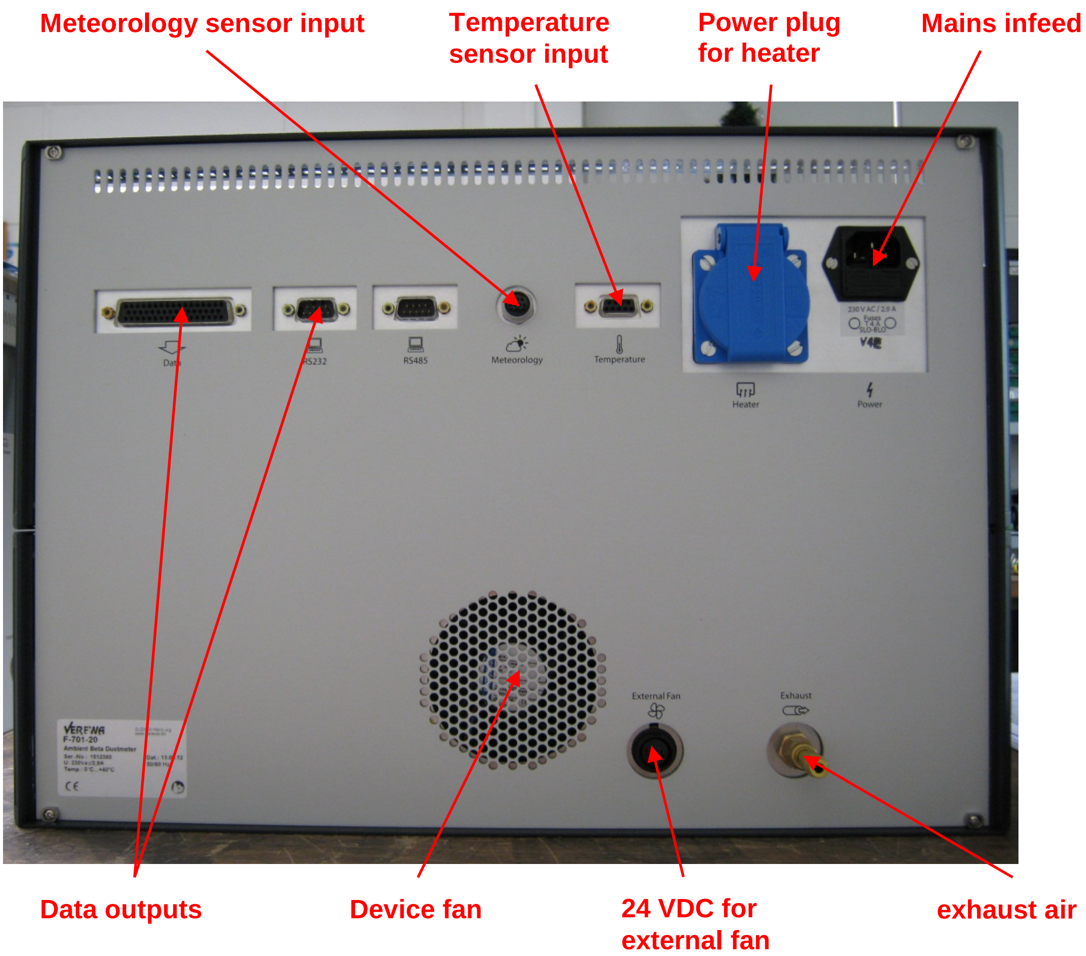


Figure 21: Rear side of the F-701-20

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 8: Certification ranges

Component	Minimum value cr	Maximum value cr	Limit value	Assessment period
	in µg/m³	in µg/m³	in µg/m³	
$PM_{2,5}$	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 [4]. For this purpose, the following values are used as reference values in accordance with the specifications of the Guide:

$PM_{2.5}$: 30 µg/m³

Refer to test item

6.1 5.4.10 Calculation of expanded uncertainty between systems under test 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 systems under test 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

As a standard, a measuring range of 0 – 1000 µg/m³ is set on the measuring system.

As appropriate default setting of the analogue output for European conditions a measuring range of 0 – 200 or 0 – 1000 µg/m³ is recommended.

(Recommended) measuring range:	0 – 200 or 0 – 1000 µg/m³
Upper limit of the certification range:	$PM_{2.5}$: 50 µg/m³

6.5 Assessment

A measuring range of 0 – 1000 µg/m³ is set as standard. Other measuring ranges are possible.

The upper limit of the measuring range of the measuring system is greater than the respective 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

The AMS can output negative values either via display or via the data outputs.

6.5 Assessment

Negative output signals are directly displayed by the AMS and are output correctly via corresponding data outputs.

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 re-starts the operation when reaching the start point of the next measurement cycle (during the type approval test after reaching the next full hour).

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 start point of the next measurement cycle (during the type approval test after reaching the next full hour).

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 to the AMS via RS232 to check data transfer and instrument status.

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

6.4 Evaluation

The AMS allows telemetric monitoring and control via RS232-interface.

6.5 Assessment

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

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 9: Operation status F-701-20

Operating status (Field NO. 6)	Meaning
Bit 0	1 - Standby, 0 - Measurement, zero point, reference or film measurement
Bit 1	Foil measurement
Bit 2	Zero point
Bit 3	Reference measurement (reference check)
Bit 4	
Bit 5	
Bit 6	
Bit 7	Measurement

Table 10: Error status F-701-20

Error status (Field NO. 7)	Description
Bit 0	Volume error
Bit 1	Vacuum break
Bit 2	Volume < 500 litres or 250 litres with 1/2 hour extraction time
Bit 3	
Bit 4	
Bit 5	Replace battery
Bit 6	Filter crack
Bit 7	

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.

However, some functions such as performance of a reference foil test in order to check the radiometric measurement can only be carried out at the AMS directly.

6.4 Evaluation

The switch-over between measurement and functional check (here: internal zero point and reference point measurement) can be initiated telemetrically or manually.

However, some functions such as performance of a reference foil test in order to check the radiometric measurement can only be carried out at the AMS directly.

6.5 Assessment

The switch-over between measurement and functional check (here: internal zero point and reference point measurement) can be initiated telemetrically or manually.

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

No ineligible drift effects during the entire field test campaign have been observed for the measuring systems. Thus, the maintenance interval is determined by the regularly appearing maintenance work (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 is determined by the necessary maintenance work and is 4 weeks.

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 5.3 respectively 10 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 11 and Table 12 provide lists of operation times, time used for maintenance, and malfunction times. The measuring systems were operated over a period of 296 days in total during the field test. This period includes 22 days of zero filter operation, audits and days that were lost due to changing from inlet to zero filter (see also annex 5).

Because of investigations to determine the unusual deviations between both candidates on October 15, 2013, the measured value for instrument SN 1512361 was also discarded (though not affected) because of long downtime due to maintenance.

Downtimes caused by external influences which the instrument cannot be blamed for have been recorded between September 05, 2013 and September 12, 2013. The measured values for both candidates had to be discarded for the entire period, as the flow rate has been systematically misadjusted before start-up due to a wrong parameter setting in the reference flow meter. Therefore the flow rates have been checked again and correctly adjusted on Sept 12, 2013.

Because of this, the total operation time is reduced to 288 (SN 1512361) respectively 288 (SN 1512401) days of measurements.

The following downtimes due to malfunctions have been recorded:

SN 1512361:

For this system no malfunctions have been observed.

SN 1512401:

For SN 1512401 it was observed at test site Cologne, autumn, that the measured values have been sometimes significantly higher than the ones from SN 1512361 and also higher than the first batch of reference values from this site. Thus the instrument was investigated intensely at the measurement site by the manufacturer on October 15, 2013 and it was observed, that the protective sheet of the Geiger-Müller counter tube appeared very ripple and as a consequence deviations can occur. The cause for this damage could not be found. It was decided then, to install a new Geiger-Müller counter tube into the device. No measured values from the past have been discarded, but there was no measurement on October 15, 2013.

Apart from that no further downtimes were recorded.

Downtimes caused by routine maintenance (without zero filter operation), e.g. for cleaning the sampling inlet or for the check of the flow rate / tightness usually lead to a loss of one measurement cycle (i.e. 1 h per day). Daily mean values affected by this have thus not been discarded.

6.5 Assessment

The availability was 100 % for SN 1512361 and 99.7 % for SN 1512401 without test-related downtimes. Including test-related downtimes it was 92.0 % for SN 1512361 and 92.0 % for SN 1512401.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 11: Determination of availability (without test-related downtimes)

		System 1 (SN 1512361)	System 2 (SN 1512401)
Operating time	d	288	288
Downtime	d	0	1
Maintenance	d	0	0
Actual operating time	d	288	287
Availability	%	100	99.7

Table 12: Determination of availability (incl. test-related downtimes)

		System 1 (SN 1512361)	System 2 (SN 1512401)
Operating time	d	288	288
Downtime	d	0	1
Maintenance incl. zero filter	d	23	22
Actual operating time	d	265	265
Availability	%	92.0	92.0

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 can be viewed at any time in the menu “Parameter/Service” under the item “SW”.

The test was started in December 2012 with the software version 3.07. Within the frame work of the software maintenance process, the software was in the meanwhile developed and optimised up to version 3.10. The manufacturing site of the instrument manufacturer DURAG GmbH in Hamburg, Germany is part of the regular surveillance according to Standard EN 15267-2 since 2010. Since 2013 also the measuring system F-701-20 is covered in the audit scope. According to the requirements of the Standard EN 15267-2, the applied modifications of the software have been described, assessed, the type of modification classified and the information submitted to the test house.

An overview on the applied changes can be found in chapter 4.1 General.

The applied modifications are for functional extensions, bug elimination and for cosmetic maintenance. They don´t have any impact on the measuring system.

With the start of the third of in total four comparison campaigns, the software version was upgraded from 3.07 to 3.10 and the instruments were operated with this software for the comparison campaigns Cologne, autumn and Cologne, winter.

6.5 Assessment

The version of the instrument software is shown on the display. The test institute is informed on any changes in the instrument software.

Performance criterion met? yes

6.6 Detailed presentation of test results

Figure 22: Display of software version – here 3.10 – in the menu "Parameter/Service/SW"

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 1512361 and SN 1512401, 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.

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: $B_0 = 2$ µg/m³

6.5 Assessment

The tests resulted in detection limits of 0.66 µg/m³ for System 1 (SN 1512361) and 0.75 µg/m³ for System 2 (SN 1512401).

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 13: Detection limit $PM_{2.5}$

		Device SN 1512401	Device SN 1512361
Number of values n		15	15
Average of the zero values $\overline{x}_0$	µg/m³	0.28	0.34
Standard deviation of the values $s_{\bar{x}0}$	µg/m³	0.31	0.35
Student-Factor $t_{n-1;0,95}$		2.14	2.14
Detection limit x	µg/m³	**0.66**	**0.75**

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 $PM_{2.5}$ shall be tested according to performance criterion 5.4.10 “Calculation of expanded uncertainty between systems under test”.

6.2 Equipment

Refer to module 5.4.10 ($PM_{2.5}$)

6.3 Method

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

6.4 Evaluation

Refer to module 5.4.10 ($PM_{2.5}$)

6.5 Assessment

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

Performance criterion met? -

6.6 Detailed presentation of test results

Refer to module 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 +5 to +40 °C, zero filter for testing the zero point, reference foil for testing the reference point.

6.3 Method

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 1512361 and SN 1512401 by means of zero filters installed at the instrument inlets.

The reference point test comprised a check of the stability of the sensitivity of the reference foil value for both candidates SN 1512361 and SN 1512401.

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 times 24 h per temperature level) and the measured values at reference point (3 times 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.

It should be noted that concentration values could not be simulated by checking the measured value of the reference foil. It was therefore not possible to examine the range of B_1.

6.5 Assessment

The maximum dependence of ambient temperature in the range of +5 °C to +40 °C at zero was -1.0 µg/m³.

At reference point, no deviations > 3.0 % in relation to the default value at the temperature of 20 °C were observed.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 14: Dependence of zero point on ambient temperature, deviations in µg/m³, mean value of three measurements

Ambient temperature		Deviation	
Start temperature	End temperature	SN 1512361	SN 1512401
°C	°C	µg/m³	µg/m³
20	5	0.1	-0.4
5	20	0.1	0.0
20	40	-1.0	-0.5
40	20	-0.3	0.0

Table 15: Dependence of sensitivity (foil value) on ambient temperature, deviation in %, mean value of three measurements

Ambient temperature		Deviation	
Start temperature	End temperature	SN 1512361	SN 1512401
°C	°C	[%]	[%]
20	5	-0.7	-1.6
5	20	1.0	-2.6
20	40	-2.3	-3.0
40	20	-2.3	-2.1

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, reference foil 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 of the stability of the sensitivity of the reference foil value for both candidates SN 1512361 and SN 1512401.

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.

It should be noted that concentration values could not be simulated by checking the measured value of the reference foil. It was therefore not possible to examine the range of B_1.

6.5 Assessment

No deviations > -1.4 % for $PM_{2.5}$ in relation to the default value at the mains voltage 230 V due to changes in supply voltage were detected.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 16 presents a summary of test results.

Table 16: Dependence of measured value on supply voltage, deviation in %

Mains voltage		Deviation	
Start voltage	End voltage	SN 1512361	SN 1512401
V	V	[%]	[%]
230	210	-0.7	-0.2
210	230	-0.3	-0.4
230	245	-1.4	-0.4
245	230	-1.1	-0.7

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 = 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 1512361) at i^{th} concentration
- x_{2i} = Measured signal of system 2 (e.g. SN 1512401) at i^{th} concentration

6.5 Assessment

In the field test, the reproducibility for the full dataset was 21 for $PM_{2.5}$.

Performance criterion met? yes

6.6 Detailed presentation of test results

The test results are summarised in Table 17. The graphical representation for $PM_{2.5}$ is given in Figure 29 to Figure 33.

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

Table 17: Concentration mean values, standard deviation, uncertainty range, and reproducibility in the field, measured component $PM_{2.5}$

Site	Number	$\bar{c}$ (SN 1512361)	$\bar{c}$ (SN 1512401)	$\bar{c}_{ges}$	s_D	t	U	R
		µg/m³	µg/m³	µg/m³	µg/m³		µg/m³	
Bonn, winter	61	19.3	19.2	19.2	0.598	2.000	1.20	21
Bornheim, summer	67	10.8	10.9	10.9	0.436	1.996	0.87	29
Cologne, autumn	85	10.6	11.1	10.9	0.735	1.988	1.46	17
Cologne, winter	52	11.5	11.6	11.6	0.321	2.007	0.64	39
All sites	265	12.9	13.0	12.9	0.601	1.969	1.18	21

$\bar{c}$ (SN 1512361): Mean value of concentrations for System SN 1512361

$\bar{c}$ (SN 1512401): Mean value of concentrations for System SN 1512401

$\bar{c}_{ges}$: Mean value of concentrations for Systems SN 1512361 & SN 1512401

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, reference foil for testing the reference point.

6.3 Method

The test was carried out as part of the field test over a period of about 12 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 measured value for the reference foil was checked and evaluated regularly during the entire field test campaign in order to check the reference point.

6.4 Evaluation

An evaluation of the drift of zero point and measured value in 24 h is possible for this system via the internal check procedure for zero- and reference point, but is uncommon for particulate measuring systems in practice.

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 evaluation at reference point is made on the basis of the measurement results for the reference foil by comparing the respective values with the corresponding "measured values" of the previous test and the "measured value" of the first test.

It should be noted that concentration values could not be simulated by checking the measured value of the reference foil. It was therefore not possible to examine the range of B_1.

6.5 Assessment

The maximum deviation at zero point was 1.5 µg/m³ in relation to the previous value and 1.7 µg/m³ in relation to the start value.

The sensitivity drift values that were determined during testing are max. -2.7 % for $PM_{2.5}$ in relation to the respective start value.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 18 provides 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 23 to Figure 24 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 19.

Figure 25 and Figure 26 present graphical representations of the drift of measured values (in relation to the previous values).

Table 18: Zero point drift SN 1512361 & SN 1512401, $PM_{2.5}$, with zero filter

Date	SN 1512361			Date	SN 1512401		
	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
2/28/2013	0.1	-	-	2/28/2013	1.0	-	-
3/30/2013	0.5	0.4	0.4	3/30/2013	0.7	-0.3	0.6
3/31/2013	1.0	0.4	0.9	3/31/2013	0.4	-0.2	0.4
4/1/2013	0.5	-0.4	0.4	4/1/2013	0.4	0.0	0.3
4/26/2013	0.8	0.3	0.7	4/26/2013	0.3	-0.1	0.2
4/27/2013	0.3	-0.5	0.2	4/27/2013	0.6	0.3	0.5
4/28/2013	1.8	1.5	1.7	4/28/2013	1.6	1.0	1.5
5/14/2013	0.9	-0.9	0.8	5/14/2013	0.6	-1.1	0.5
5/15/2013	0.8	-0.1	0.8	5/15/2013	0.6	0.1	0.5
6/22/2013	1.2	0.3	1.1	6/22/2013	0.8	0.2	0.7
6/23/2013	0.6	-0.5	0.6	6/23/2013	1.4	0.6	1.3
7/26/2013	1.8	1.1	1.7	7/26/2013	-0.1	-1.5	-0.2
9/4/2013	0.7	-1.1	0.6	9/4/2013	0.6	0.7	0.6
10/16/2013	0.1	-0.6	0.0	10/16/2013	0.7	0.1	0.6
11/8/2013	0.3	0.2	0.2	11/8/2013	0.4	-0.3	0.4
11/9/2013	0.1	-0.2	0.0	11/9/2013	0.2	-0.2	0.1
11/10/2013	0.3	0.2	0.2	11/10/2013	0.2	0.0	0.1
12/14/2013	0.1	-0.2	0.0	12/14/2013	0.6	0.4	0.5
12/15/2013	0.3	0.2	0.2	12/15/2013	0.3	-0.3	0.2
1/13/2014	0.3	0.0	0.2	1/13/2014	0.0	-0.3	-0.1
2/7/2014	0.4	0.2	0.4	2/7/2014	1.0	1.0	0.9
2/8/2014	0.0	-0.5	-0.1	2/8/2014	0.4	-0.6	0.3
2/9/2014	0.4	0.4	0.3	2/9/2014	0.3	-0.1	0.3
3/10/2014	0.4	0.0	0.4	3/10/2014	0.6	0.2	0.5

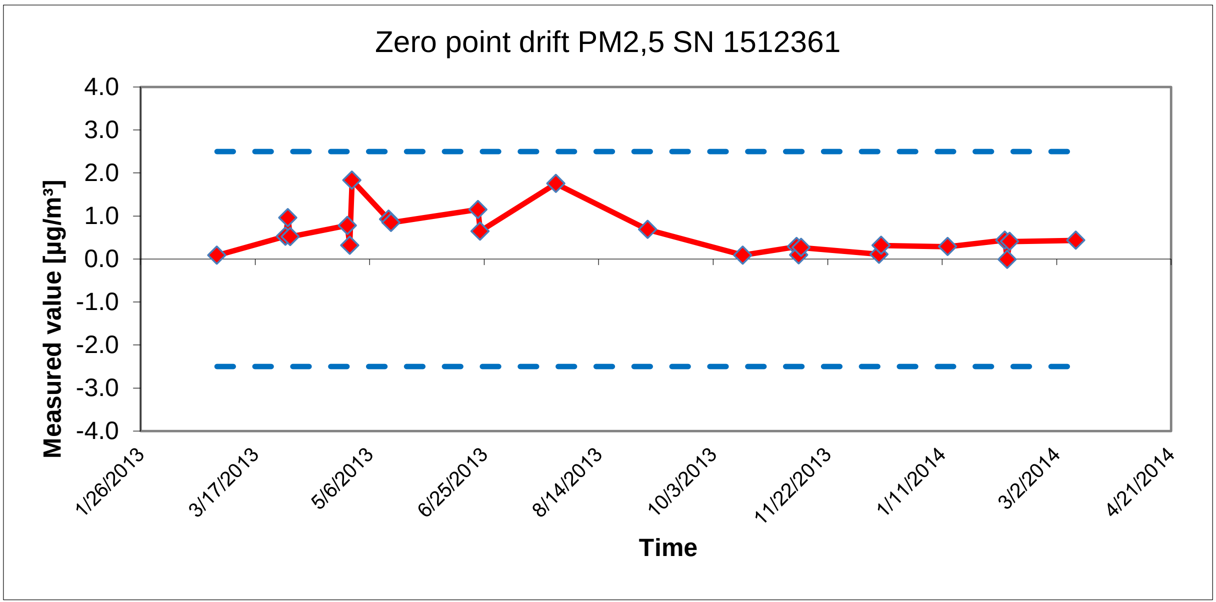


Figure 23: Zero point drift SN 1512361, measured component $PM_{2.5}$

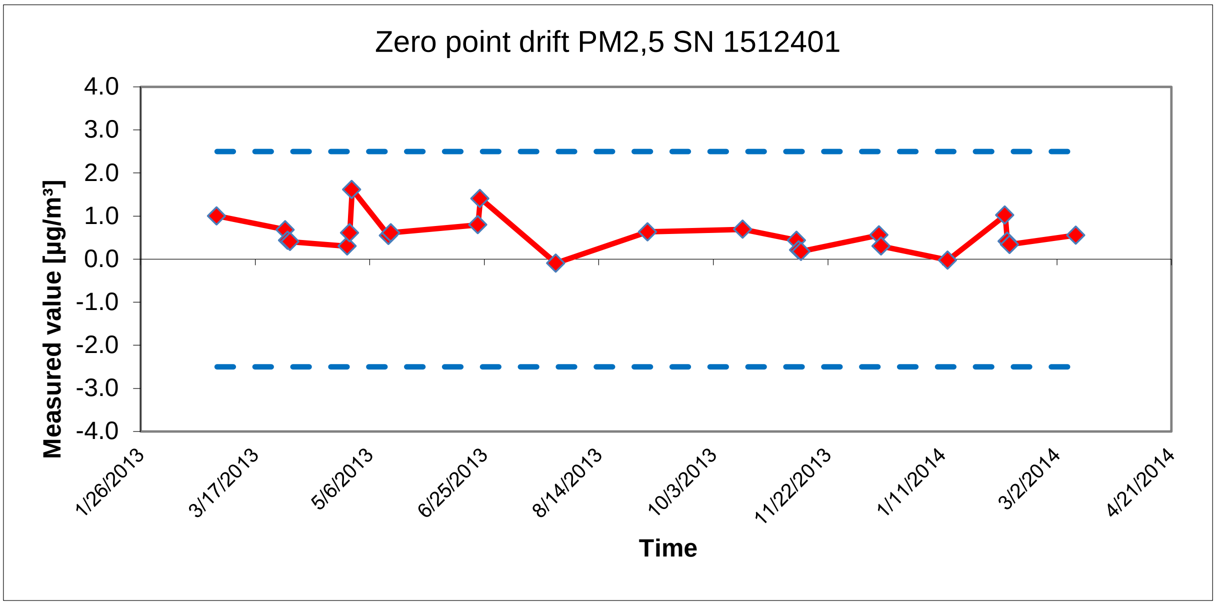


Figure 24: Zero point drift SN 1512401, measured component $PM_{2.5}$

Table 19: Sensitivity drift SN 1512361 & SN 1512401, $PM_{2.5}$

Date	SN 1512361			Date	SN 1512401		
	Measured Value	Deviation from previous value	Deviation from start value		Measured Value	Deviation from previous value	Deviation from start value
		%	%			%	%
2/27/2013	289.4	-	-	2/27/2013	291.1	-	-
5/2/2013	295.0	1.9	1.9	5/2/2013	294.0	1.0	1.0
9/3/2013	301.0	2.0	4.0	9/3/2013	293.0	-0.3	0.7
12/12/2013	293.0	-2.7	1.2	12/12/2013	289.0	-1.4	-0.7
3/11/2014	286.0	-2.4	-1.2	3/11/2014	288.0	-0.3	-1.1

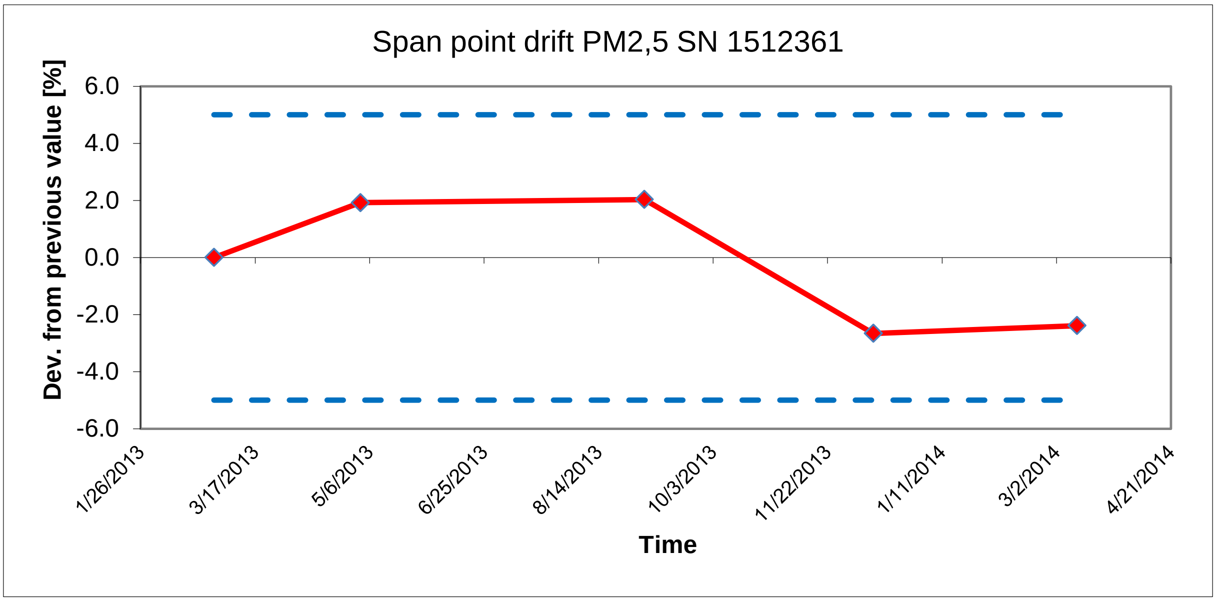


Figure 25: Drift of the measured value SN 1512361, measured component $PM_{2.5}$

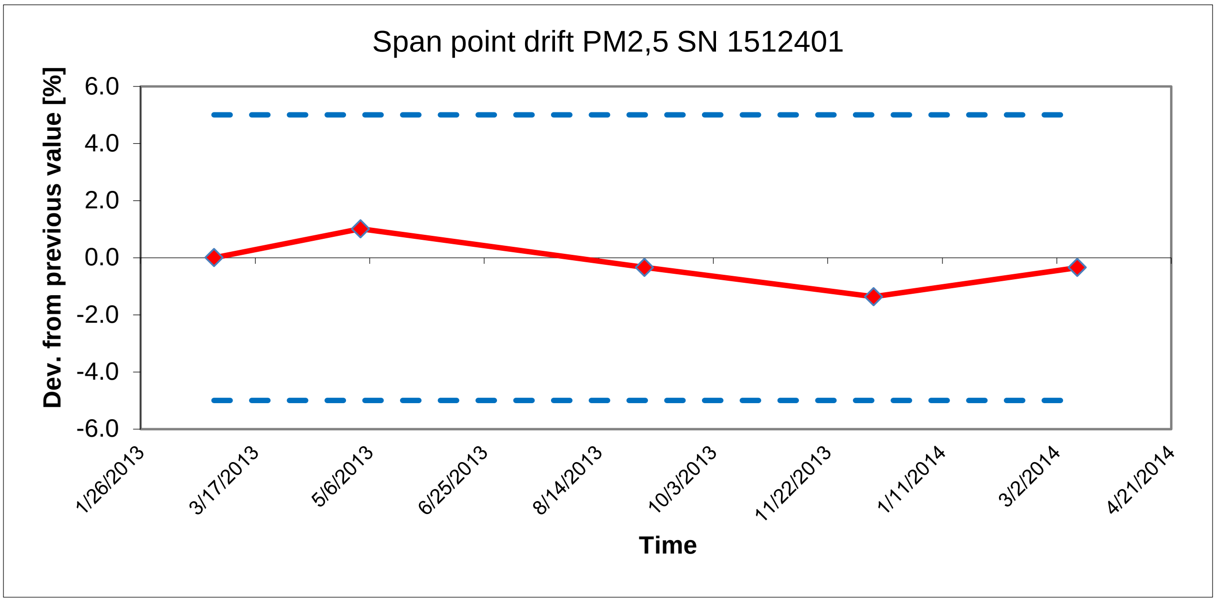


Figure 26: Drift of the measured value SN 1512401, measured component $PM_{2.5}$

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 measuring system F-701-20 is a radiometric measuring system. The mass, which is separated at the filter tape, is determined by a radiometric measurement. The determined mass is related to a defined and actively controlled sample volume and thus the particulate mass concentration is determined.

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 determined mass is related to a defined and actively controlled sample volume and thus the particulate mass concentration is determined.

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

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

6.3 Method

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

6.4 Evaluation

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

6.5 Assessment

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

Performance criterion met? -

6.6 Detailed presentation of test results

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

6.1 5.4.3 Reproducibility of the sampling systems

The PM_{10} sampling systems of two identical systems under test 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 5.4.9 in this report.

6.2 Equipment

Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.9 in this report.

6.3 Method

Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.9 in this report.

6.4 Evaluation

Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.9 in this report.

6.5 Assessment

Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.9 in this report.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable to $PM_{2.5}$ sampling systems. Please refer to module 5.4.9 in this report.

6.1 5.4.4 Calibration

The systems under test 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 5.4.10

6.3 Method

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 (213 valid data pairs (SN 1512361) and 213 valid data pairs (SN 1512401)).

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.

6.4 Evaluation

The resulting quantities are given in Table 20.

Table 20: 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 1512361)	0.921	0.457	1.086	0.496
System 2 (SN 1512401)	0.915	0.689	1.093	0.753

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 module 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

It was also examined whether the reproducibility of the measuring systems under test using the reference method according to Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" [4] 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 > -0.6 µg/m³ caused by interference due to moisture in the sample could be observed for $PM_{2.5}$. No negative influence on the measured values at varying relative humidity was detected during the field test. The comparability of the candidates with the reference method according to the Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" [4] is ensured even for days with a relative humidity of > 70 %.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 21 provides a summary of the results.

Table 21: Deviation between reference measurement and candidate on days with a relative humidity of > 70 %, measured component $PM_{2.5}$

Field test, days with rH >70 %				
		Reference	SN 1512361	SN 1512401
Mean	µg/m³	13.8	13.2	13.3
Deviation to mean value of reference in µg/m³	µg/m³	-	-0.6	-0.5
Deviation in % of mean value of reference	%	-	-4.3	-3.6
Deviation in % of ALV	%	-	-2.4	-2.0

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 22. Single values are provided in annexes 5 and 6.

Table 22: Comparison of the candidates 1512361 / 1512401 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	F-701-20	SN	SN 1512361 / SN 1512401	
		Limit value	30	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
All test sites, rH>70%				
Uncertainty between Reference	**0.57**	**µg/m³**		
Uncertainty between Candidates	**0.61**	**µg/m³**		
	SN 1512361		**SN 1512401**	
Number of data pairs	**203**		**203**	
Slope b	**0.920**		**0.913**	
Uncertainty of b	**0.009**		**0.011**	
Ordinate intercept a	**0.486**		**0.728**	
Uncertainty of a	**0.154**		**0.176**	
Expanded meas. uncertainty W_{CM}	**14.75**	**%**	**15.26**	**%**

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 measuring system operates with measurement cycles between 15 min and 24 h.

The sampling time corresponds to the respective programmed cycle time and the programmed sample count minus the measuring time respectively the time for filter tape movements. With the help of the sample count, a multiple sampling on a filter spot can be set. It can be set between 1 (=for each cycle a new filter spot) and 24 (=one filter spot is sampled upon for 24times).

The sampling time is thus:

For cycle time 60 min and sample count 1:

60 min – (2 x 300 s measuring time + 120 s for filter tape movements) = 48 min

In case of a sample count >1, the measurement after sampling serves for the calculation of the measured value of the finished cycle as well as a start measurement for the following cycle, i.e. only one radiometric measurement is necessary per cycle.

During the type approval test a cycle time of 60 min with a sample count of 24 was set. The sampling time is then:

Cycle 1: 60 min – (2 x 300 s measuring time + 120 s for filter tape movements) = 48 min

Cycle 2-24: 60 min – (1 x 300 s measuring time + 120 s for filter tape movements) = 53 min

Thus the available sampling time per measurement cycle is between 80 % and 88.3 % of the total cycle time. The results from the field investigations according to chapter

6.1 5.4.10 Calculation of expanded uncertainty between systems under test in this report show, that for this instrument configuration the comparability of the candidates with the reference method could be demonstrated and thus, the formation of daily mean values can be guaranteed.

6.5 Assessment

With the described instrument configuration and a measurement cycle of 1 h with a sample count of 24, the measuring system allows the formation of daily mean values based on 24 measurement cycles.

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.

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 (August 2013) [8].

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 23.

Table 23: Results of flow rate checks

Flow rate check before testing at	SN 1512361		SN 1512401	
Test site:	[l/min]	Deviation from nominal value [%]	[l/min]	Deviation from nominal value [%]
Bonn, winter	16.67*	-	16.67*	-
Bornheim, summer	16.69	0.12	16.72	0.30
Cologne, autumn	16.35	-1.92	16.42	-1.50
Cologne, winter	16.58	-0.54	16.68	0.06

* adjusted on February 27, 2013

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 16.67 l/min 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 24 shows the parameters determined for the flow. Figure 27 and Figure 28 present a graphic representation of the flow measurements of the two candidates SN 1512361 and SN 1512401.

Table 24: Parameters for total flow measurement (24 h mean), SN 1512361 & SN 1512401

Device	Mean [l/min]	Deviation from nominal [%]	Std. Dev. [l/min]	Max [l/min]	Min [l/min]
SN 1512361	16.662	-0.05	0.1228	17.22	16.27
SN 1512401	16.637	-0.20	0.1234	17.03	16.18

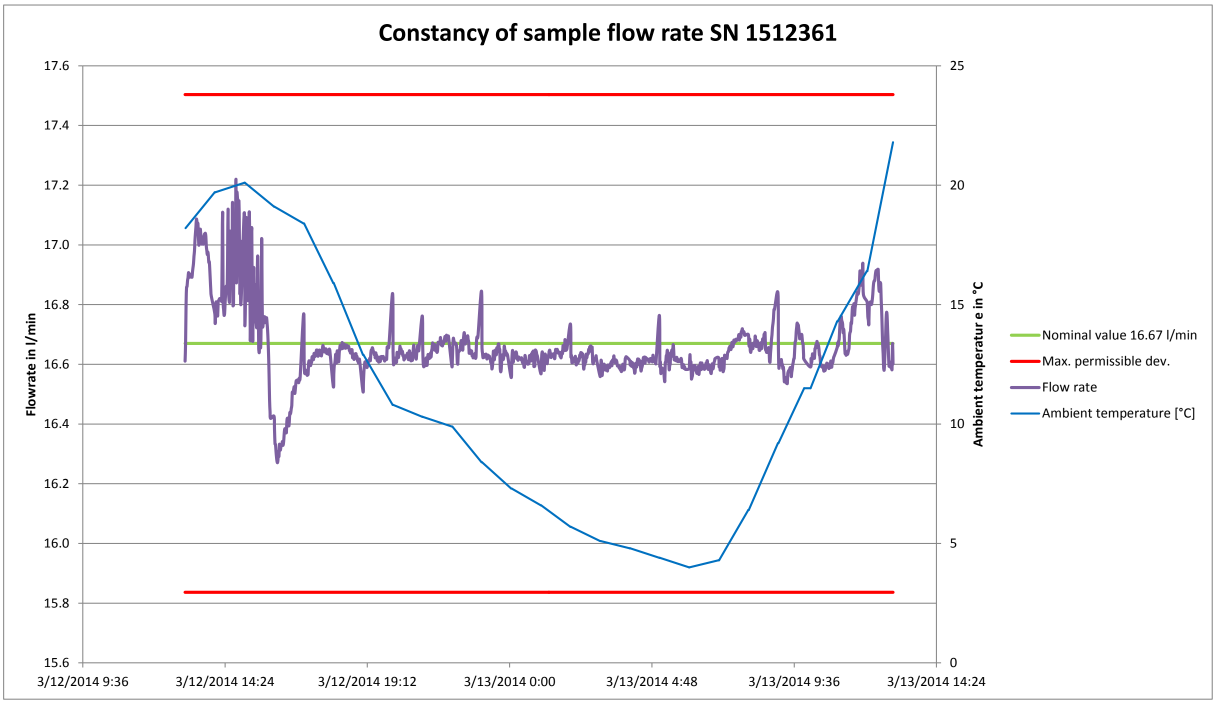


Figure 27: Flow rate of device SN 1512361

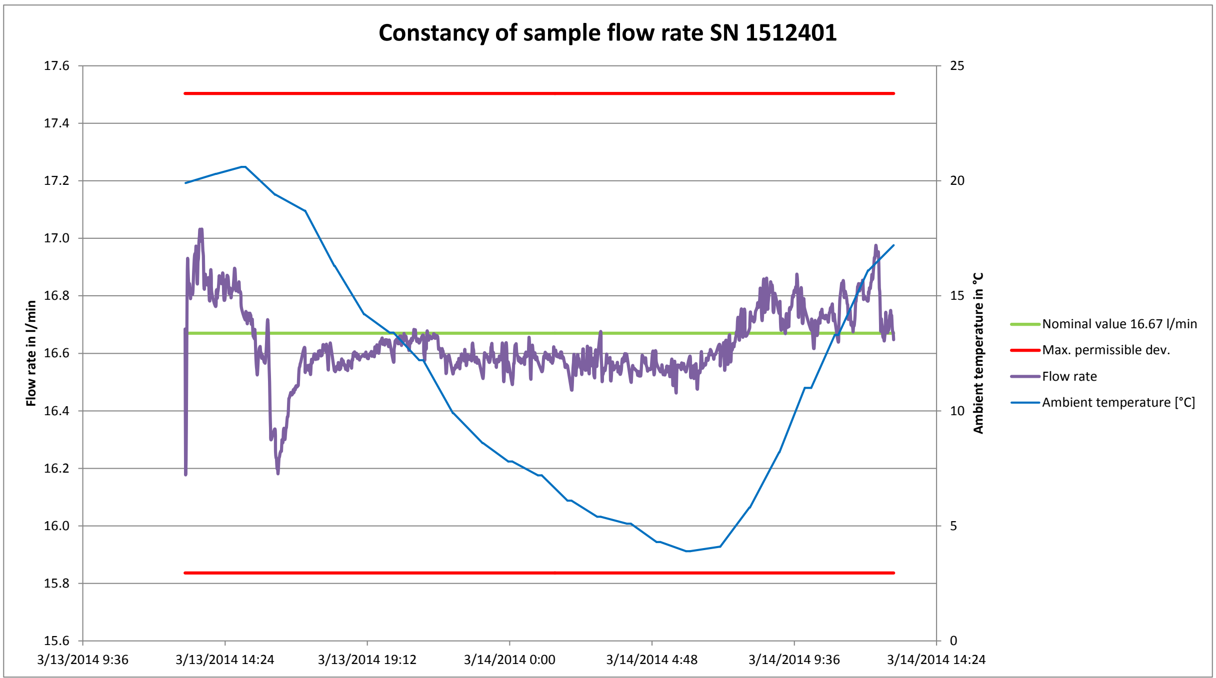


Figure 28: Flow rate of device SN 1512401

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

Plug for blocking the sampling tube

6.3 Method

The flow meter of the measuring system F-701-20 is located directly upstream the pump. To determine the leak rate of the AMS, the instrument is started up according to chapter 5.3.3 of the instrument´s manual and after reaching the nominal flow rate of 1000 l/h, the inlet of the sampling tube is sealed by e.g. a thumb or a plug. According to the manufacturer, the flow rate, measured by the device, has to drop lower than 10 l/h, ideally 0 l/h.

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 afore-mentioned procedure every three months right before the regular flow rate check.

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 10 l/h), proved to be an appropriate parameter for monitoring instrument tightness.

The detected maximum leak rate of 1 l/h is less than 1 % of the nominal flow rate of 1000 l/h (16.67 l/min).

6.5 Assessment

The criterion for passing the leakage test, which has been specified by the manufacturer, (flow at blocked inlet max. 10 l/h) proved to be an appropriate parameter for monitoring instrument tightness. The detected maximum leak rate of 1 l/h is less than 1 % of the nominal flow rate of 1000 l/h (16.67 l/min).

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 25 lists the values obtained in leakage testing.

Table 25: Results from leakage testing during the field tests

Leak test before	SN 1512361		SN 1512401	
Test site:	Nominal [l/h]	Actual [l/h]	Nominal [l/h]	Actual [l/h]
Bonn, winter	< 10	0	< 10	0
Bornheim, summer	< 10	1	< 10	0
Cologne, autumn	< 10	0	< 10	0
Cologne, winter	< 10	0	< 10	0

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

According to the January 2010 version of the Guide [4], 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 [7], i.e. 28 µg/m³ for PM_{10} and 17 µg/m³ for $PM_{2.5}$.
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 %:
   - Full 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 systems under test u_{bs} criteria 1 and 2 will be checked.

In chapter

6.1 5.4.10 Calculation of expanded uncertainty between systems under test 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 systems under test u_{bs}

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.

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 $PM_{2.5}$ 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 [7]. The upper assessment threshold is 17 µg/m³ for $PM_{2.5}$.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (4 test sites, 213 valid data pairs for SN 1512361 and 213 valid data pairs for SN 1512401), 27.2 % of the measured values exceed the upper assessment threshold of 17 µg/m for $PM_{2.5}$. The measured concentrations are related to 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 (full dataset)
- 1 dataset with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (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)

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 $PM_{2.5}$ does not exceed the required value of 2.5 µg/m³.

Performance criterion met? yes

6.6 Detailed presentation of test results

Table 26 lists the calculated values for the uncertainty between candidates u_{bs}. Graphical representations of the results are provided in Figure 29 to Figure 35.

Table 26: Uncertainty between candidates u_{bs} for the devices SN 1512361 and SN 1512401, measured component $PM_{2.5}$

Device	Test site	No. of values	Uncertainty u_{bs}
SN			µg/m³
1512361 / 1512401	**All test sites**	**265**	**0.61**
Single test sites			
1512361 / 1512401	Bonn, winter	61	0.62
1512361 / 1512401	Bornheim, summer	67	0.45
1512361 / 1512401	Cologne, autumn	85	0.81
1512361 / 1512401	Cologne, winter	52	0.33
Classification over reference value			
1512361 / 1512401	**Values ≥ 18 µg/m³**	**53**	**0.84**
1512361 / 1512401	Values < 18 µg/m³	160	0.50

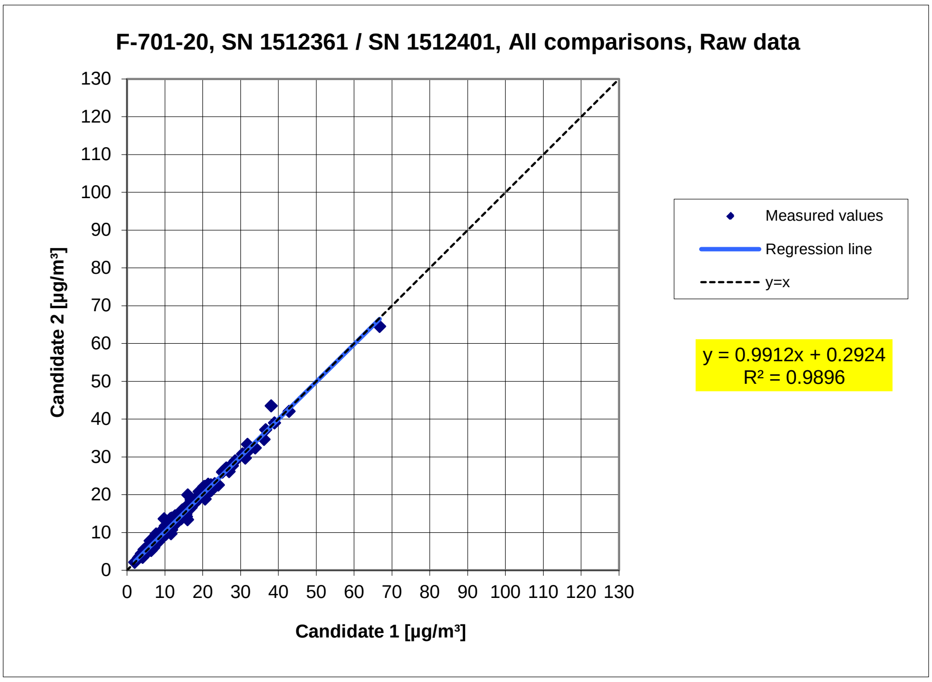


Figure 29: Results of the parallel measurements with the devices SN 1512361 / SN 1512401, measured component $PM_{2.5}$, all test sites

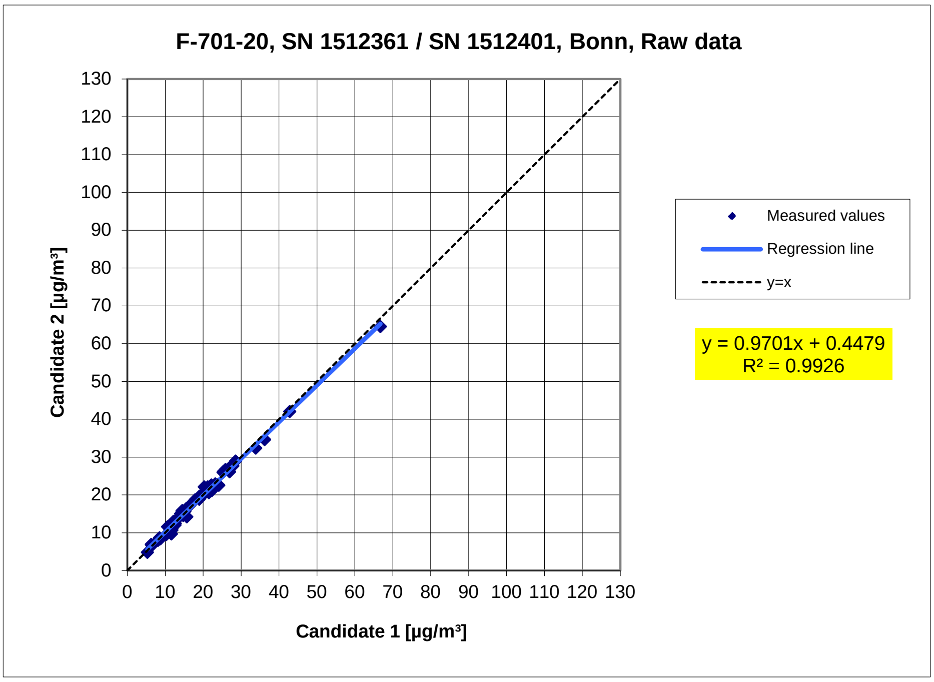


Figure 30: Results of the parallel measurements with the devices SN 1512361 / SN 1512401, measured component $PM_{2.5}$, test site Bonn, road junction, winter

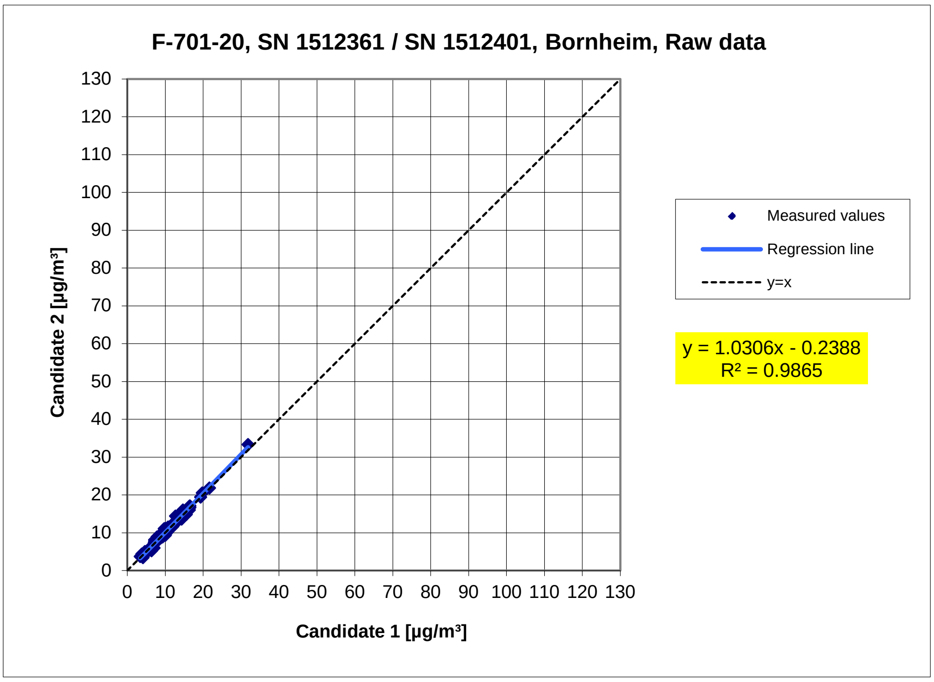


Figure 31: Results of the parallel measurements with the devices SN 1512361 / SN 1512401, measured component $PM_{2.5}$, test site Bornheim, summer

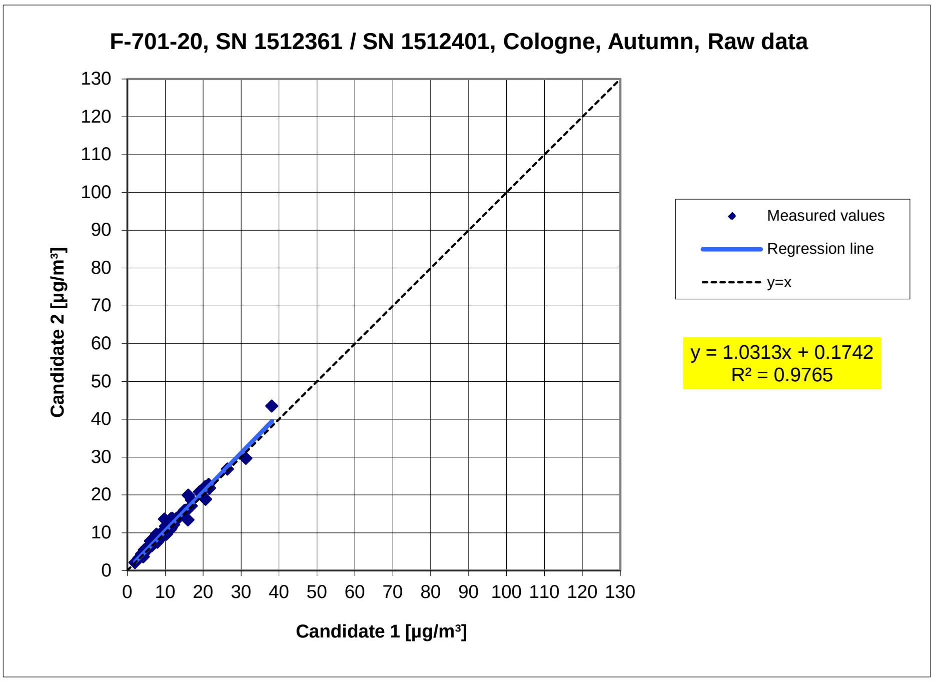


Figure 32: Results of the parallel measurements with the devices SN 1512361 / SN 1512401, measured component $PM_{2.5}$, test site Cologne, autumn

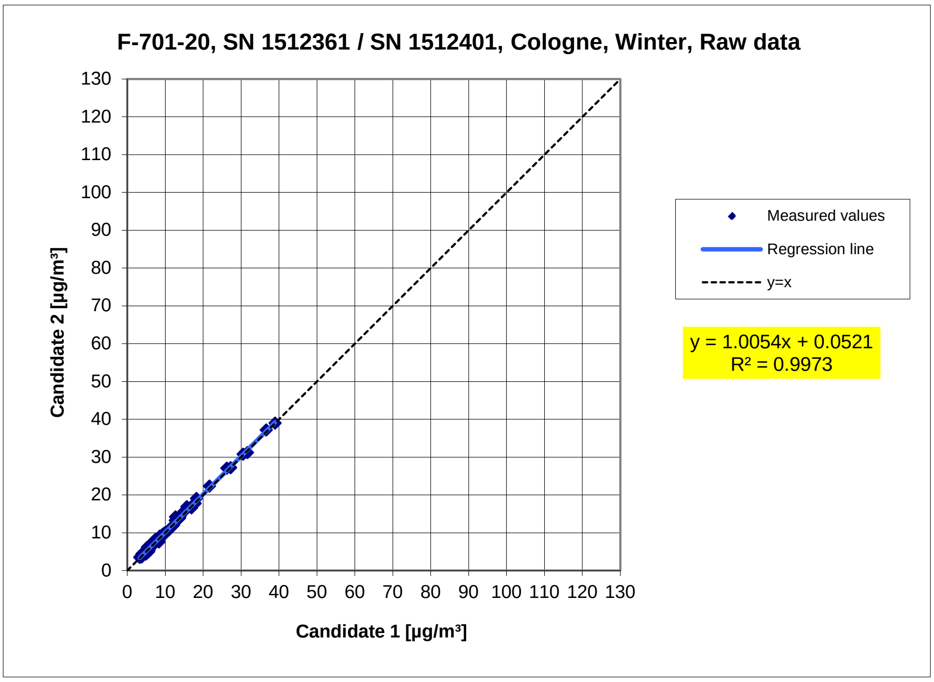


Figure 33: Results of the parallel measurements with the devices SN 1512361 / SN 1512401, measured component $PM_{2.5}$, test site Cologne, winter

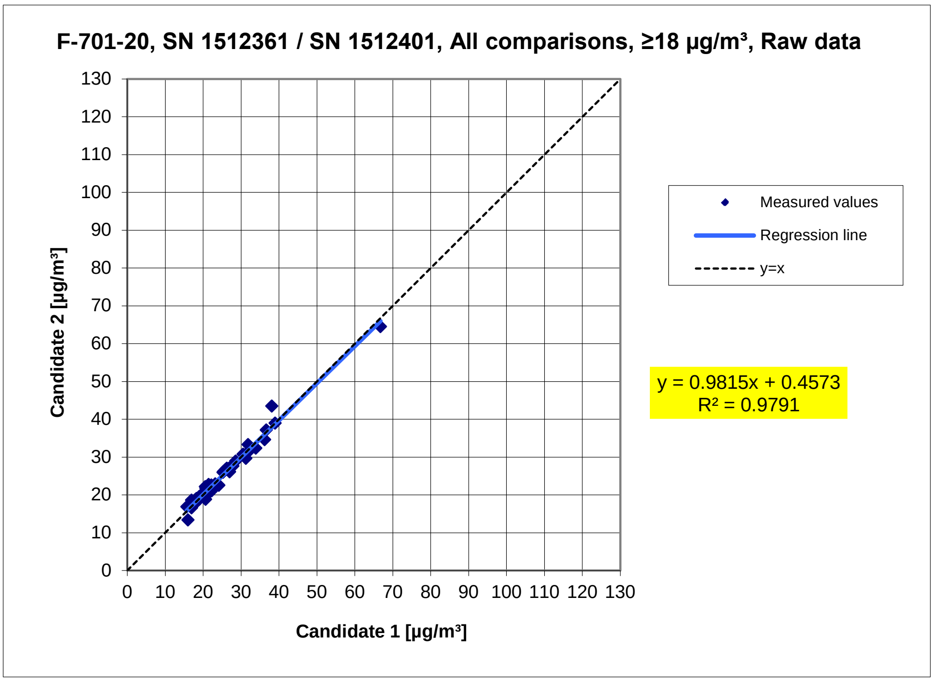


Figure 34: Results of the parallel measurements with the devices SN 1512361 / SN 1512401, measured component $PM_{2.5}$, all test sites, values ≥ 18 µg/m³

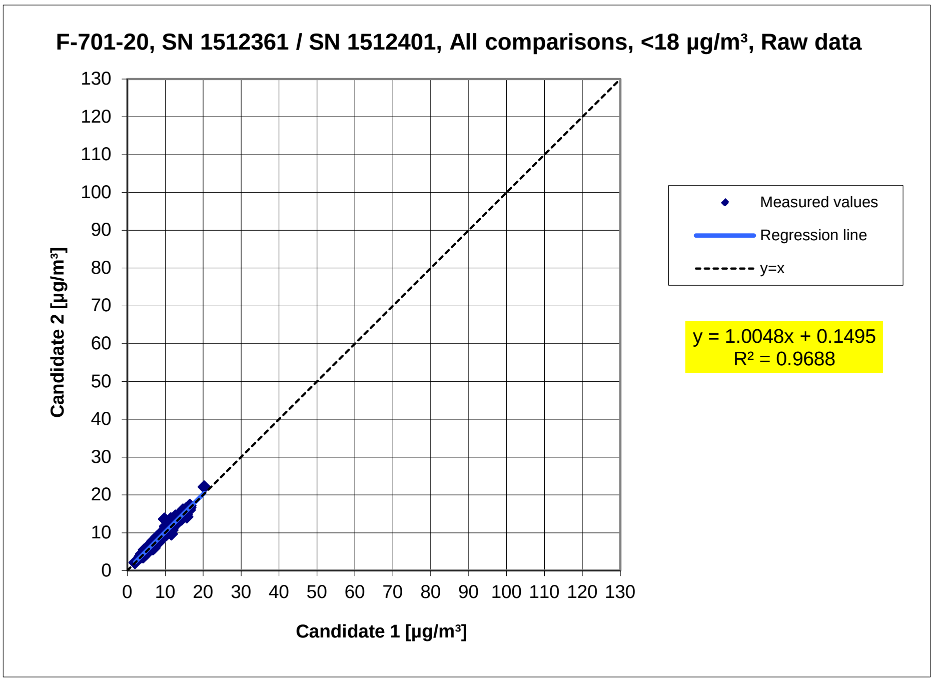


Figure 35: Results of the parallel measurements with the devices SN 1512361 / SN 1512401, measured component $PM_{2.5}$, all test sites, values < 18 µg/m³

6.1 5.4.10 Calculation of expanded uncertainty between systems under test

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).

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 $PM_{2.5}$ 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 [7]. The upper assessment threshold is 17 µg/m³ for $PM_{2.5}$.

At least 40 valid data pairs were determined per comparison. Out of the complete dataset (4 test sites, 213 valid data pairs for SN 1512361 and 213 valid data pairs for SN 1512401), 27.2 % of the measured values exceed the upper assessment threshold of 17 µg/m for $PM_{2.5}$. The measured concentrations are related to 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)

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 systems under test 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 [4].

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)

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

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

and that

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

with u(b) and u(a) being the standard uncertainties of slope and intercept, each calculated as the square root of their variances. If these preconditions are not met, the candidates may be calibrated according to item 9.7 of the guideline (refer to

6.1 5.4.11 Application of correction factors and terms. The calibration shall only be applied to the full 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 $PM_{2.5}$.

[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 praxis 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 [7] 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 % [7].

6.5 Assessment

The determined uncertainties W_{CM} for all datasets under consideration lie below the defined expanded relative uncertainty W_{dqo} of 25 % for suspended particulate matter without application of correction factors.

Performance criterion met? yes

Because of the significance of the slope and the intercept for the complete data set, correction factors are applied according to chapter

6.1 5.4.11 Application of correction factors and terms.

Table 27 provides an overview of all results from the equivalence test of the F-701-20 for $PM_{2.5}$. In the event that a criterion has not been met, the respective cell is marked in red.

Table 27: Overview of equivalence test of F-701-20 for $PM_{2.5}$

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	F-701-20		SN	SN 1512361 / SN 1512401	
			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	**0.61**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**213**				
Slope b	**0.917**	**significant**			
Uncertainty of b	**0.009**				
Ordinate intercept a	**0.587**	**significant**			
Uncertainty of a	**0.153**				
Expanded meas. uncertainty W_{CM}	**14.64**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.70**	**µg/m³**			
Uncertainty between Candidates	**0.84**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**53**				
Slope b	**0.922**				
Uncertainty of b	**0.025**				
Ordinate intercept a	**0.368**				
Uncertainty of a	**0.700**				
Expanded meas. uncertainty W_{CM}	**16.33**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.50**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**160**				
Slope b	**0.936**				
Uncertainty of b	**0.022**				
Ordinate intercept a	**0.431**				
Uncertainty of a	**0.224**				
Expanded meas. uncertainty W_{CM}	**11.82**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	F-701-20		SN	SN 1512361 / SN 1512401	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Bonn					
Uncertainty between Reference	0.62	µg/m³			
Uncertainty between Candidates	0.62	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	51			51	
Slope b	0.925			0.903	
Uncertainty of b	0.018			0.020	
Ordinate intercept a	0.882			1.105	
Uncertainty of a	0.400			0.457	
Expanded meas. uncertainty W_{CM}	11.97	%		15.11	%
Bornheim					
Uncertainty between Reference	0.52	µg/m³			
Uncertainty between Candidates	0.45	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	54			54	
Slope b	1.020			1.045	
Uncertainty of b	0.031			0.030	
Ordinate intercept a	-0.429			-0.611	
Uncertainty of a	0.377			0.365	
Expanded meas. uncertainty W_{CM}	6.70	%		8.07	%
Cologne, Autumn					
Uncertainty between Reference	0.65	µg/m³			
Uncertainty between Candidates	0.81	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	62			62	
Slope b	0.922			0.962	
Uncertainty of b	0.021			0.029	
Ordinate intercept a	0.284			0.315	
Uncertainty of a	0.270			0.386	
Expanded meas. uncertainty W_{CM}	15.06	%		11.53	%
Cologne, Winter					
Uncertainty between Reference	0.49	µg/m³			
Uncertainty between Candidates	0.33	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	46			46	
Slope b	0.852			0.856	
Uncertainty of b	0.010			0.009	
Ordinate intercept a	0.775			0.875	
Uncertainty of a	0.165			0.155	
Expanded meas. uncertainty W_{CM}	24.65	%		23.12	%
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	0.70	µg/m³			
Uncertainty between Candidates	0.84	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	53			53	
Slope b	0.929			0.920	
Uncertainty of b	0.023			0.030	
Ordinate intercept a	0.195			0.422	
Uncertainty of a	0.629			0.85	
Expanded meas. uncertainty W_{CM}	15.49	%		17.99	%
All comparisons, <18 µg/m³					
Uncertainty between Reference	0.53	µg/m³			
Uncertainty between Candidates	0.50	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	160			160	
Slope b	0.930			0.950	
Uncertainty of b	0.022			0.023	
Ordinate intercept a	0.396			0.395	
Uncertainty of a	0.233			0.236	
Expanded meas. uncertainty W_{CM}	13.31	%		10.11	%
All comparisons					
Uncertainty between Reference	0.58	µg/m³			
Uncertainty between Candidates	0.61	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	213			213	
Slope b	0.921	significant		0.915	significant
Uncertainty of b	0.009			0.010	
Ordinate intercept a	0.457	significant		0.689	significant
Uncertainty of a	0.151			0.172	
Expanded meas. uncertainty W_{CM}	14.60	%		15.02	%

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 of the expanded uncertainties are below 25 %.

Criterion 5: The slopes and the intercepts obtained from the evaluation of the full dataset are significantly greater than the permissible values for SN 1512361 and SN 1512401.

Other: The evaluation of the full data set for both candidates together shows, that the measuring system has got a very good correlation with the reference method with a slope of 0.917 and an intercept of 0.587 at an expanded overall uncertainty of 14.6 %.

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 [9] 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 F-701-20 measuring system for $PM_{2.5}$ 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 27, the slope and intercept should be corrected for $PM_{2.5}$ due to its determined significance. Nonetheless it should be noted that, even without application of correction factors, the determined uncertainties W_{CM} for $PM_{2.5}$ lie below the specified expanded relative uncertainty W_{dqo} of 25 % for particulate matter for all datasets considered.

The slope for the complete dataset is 0.917. The intercept for the complete dataset is 0.587. 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.

The revised January 2010 version of the Guide requires that, in order to monitor the processes in compliance with the Directive, 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 full dataset (here: uncorrected raw data) shall be referred to, i.e. 14.6 % for PM2.5, which would require annual checks at 3 sites (Guide [4], 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 28 presents an overview of the uncertainties between the reference devices u_{ref} obtained in the field tests.

Table 28: 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	Bonn, winter	51	0.62
1 / 2	Bornheim, summer	54	0.52
1 / 2	Cologne, autumn	62	0.65
1 / 2	Cologne, winter	46	0.49
1 / 2	All test sites	213	0.58

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

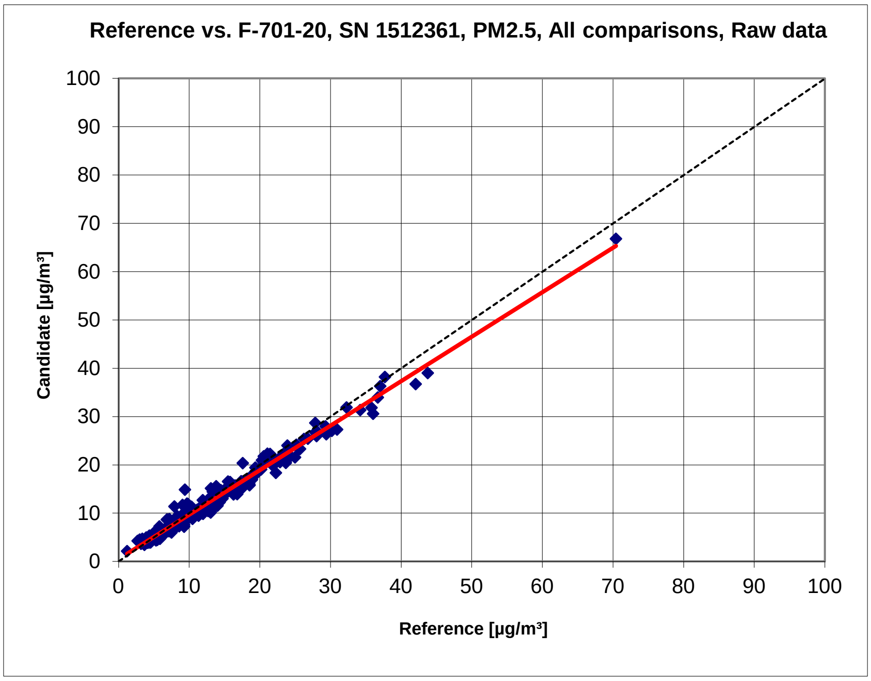


Figure 36: Reference device vs. candidate, SN 1512361, measured component $PM_{2.5}$, all test sites

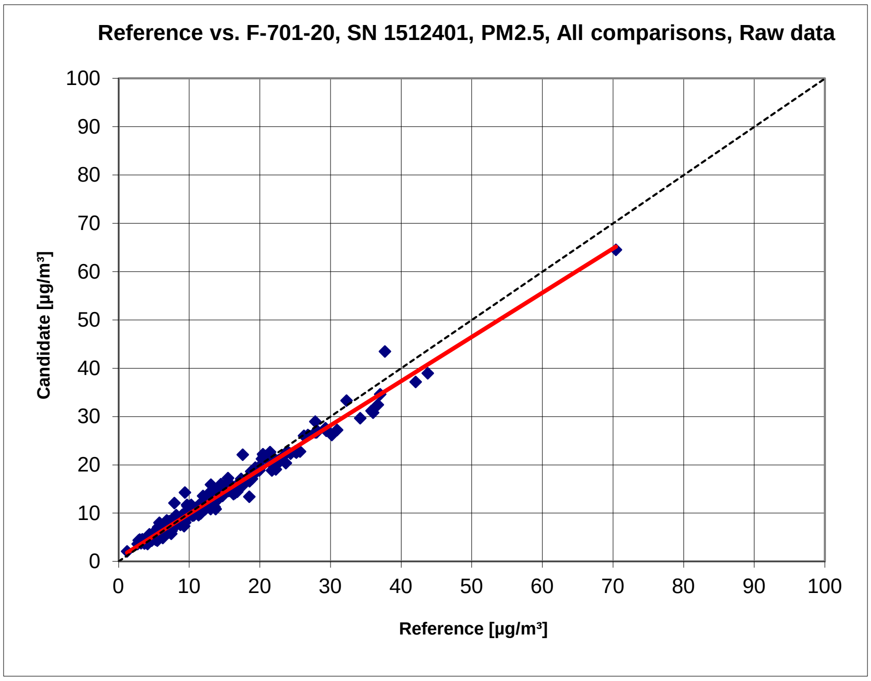


Figure 37: Reference device vs. candidate, SN 1512401, measured component $PM_{2.5}$, all test sites

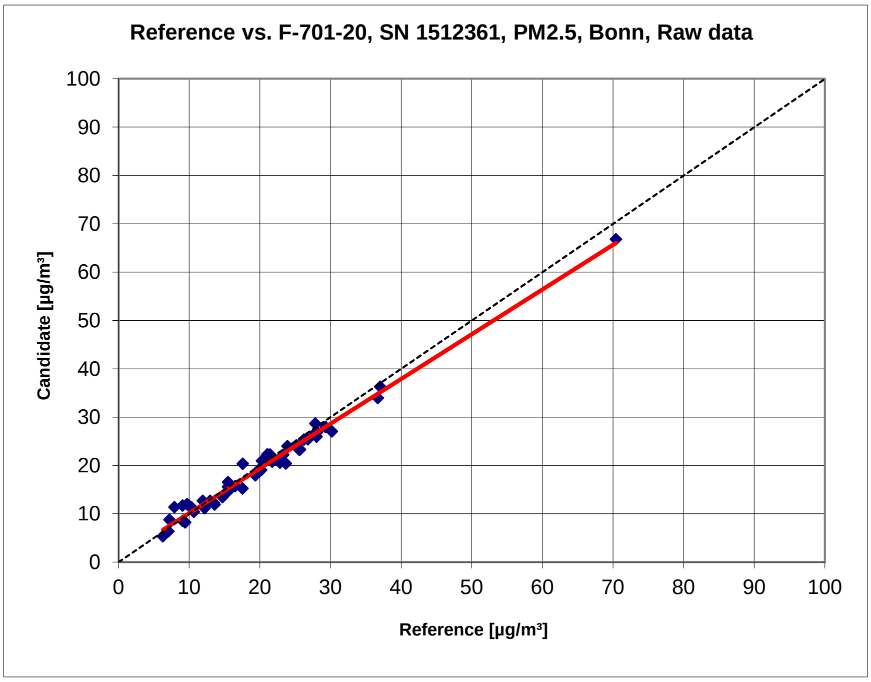


Figure 38: Reference device vs. candidate, SN 1512361, measured component $PM_{2.5}$, Bonn, road junction, winter

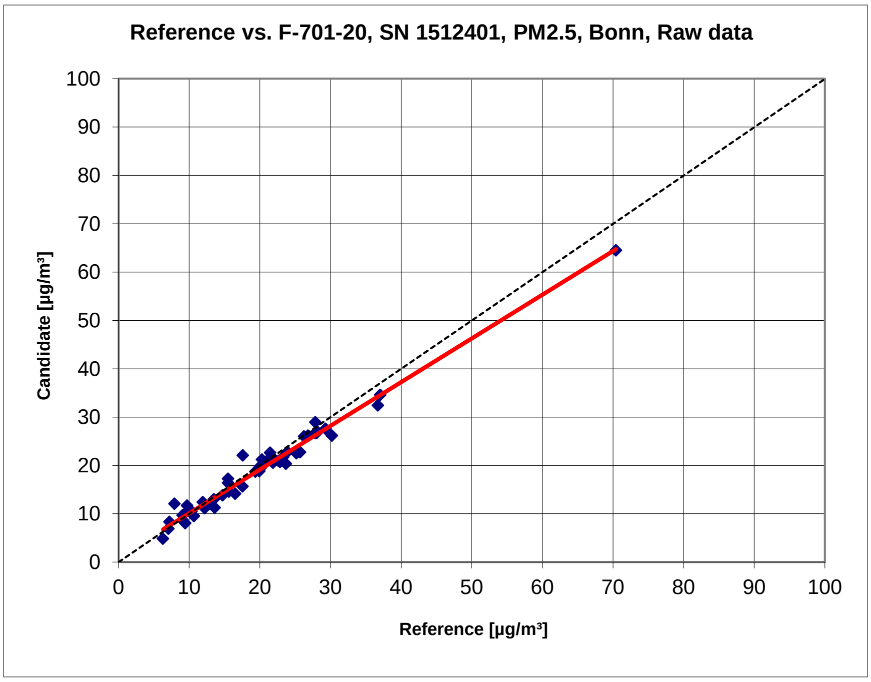


Figure 39: Reference device vs. candidate, SN 1512401, measured component $PM_{2.5}$, Bonn, road junction, winter

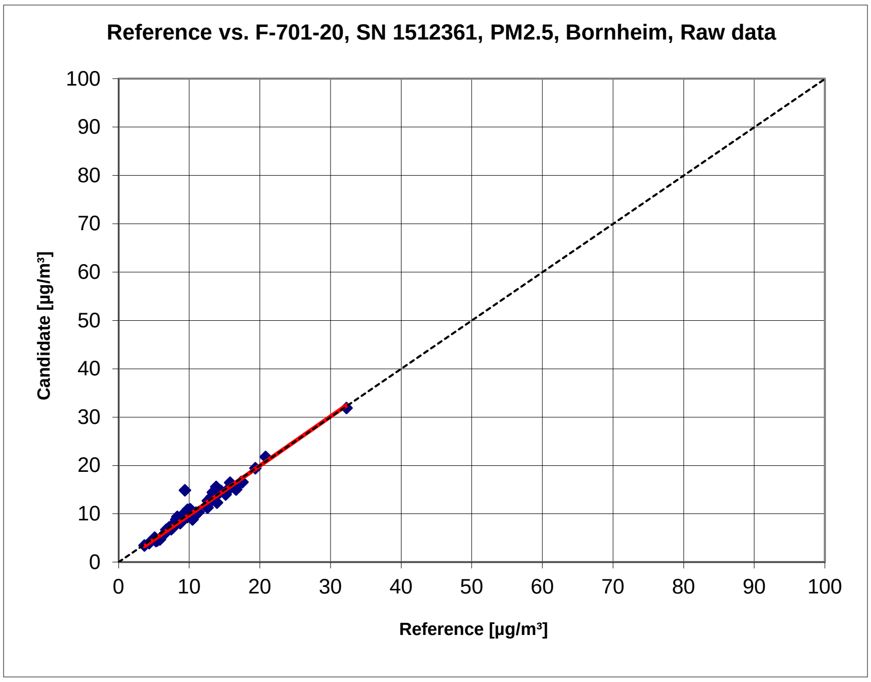


Figure 40: Reference device vs. candidate, SN 1512361, measured component $PM_{2.5}$, Bornheim, summer

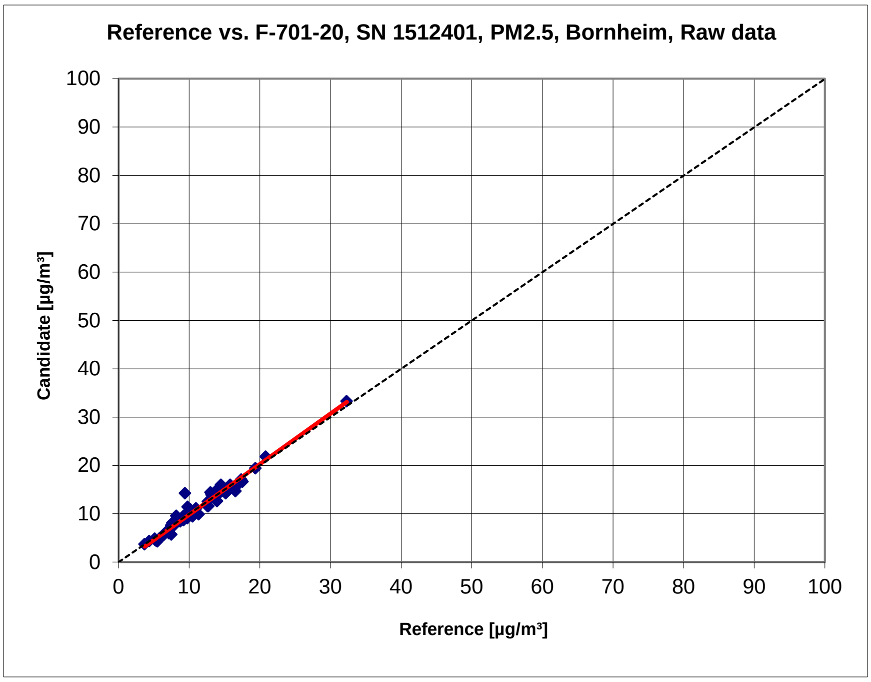


Figure 41: Reference device vs. candidate, SN 1512401, measured component $PM_{2.5}$, Bornheim, summer

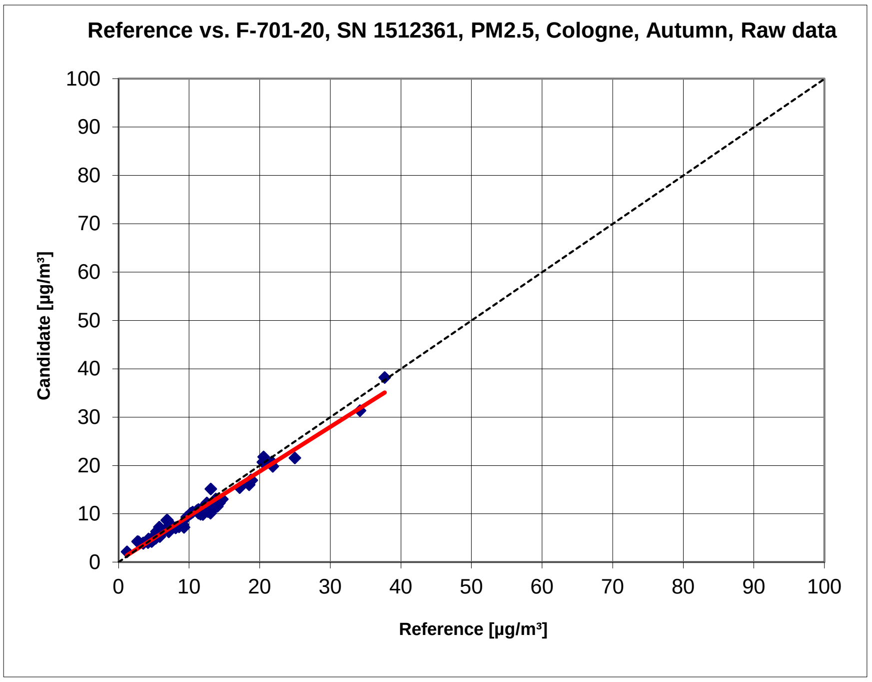


Figure 42: Reference device vs. candidate, SN 1512361, measured component $PM_{2.5}$, Cologne, autumn

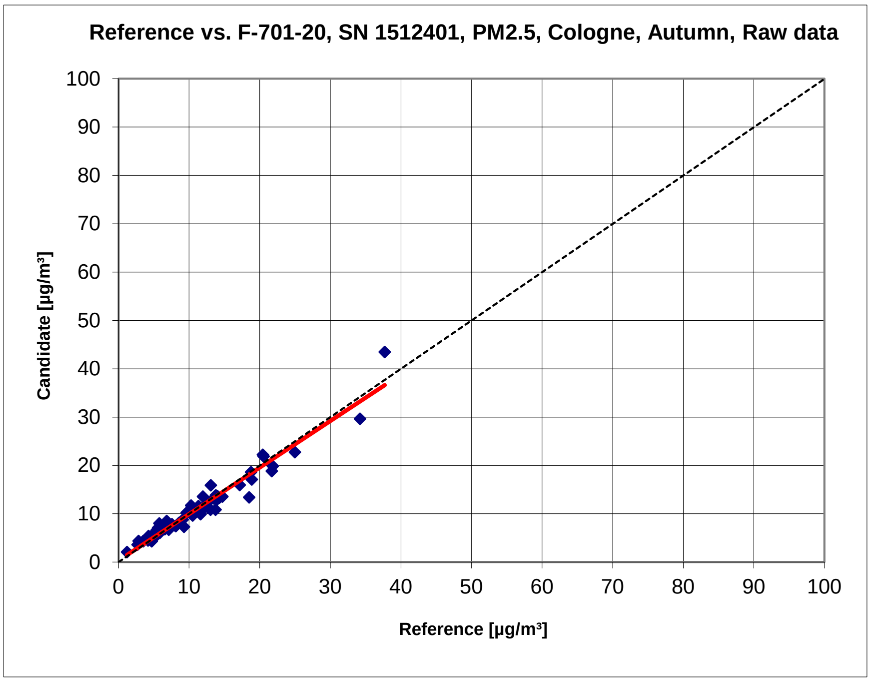


Figure 43: Reference device vs. candidate, SN 1512401, measured component $PM_{2.5}$, Cologne, autumn

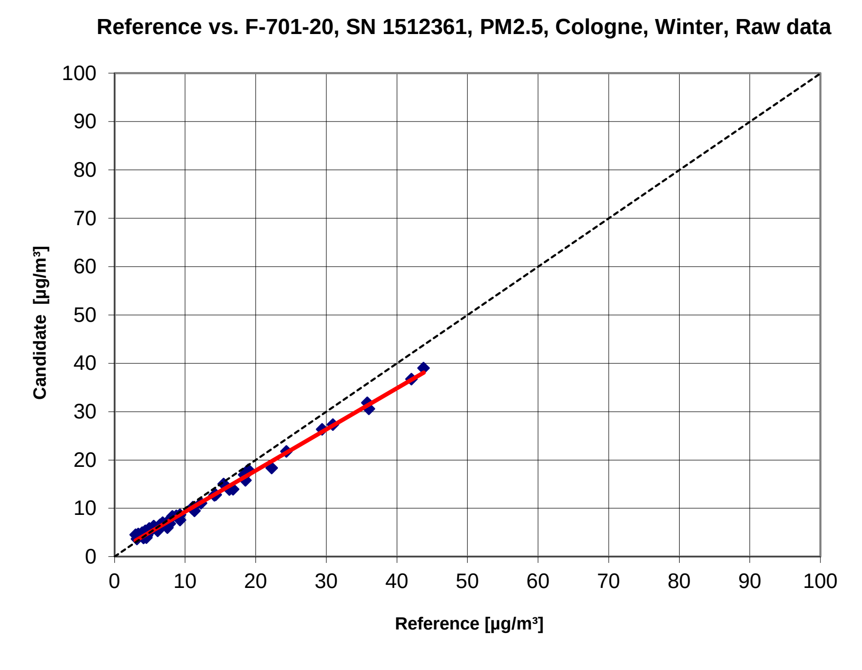


Figure 44: Reference device vs. candidate, SN 1512361, measured component $PM_{2.5}$, Cologne, winter

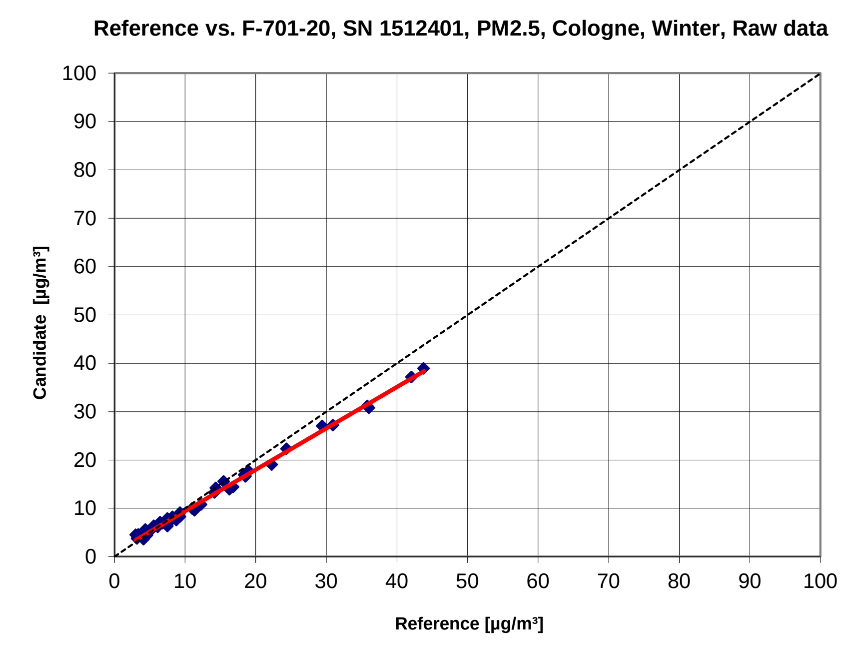


Figure 45: Reference device vs. candidate, SN 1512401, measured component $PM_{2.5}$, Cologne, winter

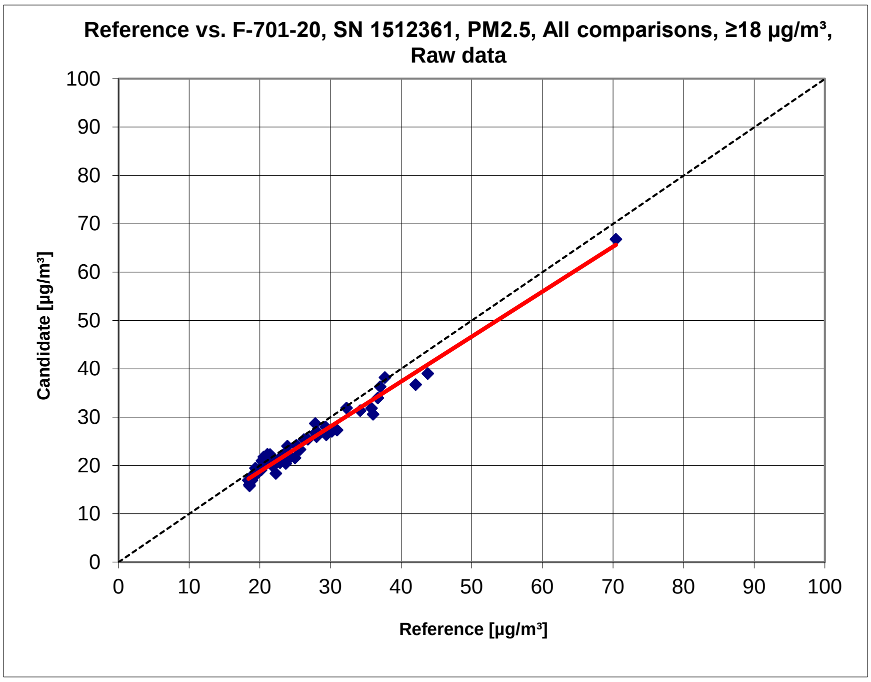


Figure 46: Reference device vs. candidate, SN 1512361, measured component $PM_{2.5}$, values ≥ 18 µg/m³

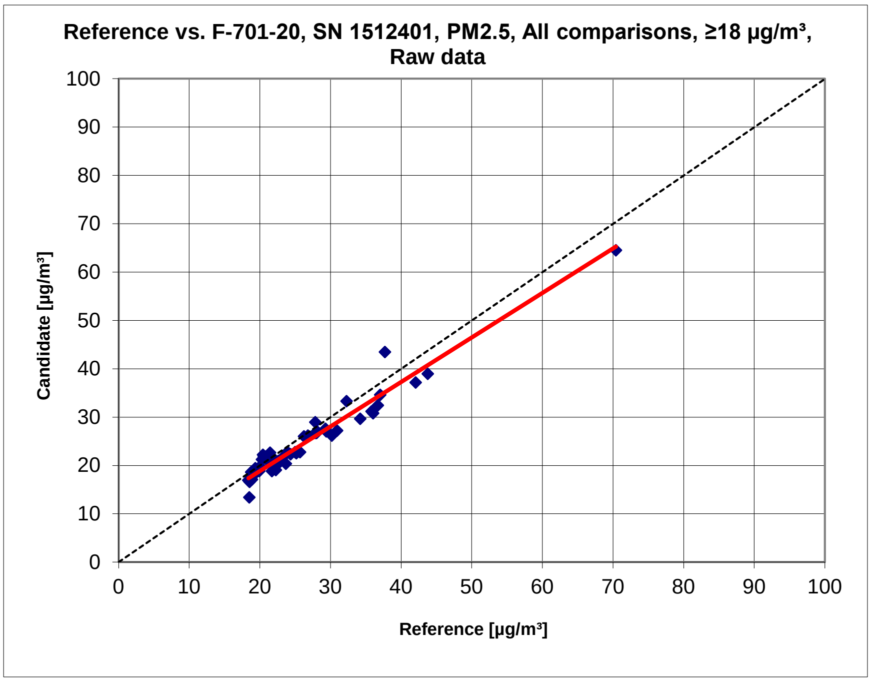


Figure 47: Reference device vs. candidate, SN 1512401, measured component $PM_{2.5}$, values ≥ 18 µg/m³

6.1 5.4.11 Application of correction factors and terms

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}.

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 full dataset. The corrected values shall satisfy the requirements for all datasets or subsets (refer to module 5.4.10). Moreover, a correction factor may be applied even for $W_{CM} \leq W_{dqo}$ in order to improve the accuracy of the candidate systems.

Three different cases may occur:

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

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

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

With respect to a)

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

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

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

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

and

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

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

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

With respect to b)

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

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

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

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

and

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

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

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

With respect to c)

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

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

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

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

and

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

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

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

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

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

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

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

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

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

The highest resulting uncertainty $W_{CM,corr}$ is compared and assessed with the requirements on data quality of ambient air measurements according to EU Standard [7]. 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 % [7].

6.5 Assessment

The candidates meet the requirements on data quality of ambient air quality measurements already without application of correction factors. A correction of the slope and the intercept nevertheless leads to a further significant improvement of the expanded measurement uncertainties of the full data set.

Performance criterion met? yes

The evaluation of the full dataset for both candidates shows a significant slope and a significant intercept for the measuring component $PM_{2.5}$.

The slope for the full dataset is 0.917. The intercept for the full dataset is 0.587 (refer to Table 27).

Slope and intercept were corrected 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. Only the test site “Bornheim, summer” gets worse significantly by the correction, but the expanded uncertainty is still below the permissible 25 %.

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 is in the range 10 % to 15 % before 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 full dataset, i.e. for $PM_{2.5}$ 14.6 % (uncorrected dataset) and 8.5 % (dataset after slope/offset correction), which would require an annual test at 3 measurement sites (uncorrected) or 2 measurement sites (corrected).

6.6 Detailed presentation of test results

Table 29 presents the results of the evaluations of the equivalence test after application of the correction factors for slope and intercept on the full dataset.

Table 29: Summary of the results of the equivalence test, SN 1512361 & SN 1512401, 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	F-701-20		SN	SN 1512361 / SN 1512401	
			Limit value	30	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**213**				
Slope b	**1.001**	**not significant**			
Uncertainty of b	**0.010**				
Ordinate intercept a	**-0.013**	**not significant**			
Uncertainty of a	**0.167**				
Expanded meas. uncertainty W_{CM}	**8.46**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.70**	**µg/m³**			
Uncertainty between Candidates	**0.92**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**53**				
Slope b	**1.007**				
Uncertainty of b	**0.027**				
Ordinate intercept a	**-0.283**				
Uncertainty of a	**0.763**				
Expanded meas. uncertainty W_{CM}	**11.12**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.54**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**160**				
Slope b	**1.025**				
Uncertainty of b	**0.024**				
Ordinate intercept a	**-0.209**				
Uncertainty of a	**0.244**				
Expanded meas. uncertainty W_{CM}	**8.36**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	F-701-20		SN	SN 1512361 / SN 1512401	
			Limit value	30	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
Bonn					
Uncertainty between Reference	**0.62**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**51**			**51**	
Slope b	**1.010**			**0.986**	
Uncertainty of b	**0.019**			**0.022**	
Ordinate intercept a	**0.306**			**0.544**	
Uncertainty of a	**0.436**			**0.499**	
Expanded meas. uncertainty W_{CM}	**9.79**	**%**		**10.46**	**%**
Bornheim					
Uncertainty between Reference	**0.52**	**µg/m³**			
Uncertainty between Candidates	**0.49**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**54**			**54**	
Slope b	**1.114**			**1.142**	
Uncertainty of b	**0.033**			**0.032**	
Ordinate intercept a	**-1.134**			**-1.330**	
Uncertainty of a	**0.411**			**0.398**	
Expanded meas. uncertainty W_{CM}	**17.07**	**%**		**20.87**	**%**
Cologne, Autumn					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.89**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**62**			**62**	
Slope b	**1.007**			**1.051**	
Uncertainty of b	**0.022**			**0.032**	
Ordinate intercept a	**-0.345**			**-0.327**	
Uncertainty of a	**0.295**			**0.421**	
Expanded meas. uncertainty W_{CM}	**7.54**	**%**		**13.97**	**%**
Cologne, Winter					
Uncertainty between Reference	**0.49**	**µg/m³**			
Uncertainty between Candidates	**0.36**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**46**			**46**	
Slope b	**0.929**			**0.934**	
Uncertainty of b	**0.011**			**0.010**	
Ordinate intercept a	**0.201**			**0.311**	
Uncertainty of a	**0.180**			**0.169**	
Expanded meas. uncertainty W_{CM}	**13.56**	**%**		**11.90**	**%**
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.70**	**µg/m³**			
Uncertainty between Candidates	**0.92**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**53**			**53**	
Slope b	**1.014**			**1.006**	
Uncertainty of b	**0.025**			**0.033**	
Ordinate intercept a	**-0.464**			**-0.246**	
Uncertainty of a	**0.686**			**0.92**	
Expanded meas. uncertainty W_{CM}	**9.81**	**%**		**13.79**	**%**
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.54**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**160**			**160**	
Slope b	**1.018**			**1.040**	
Uncertainty of b	**0.025**			**0.025**	
Ordinate intercept a	**-0.250**			**-0.251**	
Uncertainty of a	**0.254**			**0.257**	
Expanded meas. uncertainty W_{CM}	**8.15**	**%**		**10.24**	**%**
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**213**			**213**	
Slope b	**1.005**	**not significant**		**0.999**	**not significant**
Uncertainty of b	**0.010**			**0.011**	
Ordinate intercept a	**-0.155**	**not significant**		**0.095**	**not significant**
Uncertainty of a	**0.165**			**0.187**	
Expanded meas. uncertainty W_{CM}	**8.33**	**%**		**9.64**	**%**

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

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Performance criterion met? -

6.6 Detailed presentation of test results

Not applicable.

7. Recommendations for practical use

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
- No error messages
- No contamination
- Check of instrument functions according to manufacturer
- Check of filter tape stock
- Maintenance of sampling inlet according to manufacturer

As for the rest, the instructions and recommendations provided by the manufacturer shall be followed.

Further maintenance work

In addition to the regular maintenance work in the maintenance interval, the following procedures are necessary:

- Check of the filter tape stock –
  A filter tape with 45 m length is lasting theoretically for 30,000 measurement cycles in case of a cycle time of 1 h and a sample count of 24 (setting during type approval test), which equals to 1,250 days. As - because of a possible exceedance of the maximum allowed mass per filter spot of 400 µg, which is dependent on the PM concentration level under practical conditions - a new filter spot might be used earlier than by reaching the 24times sampling, the time for consumption of the filter tape might be reduced accordingly.
  In case of a cycle time of 1 h and a minimum sample count of 1 (i.e. for each cycle a new filter spot is used), there are 1,250 measurement cycles possible, which equals 52 days. Thus it is recommended to check the filter tape stock during each visit of the measuring system for regular maintenance (e.g. in the framework of cleaning the sampling inlet).
- According to the manufacturer. the pump needs maintenance approx. every 6 weeks after one year of operation, i.e. the filters must be blown out and the blade height has to be checked and the blades to be replaced if necessary.
- According to CEN/TS 16450 [8], a check of the sensors for ambient temperature and ambient pressure should be done every 3 months.
- According to CEN/TS 16450 [8], a check of the sampling flow rate should be done every 3 months.
- Within the framework of the check of the sampling flow rate, the tightness should also be checked every 3 months.
- The filter adapter, the transport reel and the pressure rollers have to be cleaned every 6 months.

- The waste air filter and the hose connections have to be checked and if necessary blown out every 6 months.
- The pump filter and seals shall be replaced once a year.
- Once per year, the meteorological sensor has to be sent to the manufacturer for recalibration. Furthermore it is recommended to check the radiometric measurement with the help of the reference foil once a year.
- During the annual maintenance, the cleaning of the sampling tube needs also to be considered.

Further details are provided in the user manual.

Department of Environmental Protection/Air Pollution Control

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Cologne, 17th March 2014
936/21220478/A

8. 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 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 of January 2010

[5] Operator’s manual F-701-20 Rev. 04 von 03 / 2014

[6] Operator’s manual LVS3, Stand 2000

[7] 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

[8] Technical Specification CEN/TS 16450, “Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2.5)”; German version, August 2013

[9] Report “UK Equivalence Programme for Monitoring of Particulate Matter”, Report No.: BV/AQ/AD202209/DH/2396 of 5 June 2006

9. Annex

Appendix 1 Measured and calculated values

Annex 1: Detection limit
Annex 2: Temperature dependence of zero point
Annex 3: Temperature dependence of the sensitivity
Annex 4: Dependence on supply voltage
Annex 5: Measured values at the field test sites
Annex 6: Ambient conditions at the field test sites

Appendix 2 Filter weighing procedure

Appendix 3 Manuals

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

Manufacturer DURAG GmbH

Type F-701-20

Standards ZP Measured values with zero filter

Serial-No. SN 1512401 / SN 1512361

No.	Date	Measured values [µg/m³] SN 1512401	Date	Measured values [µg/m³] SN 1512361
1	20.12.12	0.4	20.12.12	0.3
2	21.12.12	0.6	21.12.12	0.1
3	22.12.12	0.3	22.12.12	0.7
4	23.12.12	0.1	23.12.12	0.0
5	24.12.12	0.3	24.12.12	0.8
6	25.12.12	0.7	25.12.12	-0.4
7	26.12.12	-0.3	26.12.12	0.5
8	27.12.12	0.0	27.12.12	0.7
9	28.12.12	0.9	28.12.12	-0.1
10	29.12.12	0.1	29.12.12	0.4
11	30.12.12	0.0	30.12.12	0.2
12	31.12.12	0.2	31.12.12	0.6
13	01.01.13	0.5	01.01.13	0.5
14	02.01.13	0.5	02.01.13	0.0
19	03.01.13	0.0	03.01.13	0.6
	No. of values	15	No. of values	15
	Mean	0.28	Mean	0.34
	Standard deviation s_{x0}	0.31	Standard deviation s_{x0}	0.35
	Detection limit x	0.66	Detection limit x	0.75

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

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

Manufacturer DURAG GmbH

Type F-701-20

Serial-No. SN 1512361 / SN 1512401

Standards ZP Zero filter

			Cycle 1		Cycle 2		Cycle 3	
SN 1512361	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	1.0	-	0.5	-	0.7	-
	2	5	1.2	0.2	0.8	0.3	0.4	-0.3
	3	20	1.4	0.5	0.4	-0.1	0.7	0.0
	4	40	0.0	-0.9	-0.4	-0.9	-0.4	-1.1
	5	20	0.7	-0.3	0.5	0.1	0.1	-0.7
SN 1512401	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	0.5	-	0.1	-	0.3	-
	2	5	-0.1	-0.6	-0.2	-0.3	0.0	-0.2
	3	20	-0.2	-0.6	0.7	0.6	0.4	0.1
	4	40	-0.5	-1.0	-0.4	-0.5	0.2	0.0
	5	20	0.2	-0.2	0.4	0.4	0.2	0.0

Annex 3 — Dependence of measured value on ambient temperature — Page 1 of 1

Manufacturer DURAG GmbH

Standards — Reference foil

Type F-701-20

Serial-No. SN 1512361 / SN 1512401

			Cycle 1		Cycle 2		Cycle 3			
SN 1512361	No.	Temperature [°C]	Measured value	Dev. [%]	Measured value	Dev. [%]	Measured value	Dev. [%]		
RP	1	20	294.0	-	289.0	-	290.0	-		
	2	5	292.0	-0.7	292.0	1.0	283.0	-2.4		
	3	20	292.0	-0.7	292.0	1.0	298.0	2.8		
	4	40	288.0	-2.0	280.0	-3.1	280.0	-3.4		
	5	20	284.0	-3.4	284.0	-1.7	285.0	-1.7		
SN 1512401	No.	Temperature [°C]	Measured value	Dev. [%]	Measured value	Dev. [%]	Measured value	Dev. [%]		
RP	1	20	277.0	-	272.0	-	274.0	-		
	2	5	267.0	-3.6	270.0	-0.7	273.0	-0.4		
	3	20	262.0	-5.4	275.0	1.1	265.0	-3.3		
	4	40	261.0	-5.8	263.0	-3.3	274.0	0.0		
	5	20	267.0	-3.6	268.0	-1.5	271.0	-1.1		

Annex 4 **Dependence of measured value on mains voltage** **Page 1 of 1**

Manufacturer DURAG GmbH

Standards Reference foil

Type F-701-20

Serial-No. SN 1512361 / SN 1512401

			Cycle 1		Cycle 2		Cycle 3	
SN 1512361	No.	Mains voltage [V]	Measured value	Dev. [%]	Measured value	Dev. [%]	Measured value	Dev. [%]
RP	1	230	294.0	-	284.0	-	295.0	-
	2	210	288.0	-2.0	286.0	0.7	293.0	-0.7
	3	230	294.0	0.0	289.0	1.8	287.0	-2.7
	4	245	284.0	-3.4	294.0	3.5	294.0	-0.3
	5	230	292.0	-0.7	289.0	1.8	282.0	-4.4
SN 1512401	No.	Mains voltage [V]	Measured value	Dev. [%]	Measured value	Dev. [%]	Measured value	Dev. [%]
RP	1	230	270.0	-	279.0	-	273.0	-
	2	210	272.0	0.7	269.0	-3.6	279.0	2.2
	3	230	261.0	-3.3	279.0	0.0	279.0	2.2
	4	245	283.0	4.8	271.0	-2.9	265.0	-2.9
	5	230	283.0	4.8	267.0	-4.3	266.0	-2.6

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 1 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM2,5 [µg/m³]	SN 1512401 PM2,5 [µg/m³]	Remark	Test site
1	2/28/2013								Zero point	Bonn, Winter
2	3/1/2013	24.9	23.0	36.3	36.7	65.6	24.0	22.8		
3	3/2/2013						27.7	27.8		
4	3/3/2013	22.1	23.2	29.3	29.8	76.6	21.2	20.9		
5	3/4/2013	19.6	20.5	28.2	28.7	70.2	19.3	19.7		
6	3/5/2013	28.4	27.7	40.2	39.9	70.1	26.0	26.7		
7	3/6/2013	25.8	24.5	39.3	39.7	63.8	24.2	22.5		
8	3/7/2013	28.0	28.3	39.5	39.5	71.2	26.9	27.0		
9	3/8/2013	28.8	27.0	35.4	34.8	79.5	28.6	28.9		
10	3/9/2013						12.0	11.5		
11	3/10/2013	21.8	22.0	23.1	22.3	96.5	21.6	20.6		
12	3/11/2013	27.6	28.1	31.2	30.3	90.6	26.7	26.7		
13	3/12/2013	15.6	15.6	17.8	17.7	87.9	14.8	14.5		
14	3/13/2013	36.7	36.7	50.8	50.0	72.9	33.9	32.4		
15	3/14/2013	19.6	19.2	27.5	27.6	70.3	18.0	18.7		
16	3/15/2013	22.0	21.5	31.7	31.7	68.7	20.8	21.7		
17	3/16/2013						14.4	15.7		
18	3/17/2013	7.0	7.4	11.0	10.5	67.2	8.8	8.3		
19	3/18/2013	7.7	8.2	17.4	17.2	45.9	11.4	12.0		
20	3/19/2013	9.5	9.9	17.1	16.8	57.5	11.9	11.7		
21	3/20/2013	21.3	20.9	25.2	24.5	84.7	22.3	21.1		
22	3/21/2013	37.5	36.6	46.3	45.9	80.5	36.2	34.6		
23	3/22/2013	21.4	21.6	26.0	26.3	82.2	22.2	22.6		
24	3/23/2013						23.4	22.5		
25	3/24/2013	15.1	15.9	19.7	18.8	80.6	16.5	17.2		
26	3/25/2013	20.1	20.6	26.0	25.6	78.9	20.9	21.2		
27	3/26/2013	15.7	15.3	21.1	20.4	74.7	15.6	16.4		
28	3/27/2013	26.6	25.9	33.3	32.8	79.5	25.3	26.0		
29	3/28/2013						42.9	42.0		
30	3/29/2013	71.1	69.8	76.5	76.3	92.2	66.8	64.5		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 2 of 10**

Manufacturer	DURAG
Type of instrument	F701-20
Serial-No.	SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
31	3/30/2013								Zero point	Bonn, Winter
32	3/31/2013								Zero point	
33	4/1/2013								Zero point	
34	4/2/2013	20.2	20.2	24.7	25.2	81.0	19.0	19.5		
35	4/3/2013	27.2	26.5	31.4	30.8	86.3	25.4	26.2		
36	4/4/2013	29.5	29.1	33.5	33.2	88.0	27.9	27.6		
37	4/5/2013	25.8	25.4	30.8	30.0	84.1	23.2	22.9		
38	4/6/2013						21.3	22.1		
39	4/7/2013	23.0	22.8	30.9	30.2	74.9	20.6	20.7		
40	4/8/2013	26.3	25.1	31.7	31.7	81.0	23.3	22.7		
41	4/9/2013	16.5	16.5	21.6	21.0	77.4	15.7	14.1		
42	4/10/2013	12.2	12.2	17.9	17.8	68.4	11.1	11.1		
43	4/11/2013	9.4	8.8	15.9	15.7	57.4	8.5	8.7		
44	4/12/2013	6.2	6.3	10.4	10.4	60.4	5.3	4.8		
45	4/13/2013						6.5	6.6		
46	4/14/2013	7.2	6.9	11.9	11.1	61.4	6.4	6.9		
47	4/15/2013	18.5	16.8	31.2	30.2	57.3	20.3	22.1		
48	4/16/2013	12.7	11.2	21.1	20.7	57.2	12.7	12.4		
49	4/17/2013	9.9	9.8	19.5	19.7	50.2	11.8	10.7		
50	4/18/2013	9.4	8.7	21.4	21.5	42.2	11.7	9.7		
51	4/19/2013	10.3	10.3	21.0	20.8	49.4	11.3	10.5		
52	4/20/2013						10.6	11.5		
53	4/21/2013	24.4	23.0	36.7	37.6	63.8	20.4	20.3		
54	4/22/2013	31.0	29.4	44.7	43.9	68.3	27.0	26.1		
55	4/23/2013	11.0	10.4	18.2	18.8	57.6	10.4	9.5		
56	4/24/2013	14.3	12.7	24.2	24.4	55.6	12.2	13.0		
57	4/25/2013	13.8	12.1	23.3	23.6	55.3	12.6	12.0		
58	4/26/2013								Zero point	
59	4/27/2013								Zero point	
60	4/28/2013								Zero point	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 3 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
61	4/29/2013	14.3	12.9	20.6	21.4	64.9	11.9	11.2		Bonn, Winter
62	4/30/2013						14.1	15.0		
63	5/1/2013	16.9	18.2	21.4	22.2	80.7	15.2	15.6		
64	5/2/2013						14.5	15.8		
65	5/3/2013	23.2	23.4	33.7	34.4	68.5	22.2	21.7		
66	5/4/2013	20.2	19.7	30.1	30.6	65.7	19.1	18.8		
67	5/5/2013	9.6	9.3	14.0	14.8	65.4	8.2	8.0		
68	5/6/2013	14.5	15.0	23.3	22.9	63.9	13.4	13.8		
69	5/14/2013								Zero point	Bornheim, Summer
70	5/15/2013								Zero point	
71	5/16/2013	21.0	20.7	24.5	24.7	84.6	21.7	21.8		
72	5/17/2013	16.1	15.5	18.3	19.4	83.8	16.4	16.0		
73	5/18/2013						8.8	9.3		
74	5/19/2013						19.9	20.5		
75	5/20/2013	11.3	10.3	13.9	14.7	75.2	9.5	10.2		
76	5/21/2013		5.4	8.3	8.8		5.1	4.9	Power loss Ref. PM2,5 G#1	
77	5/22/2013						6.4	5.2		
78	5/23/2013						5.3	4.8		
79	5/24/2013			10.1	10.7		6.6	6.1	Power loss Ref. PM2,5	
80	5/25/2013						10.4	10.8		
81	5/26/2013		6.6	12.9	13.4		7.2	7.0	Power loss Ref. PM2,5 G#2	
82	5/27/2013	11.7	11.0	16.9	17.6	65.7	10.3	9.9		
83	5/28/2013	8.7	7.7	12.8	12.2	65.8	7.9	8.9		
84	5/29/2013						4.2	3.4		
85	5/30/2013						9.8	11.0		
86	5/31/2013						16.4	16.9		
87	6/1/2013						13.3	13.0		
88	6/2/2013	5.3	5.0	10.8	10.7	47.7	5.0	4.8		
89	6/3/2013	8.0	7.0	14.5	14.5	51.5	7.2	7.6		
90	6/4/2013	9.5	9.5	18.2	18.4	51.9	10.1	9.3		

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

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
91	6/5/2013	9.1	9.3	17.2	18.8	51.2	8.9	8.7		Bornheim, Summer
92	6/6/2013	10.8	10.2	17.0	17.5	60.8	8.8	9.4		
93	6/7/2013	17.0	16.1	28.6	29.9	56.6	15.1	14.7		
94	6/8/2013						15.0	15.7		
95	6/9/2013	14.0	13.6	20.1	21.3	66.9	15.6	14.8		
96	6/10/2013	16.1	15.4	26.1	27.1	59.1	15.4	15.0		
97	6/11/2013	13.0	12.2	20.8	20.7	60.7	11.3	11.6		
98	6/12/2013	7.1	6.4	14.6	14.0	47.4	6.7	6.3		
99	6/13/2013	5.6	5.4	13.4	12.7	42.1	4.4	4.3		
100	6/14/2013	5.0	5.7	10.8	10.8	49.3	4.3	4.4		
101	6/15/2013	5.1	5.3	10.6	10.2	50.0	4.5	4.6		
102	6/16/2013	7.3	7.6	16.7	16.6	44.8	6.8	5.7		
103	6/17/2013	12.2	13.3	21.3	20.9	60.3	12.0	11.6		
104	6/18/2013	17.8	17.3	28.6	29.1	60.9	16.5	16.7		
105	6/19/2013	31.9	32.7	48.7	48.5	66.5	31.9	33.3		
106	6/20/2013	8.7	10.1	15.5	14.9	62.1	14.9	14.2		
107	6/21/2013	4.2	4.5	7.2	6.8	62.2	3.9	4.3		
108	6/22/2013	3.3	4.1	5.7	5.9	63.8			Zero point	
109	6/23/2013	3.1	3.0	4.6	5.5	59.8			Zero point	
110	6/24/2013	8.7	8.0	13.9	13.2	61.6	9.3	8.8		
111	6/25/2013	6.3	6.6	12.9	12.7	50.4	5.7	5.6		
112	6/26/2013	9.1	9.4	14.6	14.5	63.4	10.0	9.6		
113	6/27/2013	9.8	9.6	14.2	13.8	69.5	9.3	9.0		
114	6/28/2013	8.8	8.7	14.2	14.7	60.4	8.0	8.4		
115	6/29/2013	6.0	5.8	11.7	11.5	50.8	4.7	5.0		
116	6/30/2013	7.4	6.9	14.6	14.4	49.3	7.1	6.0		
117	7/1/2013	7.7	7.6	13.4	13.2	57.5	7.2	8.1		
118	7/2/2013	7.9	7.9	12.5	12.0	64.9	8.1	7.9		
119	7/3/2013	3.6	3.8	9.0	9.9	39.1	3.4	3.7		
120	7/4/2013	7.5	7.9	13.5	13.6	56.8	7.1	7.3		

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

Manufacturer	DURAG
Type of instrument	F701-20
Serial-No.	SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
121	7/5/2013	12.9	13.1	20.9	19.9	63.8	12.7	14.4		Bornheim, Summer
122	7/6/2013	13.3	13.1	18.7	18.5	71.0	13.5	13.9		
123	7/7/2013	11.3	10.7	14.9	14.4	75.0	10.1	11.1		
124	7/8/2013	11.3	10.6	16.3	16.1	67.7	10.2	11.1		
125	7/9/2013	14.2	14.5	24.9	22.6	60.5	14.4	14.4		
126	7/10/2013	9.7	10.2	19.1	17.5	54.6	9.6	9.9		
127	7/11/2013	13.6	14.3	26.6	24.9	54.1	12.3	12.6		
128	7/12/2013	16.5	16.8			53.6	15.0	15.7	Outlier Ref. PM10	
129	7/13/2013	15.3	15.3	20.4	20.7	74.5	14.5	15.1		
130	7/14/2013	14.5	14.5	22.2	21.5	66.5	14.7	16.0		
131	7/15/2013	17.4	17.4	26.2	25.6	67.1	16.6	17.1		
132	7/16/2013	20.4	18.4	30.2	28.9	65.5	19.4	19.4		
133	7/17/2013	13.6	13.2	18.7	18.0	72.9	14.4	13.8		
134	7/18/2013	11.3	9.0	17.0	17.3	59.2	10.9	10.9		
135	7/19/2013	9.0	7.3	16.3	14.8	52.7	8.8	9.6		
136	7/20/2013	10.1	9.5	17.3	16.0	58.7	10.8	11.4		
137	7/21/2013	12.9	12.3	18.0	17.7	70.7	12.7	12.5		
138	7/22/2013	15.5	14.8	23.2	22.0	67.2	13.9	14.2		
139	7/23/2013	14.1	13.6	25.4	24.5	55.3	14.4	13.6		
140	7/24/2013	20.3	20.0	31.5	30.3	65.2			Audits	
141	7/25/2013	11.1	12.1	21.3	20.3	55.7			Switch to zero filter	
142	9/4/2013								Zero point	Cologne, Autumn
143	9/5/2013								discarded due to faulty flow cal.	
144	9/6/2013	19.7	19.9	31.6	29.9	64.4			discarded due to faulty flow cal.	
145	9/7/2013								discarded due to faulty flow cal.	
146	9/8/2013	10.9	12.5	15.0	14.9	78.3			discarded due to faulty flow cal.	
147	9/9/2013	3.6	3.8	6.7	6.7	55.6			discarded due to faulty flow cal.	
148	9/10/2013	3.9	4.9	9.1	7.4	53.2			discarded due to faulty flow cal.	
149	9/11/2013	7.8	8.0	12.3	11.7	65.7			discarded due to faulty flow cal.	
150	9/12/2013	10.3	10.6	17.6	15.9	62.5			discarded due to faulty flow cal.	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 6 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
151	9/13/2013	6.3	5.3	9.0	7.7	69.4	7.2	8.0		Cologne, Autumn
152	9/14/2013						3.1	3.3		
153	9/15/2013	4.4	5.5	9.5	7.9	56.8	4.6	5.5		
154	9/16/2013	6.0	4.5	9.8	9.8	53.9	4.9	5.3		
155	9/17/2013	4.3	4.2	7.5	6.4	61.7	4.8	5.4		
156	9/18/2013	8.8	9.4	13.9	13.1	67.3	7.8	8.7		
157	9/19/2013	5.8	5.5	10.3	10.5	54.2	6.4	7.1		
158	9/20/2013	8.2	6.9	15.2	14.8	50.5	7.5	7.8		
159	9/21/2013						11.9	13.8		
160	9/22/2013	13.1	13.1	18.9	17.1	72.8	15.1	15.8		
161	9/23/2013	14.2	13.9	20.0	18.5	72.8	11.5	13.6		
162	9/24/2013	19.6	21.3	27.5	26.3	76.1	20.6	22.2		
163	9/25/2013	36.5	38.9	49.6	48.6	76.8	38.2	43.5		
164	9/26/2013	11.1	12.8	19.1	18.9	62.9	9.8	13.6		
165	9/27/2013	6.0	7.2	11.7	11.7	56.4	6.6	6.8		
166	9/28/2013						8.2	8.5		
167	9/29/2013	7.3	8.9	11.7	11.6	69.7	7.0	7.4		
168	9/30/2013	11.9	13.2	18.5	17.9	69.0	12.2	12.1		
169	10/1/2013	11.2	12.1	16.2	16.6	70.9	9.9	9.9		
170	10/2/2013	10.6	11.6	17.1	16.4	66.3	10.6	10.7		
171	10/3/2013						7.8	9.6		
172	10/4/2013	13.1	14.5	18.3	18.4	75.3	13.0	13.8		
173	10/5/2013						16.1	19.9		
174	10/6/2013	9.9	11.1	14.1	14.6	73.2	10.3	9.6		
175	10/7/2013	9.9	10.6	15.7	15.1	66.4	10.0	10.0		
176	10/8/2013	19.9	21.2	28.9	28.8	71.3	21.7	21.8		
177	10/9/2013	7.1	6.8	12.6	11.7	57.3	6.8	7.8		
178	10/10/2013	8.4	8.8	12.6	12.4	68.8	7.3	8.1		
179	10/11/2013						7.9	8.2		
180	10/12/2013						13.4	13.7		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 7 of 10**

Manufacturer: DURAG

Type of instrument: F701-20

Serial-No.: SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
181	10/13/2013	5.0	5.6	7.7	8.2	66.8	5.5	5.7		Cologne, Autumn
182	10/14/2013	5.0	4.6	8.3	7.8	59.5	5.0	5.4		
183	10/15/2013								Maintenance SN 1512401	
184	10/16/2013								Zero point	
185	10/17/2013	9.5	11.1	25.4	25.4	40.6	10.1	11.7		
186	10/18/2013						8.9	9.3		
187	10/19/2013						9.3	9.5		
188	10/20/2013	3.8	3.3	8.3	8.1	43.1	4.0	4.3		
189	10/21/2013	5.4	5.3	13.7	13.6	39.4	6.3	6.5		
190	10/22/2013	6.8	7.1	15.5	15.2	45.2	8.6	8.3		
191	10/23/2013	5.5	6.1	11.3	11.9	50.1	6.5	6.6		
192	10/24/2013	6.9	6.9	14.9	15.4	45.2	8.6	8.5		
193	10/25/2013						6.9	7.0		
194	10/26/2013						4.9	5.2		
195	10/27/2013	3.0	2.7	6.9	7.2	40.3	4.2	4.4		
196	10/28/2013	3.0	2.4	7.1	7.4	37.3	4.2	3.6		
197	10/29/2013	4.1	4.3	7.9	8.6	51.2	4.0	4.4		
198	10/30/2013	9.6	9.8	17.0	16.6	57.5	9.3	10.2		
199	10/31/2013						8.1	8.0		
200	11/1/2013						6.3	6.7		
201	11/2/2013						3.7	3.9		
202	11/3/2013	1.9	0.5	3.9	4.6	28.6	2.1	2.1		
203	11/4/2013	5.5	4.4	10.5	11.0	46.2	5.1	5.8		
204	11/5/2013	5.8	5.1	12.8	12.3	43.6	6.3	6.6		
205	11/6/2013	3.7	3.4	8.0	9.2	41.0	3.8	4.3		
206	11/7/2013	5.8	6.0	9.8	10.3	58.6	5.3	6.1		
207	11/8/2013								Zero point	
208	11/9/2013								Zero point	
209	11/10/2013								Zero point	
210	11/11/2013	13.2	13.8	21.5	21.4	63.0	12.5	13.2		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 8 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
211	11/12/2013	11.3	11.3	18.1	18.7	61.6	10.9	11.6		Cologne, Autumn
212	11/13/2013	17.3	17.1	28.2	29.1	59.9	15.4	15.9		
213	11/14/2013	18.8	19.0	24.0	25.1	76.9	16.9	17.1		
214	11/15/2013						21.6	21.7		
215	11/16/2013						26.4	26.9		
216	11/17/2013	21.8	21.9	24.9	26.0	86.0	19.8	19.9		
217	11/18/2013	13.8	14.1	18.6	19.1	74.0	12.2	12.9		
218	11/19/2013	13.7	13.8	19.4	19.8	70.4	11.4	10.8		
219	11/20/2013	8.3	8.0	12.7	12.5	64.7	7.1	7.4		
220	11/21/2013	12.7	13.4	15.8	16.3	81.4	10.1	10.8		
221	11/22/2013						15.6	15.7		
222	11/23/2013						13.8	14.5		
223	11/24/2013	12.3	12.1	18.1	18.6	66.6	11.7	11.3		
224	11/25/2013	13.0	12.4	18.3	18.9	68.2	10.4	11.3		
225	11/26/2013	33.8	34.7	42.4	41.8	81.3	31.3	29.6		
226	11/27/2013	24.5	25.5	32.3	32.6	77.2	21.5	22.7		
227	11/28/2013	14.1	15.3	23.1	22.9	64.0	13.0	13.5		
228	11/29/2013						8.0	7.5		
229	11/30/2013						14.9	15.2		
230	12/1/2013	18.3	19.3	30.0	29.9	62.7	17.0	18.6		
231	12/2/2013	10.7	12.0	21.7	21.4	52.7	10.1	10.6		
232	12/3/2013						19.1	20.8		
233	12/4/2013	21.2	22.3	32.4	31.7	67.8	20.7	18.8		
234	12/5/2013	4.3	5.2	9.2	9.0	52.1	4.2	4.3		
235	12/6/2013						6.2	7.7		
236	12/7/2013						10.5	10.1		
237	12/8/2013	6.7	7.6	10.2	10.7	68.2	6.2	6.7		
238	12/9/2013	13.9	14.8	22.3	22.5	63.9	12.2	13.3		
239	12/10/2013	18.1	19.0	22.2	22.3	83.3	16.0	13.4		
240	12/11/2013	8.7	9.9	9.9	10.6	90.7	7.2	7.3		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 9 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
241	1/13/2014	12.9	13.6	18.2	18.9	71.5			Zero point	Cologne, Winter
242	1/14/2014	10.8	11.2	15.5	15.0	72.3	10.0	10.0		
243	1/15/2014	5.5	5.7	8.0	8.7	66.9	6.3	6.4		
244	1/16/2014	3.1	3.6	6.4	7.1	50.0	4.7	4.6		
245	1/17/2014	4.6	5.2	8.9	8.6	56.0	5.3	5.3		
246	1/18/2014						9.5	9.4		
247	1/19/2014	14.5	14.2	16.8	17.3	84.2	12.8	14.2		
248	1/20/2014	15.6	15.3	18.9	19.9	79.7	15.0	15.6		
249	1/21/2014	24.2	24.6	30.8	31.1	78.7	21.7	22.3		
250	1/22/2014	18.4	18.8	23.0	23.5	80.0	17.0	16.6		
251	1/23/2014	10.9	11.4	15.2	16.3	70.9	10.2	10.0		
252	1/24/2014	18.7	19.3	28.1	28.9	66.6	17.9	17.7		
253	1/25/2014						9.4	9.1		
254	1/26/2014	4.4	4.4	11.4	12.0	37.8	5.3	5.6		
255	1/27/2014	2.9	3.5	6.7	7.1	46.7	3.6	3.7		
256	1/28/2014	6.3	6.7	10.9	10.6	60.4	6.6	7.1		
257	1/29/2014	16.0	16.6	19.2	19.7	83.8	13.9	13.9		
258	1/30/2014	35.7	36.0	41.6	42.3	85.4	31.8	31.2		
259	1/31/2014	29.8	29.0	35.0	34.9	84.1	26.3	27.0		
260	2/1/2014						5.6	4.9		
261	2/2/2014	8.6	7.9	18.1	17.5	46.3	8.3	8.2		
262	2/3/2014	18.7	18.0	22.0	21.5	84.5	16.9	16.9		
263	2/4/2014						12.2	12.0		
264	2/5/2014	4.4	3.4	8.0	8.2	48.6	5.0	4.4		
265	2/6/2014	2.9	3.1	9.8	9.1	32.0	4.5	4.5		
266	2/7/2014								Zero point	
267	2/8/2014								Zero point	
268	2/9/2014								Zero point	
269	2/10/2014	9.8	8.8	12.9	13.1	71.4	8.6	9.1		
270	2/11/2014	4.5	3.8	9.6	8.0	47.6	3.9	3.9		

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

Manufacturer	DURAG	PM2,5
Type of instrument	F701-20	Measured values in µg/m³ (ACT)
Serial-No.	SN 1512361 / SN 1512401	

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
271	2/12/2014	4.5	3.8	8.2	7.9	51.3	3.9	3.6		Cologne, Winter
272	2/13/2014	4.8	4.3	10.3	10.0	44.8	3.9	4.4		
273	2/14/2014	0.0	0.0				3.3	3.5		
274	2/15/2014	0.0	0.0				3.7	3.6		
275	2/16/2014	5.2	4.9	8.8	9.2	56.2	5.2	5.3		
276	2/17/2014	8.0	7.0	12.7	12.5	59.7	7.2	7.9		
277	2/18/2014	14.5	13.8	19.8	19.6	71.7	12.7	13.3		
278	2/19/2014	9.6	8.9	13.2	8.9	83.8	8.5	8.3		
279	2/20/2014	4.3	4.4	6.6	6.2	67.5	5.2	4.9		
280	2/21/2014	4.8	5.0	7.8	7.8	63.2	5.8	5.4		
281	2/22/2014	4.2	5.0	4.7	5.4	90.9	4.3	4.4		
282	2/23/2014	5.6	6.6	7.1	7.0	87.0	5.3	6.2		
283	2/24/2014	9.3	9.3	13.7	12.7	70.6	7.5	8.2		
284	2/25/2014	9.0	8.6	12.8	12.1	70.5	8.4	7.5		
285	2/26/2014	11.3	11.3	19.4	17.3	61.7	9.4	9.6		
286	2/27/2014	7.5	8.2	12.0	10.4	70.3	6.8	7.2		
287	2/28/2014	7.7	7.3	10.3	9.9	74.3	6.0	6.3		
288	3/1/2014	12.1	12.4	14.7	14.7	83.5	11.0	10.7		
289	3/2/2014	16.8	16.9	18.3	19.6	88.6	13.9	14.4		
290	3/3/2014	6.8	6.9	9.9	11.8	63.0	7.0	6.9		
291	3/4/2014	19.5	17.6	25.6	24.3	74.4	15.7	16.9		
292	3/5/2014	30.8	31.2	43.5	43.7	71.0	27.3	27.2		
293	3/6/2014	36.5	35.6	44.2	43.5	82.2	30.6	30.7		
294	3/7/2014	43.6	44.0	56.7	55.5	78.0	39.0	38.9		
295	3/8/2014	42.8	41.4	49.7	50.0	84.4	36.7	37.1		
296	3/9/2014	23.2	21.4	28.1	27.2	80.7	18.3	19.0		

Annex 6 **Ambient conditions at the field test sites** **Page 1 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	2/28/2013	Bonn, Winter	4.1	1017	71.8	1.2	250	0.0
2	3/1/2013		3.5	1016	72.0	1.7	249	0.0
3	3/2/2013		3.0	1015	67.4	1.2	238	0.0
4	3/3/2013		3.1	1014	72.8	0.5	196	0.0
5	3/4/2013		6.6	1007	57.8	1.4	140	0.0
6	3/5/2013		8.5	999	56.5	1.2	136	0.0
7	3/6/2013		11.5	993	48.5	0.4	143	0.0
8	3/7/2013		12.3	990	67.5	0.5	144	2.1
9	3/8/2013		13.7	990	72.1	1.4	138	1.5
10	3/9/2013		10.6	991	72.2	1.2	178	3.6
11	3/10/2013		1.6	993	81.8	3.6	273	2.4
12	3/11/2013		-1.4	996	78.7	1.9	241	0.0
13	3/12/2013		-3.4	995	83.9	2.0	276	0.0
14	3/13/2013		-1.2	999	72.8	1.1	224	0.3
15	3/14/2013		-1.3	1004	75.3	1.1	209	2.1
16	3/15/2013		2.3	1006	58.8	1.0	132	2.1
17	3/16/2013		5.3	998	49.0	3.4	131	0.0
18	3/17/2013		4.7	988	78.3	2.2	131	0.9
19	3/18/2013		6.6	985	60.3	0.7	131	0.0
20	3/19/2013		5.8	991	74.5	0.6	157	1.2
21	3/20/2013		2.6	999	85.8	1.9	240	13.2
22	3/21/2013		0.6	1010	78.8	1.0	229	0.3
23	3/22/2013		2.9	1006	63.4	3.2	146	0.0
24	3/23/2013		1.1	1005	56.8	4.2	146	0.0
25	3/24/2013		1.0	1005	42.8	3.3	153	0.0
26	3/25/2013		0.9	1004	49.0	2.6	153	0.0
27	3/26/2013		1.6	1003	44.1	2.3	168	0.0
28	3/27/2013		2.6	1001	49.5	2.0	148	0.0
29	3/28/2013		3.0	999	58.9	1.2	243	0.0
30	3/29/2013		0.4	999	77.8	1.1	271	1.5

Annex 6 **Ambient conditions at the field test sites** **Page 2 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	3/30/2013	Bonn, Winter	1.8	1000	68.9	1.3	271	0.0
32	3/31/2013		1.7	1003	68.2	1.1	269	0.0
34	4/1/2013		3.2	1001	52.9	1.5	190	0.0
34	4/2/2013		3.6	1003	52.2	1.8	201	0.0
35	4/3/2013		3.0	1005	58.0	1.8	158	0.0
36	4/4/2013		4.4	1001	60.5	1.8	166	0.0
37	4/5/2013		3.8	1003	67.8	1.6	267	0.0
38	4/6/2013		3.6	1012	73.9	1.7	221	0.3
39	4/7/2013		6.4	1008	51.4	0.7	174	0.0
40	4/8/2013		7.0	996	63.9	1.4	130	0.9
41	4/9/2013		8.3	992	78.0	1.2	133	1.8
42	4/10/2013		9.7	996	77.3	1.4	154	6.0
43	4/11/2013		13.0	991	69.6	1.3	169	6.0
44	4/12/2013		12.2	997	69.0	1.1	154	4.4
45	4/13/2013		13.9	1011	56.8	1.4	152	0.6
46	4/14/2013		18.3	1011	57.0	1.5	136	0.0
47	4/15/2013		17.5	1011	67.0	1.5	214	2.7
48	4/16/2013		18.4	1011	54.4	0.9	149	0.0
49	4/17/2013		18.7	1009	54.3	0.6	141	0.0
50	4/18/2013		15.6	1009	46.2	3.1	210	0.0
51	4/19/2013		11.4	1017	57.7	3.5	260	0.0
52	4/20/2013		10.3	1018	51.5	3.3	274	0.0
53	4/21/2013		11.1	1009	57.4	1.1	253	0.0
54	4/22/2013		13.2	1009	46.5	1.4	217	0.0
55	4/23/2013		13.7	1014	63.6	1.7	187	0.0
56	4/24/2013		17.9	1016	56.5	1.0	167	0.0
57	4/25/2013		20.0	1010	51.5	0.4	146	0.0
58	4/26/2013		11.9	1000	77.3	2.2	230	9.9
59	4/27/2013		7.8	1003	70.3	3.2	293	0.0
60	4/28/2013		9.2	1007	68.3	0.7	169	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 3 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	4/29/2013	Bonn, Winter	12.0	1010	56.1	1.9	209	0.0
62	4/30/2013		11.8	1014	57.9	1.0	214	0.0
63	5/1/2013		14.6	1011	62.8	0.9	173	0.3
64	5/2/2013		16.5	1009	60.4	1.1	200	0.0
65	5/3/2013		16.0	1007	60.0	1.5	253	0.0
66	5/4/2013		15.7	1011	54.5	2.4	238	0.0
67	5/5/2013		16.4	1013	55.9	1.3	190	0.0
68	5/6/2013		19.8	1008	50.0	0.6	192	0.0
69	5/14/2013	Bornheim, Summer	no weather data available					
70	5/15/2013							
71	5/16/2013		12.6	989	85.5	0.7	263	8.6
72	5/17/2013		10.0	995	89.1	0.8	265	2.4
73	5/18/2013		12.0	1000	77.7	0.4	216	0.0
74	5/19/2013		16.7	998	66.5	2.7	273	7.4
75	5/20/2013		11.9	1000	83.1	0.3	175	6.2
76	5/21/2013		12.9	1001	78.8	1.8	239	13.1
77	5/22/2013		8.8	1004	82.4	2.4	258	7.4
78	5/23/2013		6.4	1000	81.9	1.8	255	2.4
79	5/24/2013		8.3	1003	69.9	0.7	192	0.9
80	5/25/2013		10.5	1005	70.9	2.8	270	3.0
81	5/26/2013		9.8	1002	79.9	3.2	271	5.7
82	5/27/2013		14.0	1000	61.4	1.6	244	0.0
83	5/28/2013		17.2	993	60.4	2.0	179	1.2
84	5/29/2013		9.7	995	88.4	0.6	207	15.0
85	5/30/2013		13.5	999	69.6	1.7	237	2.4
86	5/31/2013		16.1	1001	73.0	4.7	299	0.9
87	6/1/2013		11.9	1009	79.4	4.4	290	0.3
88	6/2/2013		13.3	1016	57.6	4.0	288	0.0
89	6/3/2013		12.9	1017	61.6	3.6	269	0.0
90	6/4/2013		15.6	1012	64.5	1.7	237	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 4 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	6/5/2013	Bornheim, Summer	19.9	1009	54.2	0.6	197	0.0
92	6/6/2013		20.9	1010	52.6	0.8	168	0.0
93	6/7/2013		21.7	1010	55.5	1.0	211	0.0
94	6/8/2013		21.1	1005	62.3	2.1	243	0.0
95	6/9/2013		15.6	1001	78.7	1.8	273	4.5
96	6/10/2013		14.4	1005	75.9	1.2	253	0.6
97	6/11/2013		18.8	1008	61.5	0.6	198	0.0
98	6/12/2013		21.1	1008	67.1	1.0	181	0.0
99	6/13/2013		17.0	1007	77.9	1.3	209	22.5
100	6/14/2013		16.1	1009	65.4	0.6	181	0.0
101	6/15/2013		17.2	1005	63.1	1.4	209	0.0
102	6/16/2013		17.7	1007	63.9	0.7	226	0.0
103	6/17/2013		23.3	1004	64.7	0.9	185	0.0
104	6/18/2013		27.2	1005	61.3	0.4	178	0.0
105	6/19/2013		26.9	1003	67.8	1.9	244	0.0
106	6/20/2013		20.5	1003	78.5	1.0	187	34.6
107	6/21/2013		19.0	1005	69.8	1.6	196	0.3
108	6/22/2013		19.0	1004	67.8	1.8	198	1.5
109	6/23/2013		16.2	1005	69.9	1.6	216	0.9
110	6/24/2013		14.2	1013	76.9	1.8	255	1.5
111	6/25/2013		13.4	1018	71.1	1.8	259	0.3
112	6/26/2013		13.9	1018	70.9	1.1	250	9.8
113	6/27/2013		13.2	1014	78.5	0.7	230	3.9
114	6/28/2013		14.1	1010	86.1	0.3	174	16.4
115	6/29/2013		14.8	1012	73.9	2.6	269	1.8
116	6/30/2013		17.7	1012	66.4	0.6	198	0.0
117	7/1/2013		18.8	1008	74.9	0.7	215	21.0
118	7/2/2013		21.6	1003	62.7	0.6	183	0.3
119	7/3/2013		17.5	1004	85.6	0.2	213	16.0
120	7/4/2013		20.0	1014	71.1	0.9	232	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 5 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
121	7/5/2013	Bornheim, Summer	19.8	1020	74.4	0.3	222	0.0
122	7/6/2013		22.4	1020	65.4	1.0	191	0.0
123	7/7/2013		23.1	1020	58.8	1.2	218	0.0
124	7/8/2013		23.0	1019	59.6	1.4	214	0.0
125	7/9/2013		23.4	1014	59.4	1.4	237	0.0
126	7/10/2013		19.5	1012	62.6	3.5	261	0.0
127	7/11/2013		15.7	1013	70.1	1.7	215	0.0
128	7/12/2013		16.5	1013	70.8	1.2	250	0.0
129	7/13/2013		17.7	1014	68.3	1.1	241	0.0
130	7/14/2013		18.9	1014	69.1	1.7	249	0.0
131	7/15/2013		21.3	1013	62.9	0.8	188	0.0
132	7/16/2013		22.5	1013	58.8	0.8	184	0.0
134	7/17/2013		23.2	1014	59.0	1.2	218	0.0
134	7/18/2013		24.5	1014	56.8	1.7	224	0.0
135	7/19/2013		23.5	1013	58.3	2.3	241	0.0
136	7/20/2013		21.1	1011	68.5	1.3	226	0.0
137	7/21/2013		25.3	1009	57.4	1.1	155	0.0
138	7/22/2013		27.6	1006	52.2	0.9	167	0.0
139	7/23/2013		25.5	1004	62.0	0.6	159	0.0
140	7/24/2013		21.7	1006	78.7	0.7	213	3.6
141	7/25/2013		22.5	1006	81.7	0.7	145	15.1
142	9/4/2013	Cologne, Autumn	22.5	1012	64.5	0.2	159	0.0
143	9/5/2013		25.5	1004	56.3	0.2	181	0.0
144	9/6/2013		24.3	1004	62.8	0.2	180	0.3
145	9/7/2013		17.7	1010	81.6	0.1	170	35.8
146	9/8/2013		14.4	1012	86.6	0.0	172	2.1
147	9/9/2013		14.9	1007	73.6	0.5	186	4.2
148	9/10/2013		13.6	1005	79.7	1.0	188	11.9
149	9/11/2013		14.0	1006	86.5	0.1	178	10.9
150	9/12/2013		15.2	1011	82.9	0.1	191	2.7

Annex 6 **Ambient conditions at the field test sites** **Page 6 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
151	9/13/2013	Cologne, Autumn	17.1	1010	76.6	0.1	190	3.0
152	9/14/2013		15.5	1005	82.7	0.2	182	4.1
153	9/15/2013		14.8	1000	74.7	0.4	198	11.6
154	9/16/2013		12.3	995	67.6	0.4	191	1.2
155	9/17/2013		12.3	992	79.7	0.5	196	7.5
156	9/18/2013		12.3	998	84.1	0.0	182	0.9
157	9/19/2013		14.1	1005	75.0	0.4	181	3.0
158	9/20/2013		14.5	1013	78.7	0.1	189	0.0
159	9/21/2013		14.4	1020	77.8	0.0	188	0.0
160	9/22/2013		16.9	1020	81.0	0.0	182	0.0
161	9/23/2013		15.9	1015	78.0	0.0	187	0.0
162	9/24/2013		15.8	1007	76.9	0.1	191	0.0
163	9/25/2013		16.8	1004	80.1	0.0	197	0.0
164	9/26/2013		13.2	1009	77.2	0.1	188	0.0
165	9/27/2013		12.5	1008	71.6	0.1	199	0.0
166	9/28/2013		14.0	1004	64.8	0.4	164	0.0
167	9/29/2013		13.4	1002	61.9	0.6	187	0.0
168	9/30/2013		13.9	1003	62.8	0.2	177	0.0
169	10/1/2013		15.2	1006	57.0	0.4	153	0.0
170	10/2/2013		no weather data available					
171	10/3/2013							
172	10/4/2013							
173	10/5/2013							
174	10/6/2013							
175	10/7/2013							
176	10/8/2013							
177	10/9/2013		12.7	1005	84.1	0.2	207	6.9
178	10/10/2013		7.8	1003	86.9	0.1	180	7.1
179	10/11/2013		6.5	1009	89.2	0.0	190	6.3
180	10/12/2013		7.1	1009	88.6	0.1	187	2.7

Annex 6 **Ambient conditions at the field test sites** **Page 7 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
181	10/13/2013	Cologne, Autumn	9.5	1009	78.9	0.5	194	0.0
182	10/14/2013		12.2	1004	82.3	0.3	183	12.4
183	10/15/2013		10.7	1002	82.5	0.2	187	10.6
184	10/16/2013		11.8	1006	83.2	0.1	206	0.6
185	10/17/2013		13.0	1008	83.5	0.4	191	0.3
186	10/18/2013		12.9	1009	79.7	0.0	166	0.0
187	10/19/2013		16.8	1004	78.4	0.1	184	0.6
188	10/20/2013		15.7	1006	81.9	0.3	174	3.3
189	10/21/2013		16.5	1005	79.6	0.2	195	0.0
190	10/22/2013		18.3	998	79.6	0.3	198	9.2
191	10/23/2013		16.6	1003	76.4	0.9	206	0.3
192	10/24/2013		14.3	1009	79.3	0.1	185	0.6
193	10/25/2013		15.9	1005	87.5	0.0	163	8.9
194	10/26/2013		18.1	1002	77.0	0.6	185	2.4
195	10/27/2013		15.7	996	69.5	2.5	217	4.8
196	10/28/2013		13.7	997	68.9	2.2	212	2.4
197	10/29/2013		10.5	1009	73.2	1.0	215	0.3
198	10/30/2013		8.2	1018	76.7	0.2	188	0.0
199	10/31/2013		11.1	1013	71.9	0.3	190	0.3
200	11/1/2013		10.0	1002	89.8	0.0	180	20.9
201	11/2/2013		11.9	995	86.3	0.2	195	7.7
202	11/3/2013		10.2	992	72.9	1.9	210	1.2
203	11/4/2013		8.9	986	82.5	0.7	186	15.1
204	11/5/2013		8.4	989	81.4	0.6	185	13.4
205	11/6/2013		13.5	997	80.2	1.1	202	8.3
206	11/7/2013		12.4	1001	89.2	0.3	174	21.2
207	11/8/2013		11.1	1000	77.6	0.9	197	1.5
208	11/9/2013		8.7	998	77.8	0.7	193	2.7
209	11/10/2013		5.4	1016	85.6	0.0	177	2.7
210	11/11/2013		6.0	1020	81.3	0.0	196	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 8 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
211	11/12/2013	Cologne, Autumn	7.8	1021	89.1	0.0	163	3.6
212	11/13/2013		4.4	1018	89.5	0.0	192	0.0
213	11/14/2013		7.0	1015	84.0	0.1	186	0.3
214	11/15/2013		3.4	1024	84.9	0.1	183	0.0
215	11/16/2013		2.6	1020	87.8	0.0	195	0.3
216	11/17/2013		5.0	1009	85.5	0.1	192	0.0
217	11/18/2013		6.0	1001	76.6	0.1	191	0.0
218	11/19/2013		5.7	1000	84.8	0.2	163	0.0
219	11/20/2013		5.2	992	71.0	0.2	185	0.9
220	11/21/2013		4.4	999	78.6	0.8	198	0.9
221	11/22/2013		5.7	1007	80.5	0.2	188	0.0
222	11/23/2013		5.2	1013	84.3	0.2	168	0.9
223	11/24/2013		5.2	1020	82.8	0.2	165	0.9
224	11/25/2013		1.1	1026	88.1	0.1	186	1.2
225	11/26/2013		1.7	1027	88.4	0.0	197	0.3
226	11/27/2013		4.5	1025	86.9	0.0	186	2.1
227	11/28/2013		7.6	1021	82.4	0.2	177	0.3
228	11/29/2013		6.2	1009	84.2	0.6	171	1.2
229	11/30/2013		4.2	1024	78.9	0.0	191	0.0
230	12/1/2013		no weather data available					
231	12/2/2013							
232	12/3/2013		2.6	1020	82.9	0.0	183	0.0
234	12/4/2013		4.9	1020	86.4	0.1	189	1.8
234	12/5/2013		4.8	1009	76.3	2.3	176	6.8
235	12/6/2013		3.0	1017	80.9	1.1	171	5.1
236	12/7/2013		6.2	1018	85.8	0.1	194	2.1
237	12/8/2013		8.7	1019	77.2	0.9	201	0.0
238	12/9/2013		8.2	1025	78.9	0.3	197	0.0
239	12/10/2013		5.9	1027	87.1	0.1	206	0.0
240	12/11/2013		5.6	1025	87.7	0.6	201	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 9 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
241	1/13/2014	Cologne, Winter	6.8	1002	82.5	0.0	210	0.0
242	1/14/2014		6.3	1001	77.9	0.3	203	0.0
243	1/15/2014		5.3	998	86.2	0.3	205	3.9
244	1/16/2014		7.8	993	80.2	0.2	220	0.0
245	1/17/2014		8.2	994	72.4	0.3	209	0.3
246	1/18/2014		6.5	992	75.3	0.7	202	0.0
247	1/19/2014		5.7	994	80.7	0.2	202	0.0
248	1/20/2014		3.8	1000	83.9	0.3	135	0.0
249	1/21/2014		4.0	1005	87.1	0.0	186	0.0
250	1/22/2014		2.7	1006	84.8	0.1	203	0.0
251	1/23/2014		3.8	1004	87.2	0.2	193	8.0
252	1/24/2014		4.1	1010	86.2	0.0	188	0.3
253	1/25/2014		5.0	1004	79.5	1.1	208	6.5
254	1/26/2014		5.1	991	79.6	0.8	207	18.9
255	1/27/2014		4.9	990	75.6	0.8	214	0.3
256	1/28/2014		3.8	992	73.6	0.6	204	0.0
257	1/29/2014		2.6	996	71.0	1.1	198	0.0
258	1/30/2014		2.5	1000	72.6	0.2	194	0.0
259	1/31/2014		5.7	996	70.7	0.6	204	0.3
260	2/1/2014		5.5	997	81.6	0.5	214	3.6
261	2/2/2014		4.2	1008	76.5	0.5	207	0.0
262	2/3/2014		4.9	1001	77.9	0.7	203	0.0
263	2/4/2014		5.9	998	75.1	0.3	204	0.0
264	2/5/2014		7.4	992	73.8	1.2	209	0.0
265	2/6/2014		10.2	989	66.1	1.6	210	5.1
266	2/7/2014		7.6	991	72.7	2.4	216	7.7
267	2/8/2014		7.7	984	70.0	1.9	219	0.6
268	2/9/2014		5.9	989	67.2	1.7	221	0.0
269	2/10/2014		5.5	990	75.2	0.3	205	1.8
270	2/11/2014		6.7	997	70.1	1.1	217	2.4

Annex 6 **Ambient conditions at the field test sites** **Page 10 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
271	2/12/2014	Cologne, Winter	7.1	994	68.5	1.7	224	0.3
272	2/13/2014		5.2	992	80.2	0.5	201	8.0
273	2/14/2014		8.6	992	74.6	1.4	217	9.5
274	2/15/2014		10.0	995	65.2	3.0	210	1.5
275	2/16/2014		7.4	1004	71.7	0.8	220	0.6
276	2/17/2014		4.2	1008	82.8	0.0	212	0.0
277	2/18/2014		7.4	1005	76.0	0.1	214	1.8
278	2/19/2014		8.3	1006	77.5	0.3	208	0.0
279	2/20/2014		9.7	999	78.3	0.9	209	5.4
280	2/21/2014		5.8	1002	77.2	0.6	207	0.9
281	2/22/2014		5.5	1010	76.2	0.7	211	1.8
282	2/23/2014		7.3	1011	70.4	0.5	206	0.0
283	2/24/2014		12.9	1005	53.2	0.5	203	0.0
284	2/25/2014							
285	2/26/2014		no weather data available					
286	2/27/2014							
287	2/28/2014		6.6	994	75.3	0.3	199	0.0
288	3/1/2014		5.8	995	78.1	0.1	223	0.6
289	3/2/2014		6.1	990	69.9	0.7	199	0.0
290	3/3/2014		6.2	988	71.5	0.6	187	0.0
291	3/4/2014		7.9	1002	70.6	0.1	199	0.0
292	3/5/2014		4.6	1018	81.8	0.2	146	0.0
293	3/6/2014		7.6	1020	67.2	0.2	191	0.0
294	3/7/2014		11.1	1021	63.3	0.1	178	0.0
295	3/8/2014		12.4	1022	56.2	0.5	202	0.0
296	3/9/2014		13.1	1020	46.8	0.3	164	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 48). 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 49 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.

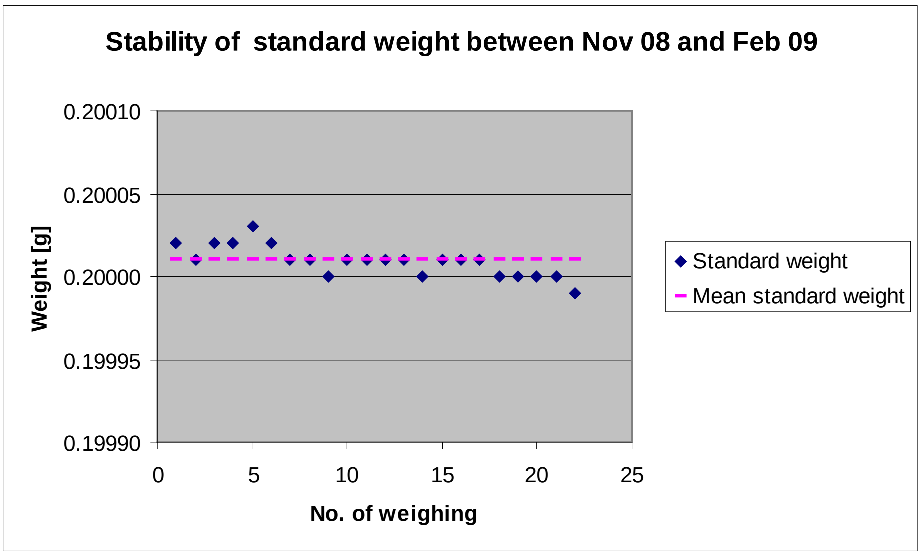

Figure 48: Stability of standard weight

Table 30: 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

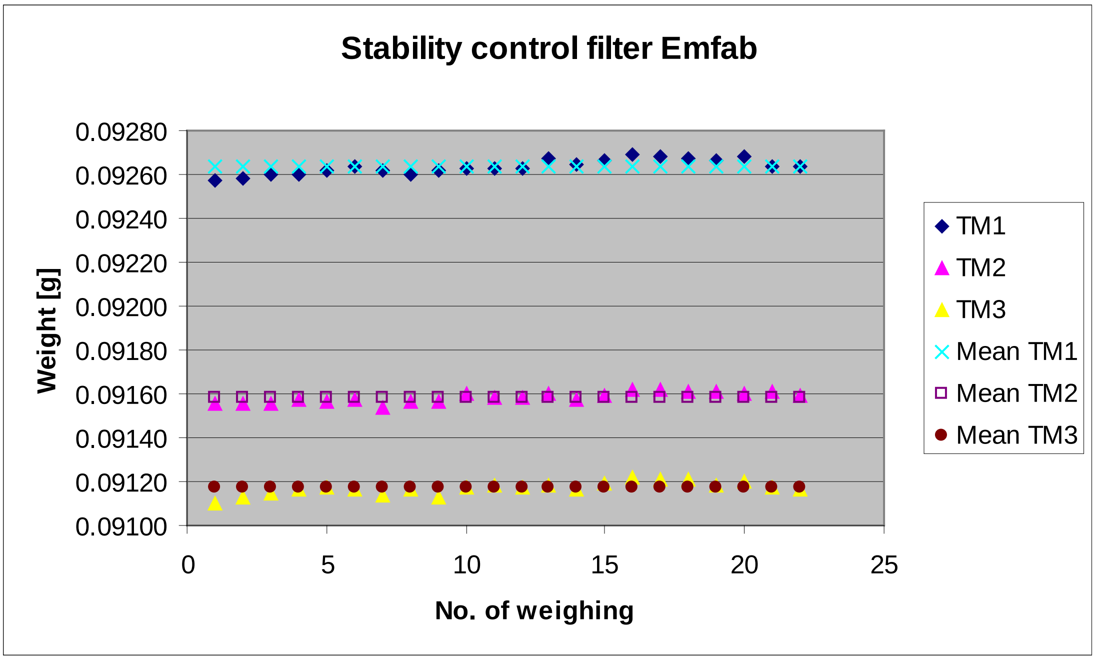

Figure 49: Stability of the control filters

Table 31: 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

Manual

TÜV RHEINLAND ENERGY GMBH

Deutsche Akkreditierungsstelle D-PL-11120-02-00

ADDENDUM

Addendum to TÜV report no. 936/21220478/A of 17 March 2014 on the performance test of the ambient air quality measuring system F-701-20 with $PM_{2,5}$ pre-separator manufactured by DURAG GmbH for suspended particulate matter $PM_{2,5}$

TÜV Report: 936/21243589/A
Cologne, 14 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 and
covers the scope specified in the annex to certificate D-PL-11120-02-00.

TÜV Rheinland Energy GmbH
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1. Summary Overview

DURAG GmbH commissioned TÜV Rheinland Energy GmbH to carry out performance testing of the F-701-20 with PM2,5 pre-separator for suspended particulate matter PM2,5 in accordance with 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.
- 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.
- 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

On the basis of the cited standards for testing, the F-701-20 with $PM_{2,5}$ pre-separator for suspended particulate matter, $PM_{2,5}$, has already been performance-tested and publically announce as such as follows:

- F-701-20 with $PM_{2,5}$ pre-separator for suspended particulates $PM_{2.5}$ as publically announced on 17 July 2014 by Federal Environment Agency (BAnz AT 05.08.2014 B11, chapter III number 3.1) –
- F-701-20 with $PM_{2,5}$ pre-separator for suspended particulate matter, $PM_{2,5}$; Federal Environment Agency announcement of 22 February 2017 (BAnz AT 15.03.2017 B6, chapter V 3rd notification) – Notification of design changes (SD chip) and new software version
- F-701-20 with $PM_{2,5}$ pre-separator for suspended particulate matter, $PM_{2,5}$; Federal Environment Agency announcement of 21 February 2018 (BAnz AT 26.03.2018 B8, chapter V 4th notification) – Notification of design changes (alternative control valve)

- F-701-20 with $PM_{2,5}$ pre-separator for suspended particulate matter, $PM_{2,5}$; Federal Environment Agency announcement of 3 July 2018 (BAnz AT 17.07.2018 B9, chapter III 27th notification) – Notification of design changes (adaptation of housing, instrument version with external pump) and 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 F-701-20 measuring system with $PM_{2,5}$ pre-separator 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. It was possible to re-assess some of the original performance data for a number of test criteria. Entirely new tests were performed only for test items 7.4.4 "Flow rate accuracy", 7.4.8 "Dependence of span on supply voltage" and 7.4.9 "Dependence of reading on water vapour concentration" in Summer 2018.

On its publication, this addendum will become an integral part of TÜV Rheinland test report no. 936/21220478/A dated 17 March 2014 and will be available online at www.qal1.de.

The F-701-20 measuring system uses a radiometric measuring principle to determine dust concentrations. A pump sucks in ambient air through the $PM_{2,5}$ sampling head (at a flow rate of 16.67 l/min). The dust-loaded sample air is then pulled to a filter tape. The determination of the mass concentration precipitated on the filter tape is then performed relying on the principle of beta absorption.

The 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

	Bonn, Junction Winter	Bornheim, Motorway parking area Summer	Cologne Parking lot, autumn	Cologne Parking lot, Winter
Period	02/2013 – 05/2013	05/2013 – 07/2013	09/2013 – 12/2013	01/2014 – 03/2014
Number of measurement pairs: Test specimens	61	68	85	52
Description	Affected by traffic	Rural area + motorway	Urban area	Urban area
Classification of ambient air pollution	average to high	low to average	average	average

The following table provides an overview of the equivalence test performed.

Table 2: Equivalence test results (raw data)

PM_x	Slope	Axis intercept	All Data sets W_{CM}<25 % Raw data	Calibration yes/no	All Data sets W_{CM}<25% cal. data
PM2,5	0.917	0.587	14.64	yes *	8.46

* 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 0 µg/m³ to 10,000 µg/m³ as a 1-hour average value, if applicable	The measuring range is set to 0–1,000 µg/m³ by default. Supplementary measuring ranges are possible up to 0–10,000 µg/m³.	yes	45
2 negative signals	Shall not be suppressed	Negative signals are directly displayed and correctly output by the measuring system.	yes	46
3 Zero level and detection limit (7.4.3)	Zero level: ≤ 2.0 µg/m³ Detection limit: ≤ 2.0 µg/m³	On the basis of testing both instruments, the zero level was determined at a maximum of 0.34 µg/m³ and the detection limit at a maximum of 1.15 µg/m³.	yes	47
4 Flow rate accuracy (7.4.4)	≤ 2.0%	The relative difference determined for the mean of the measuring results at +5°C and at +40°C did not exceed -1.53%.	yes	49
5 Constancy of sample flow rate (7.4.5)	≤ 2.0% sampling flow (averaged flow) ≤ 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	51
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 10 l/min when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness. At 1 l/m, the maximum leak rate determined remained below 2.0% of the nominal flow rate of 1000 l/h (16.67 l/m).	yes	55

Performance criterion	Requirement	Test result	satis-fied	Page
7 Dependence of measured value on surrounding temperature (7.4.7)	≤ 2.0 µg/m³	The tested temperature range at the site of installation was +5 °C to +40 °C. Taking into account at the values displayed by the instrument, we determined a maximum dependence of the zero point on the on surrounding temperature of -1.0 µg/m³.	yes	57
8 Dependence of measured value (span) on surrounding temperature (7.4.7)	≤ 5% from the value at the nominal test temperature	The tested temperature range at the site of installation was +5 °C to +40 °C. At span point, the deviations determined did not exceed -1.9%.	yes	59
9 Dependence of span on supply voltage (7.4.8)	≤ 5% from the value at the nominal test voltage	Voltage variations did not result in deviations > 2.3% compared to the initial value of 230 V.	yes	61
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 normal operating mode and automatically resumes measuring as soon as the start time for the next measurement cycle is reached (this was set to the next full hour during performance testing).	yes	63

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 -1.1 µg/m³. Various water vapour concentrations were not observed to cause any significant effect on zero readings.	yes	64
12 Zero checks (7.5.3)	Absolute value ≤ 3.0 µg/m³	The maximum measured value determined for PM2,5 at zero point was 1.8 µg/m³.	yes	66
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 sampling inlet if heated inlet is used	The measuring system allows for comprehensive remote monitoring and control via various connectors (RS232, RS485). The instrument provides operating statuses and all relevant parameters.	yes	69
14 Daily averages (7.5.5)	The AMS shall allow for the formation of daily averages or values.	The instrument configuration described and a measurement cycle set to 1 h and filter spots sampled 24 times allow the formation of valid daily averages based on 24 measurement cycles.	yes	71

Performance criterion	Requirement	Test result	satis-fied	Page
15 Availability (7.5.6)	At least 90%.	The availability for SN 1512361 was 100%, for SN 1512401 it was 99.7%.	yes	72
16 Between-AMS uncertainty ubs,AMS (7.5.8.4)	≤ 2.5 µg/m³	At no more than 0.84 µg/m³ for $PM_{2.5}$, the between-AMS uncertainty u_{bs} remains well below the permissible maximum of 2.5 µg/m³.	yes	75
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)	The uncertainty WCM determined without applying correction factors for all observed data sets is below the determined expanded relative uncertainty Wdqo of 25% for fine particulate matter.	yes	81
17 Use of correction factors/terms (7.5.8.5–7.5.8.8)	After the calibration: ≤ 25% at the level of the relevant limit value related to the 24-hour average results	During the test, the test samples met the requirements for data quality of air quality measurements without applying a correction factor. The correction of the slope and intercept results in a significant improvement of the expanded uncertainty of the complete dataset.	yes	94

Performance criterion	Requirement	Test result	satis-fied	Page
18 Maintenance interval (7.5.7)	At least 14 d	The period of unattended operation is determined by the necessary maintenance works. It is 4 weeks.	yes	100
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.	yes	102
20 Checks of temperature sensors, pressure and/or humidity sensors	Shall be checked for the AMS to be within the following criteria ± 2 °C ± 1 kPa ± 5 % RH	It is easy to check and adjust the sensors for determining ambient temperature, ambient pressure and relative humidity on-site.	yes	103

2. Task Definition

2.1 Nature of the test

DURAG GmbH commissioned TÜV Rheinland Energy GmbH to carry out a performance test of the F-701-20 with PM2,5 pre-separator.

The F-701-20 with PM2,5 pre-separator for suspended particulate matter, $PM_{2,5}$, has already been performance-tested and published as such in the Federal Gazette.

The present addendum presents an assessment of the F-701-20 with PM2,5 pre-separator regarding compliance with the requirements for automated measuring systems defined in the new standard EN 16450 (July 2017).

2.2 Objectives

The measuring system is designed to determine the $PM_{2.5}$ fractions of dust concentrations in the range between 0–1 000 µg/m³.

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]
- 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 [3]
- Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated January 2010 [4]

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 [8]

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 F-701-20 measuring system with $PM_{2,5}$ pre-separator 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. It was possible to re-assess some of the original performance data for a number of test criteria. Entirely new tests were performed only for test items 7.4.4 “Flow rate accuracy”, 7.4.8 “Dependence of span on supply voltage” and 7.4.9 “Dependence of reading on water vapour concentration” in Summer 2018.

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3. Description of the AMS tested

3.1 Measuring principle

The ambient air quality measuring system F-701-20 uses beta-attenuation as a measurement principle.

The air volume is sucked through a glass fibre tape, which separates out the dust particles onto the filter. The volumetric flow is controlled and recorded by a control system. After the intake time, the mass collected on the filter is measured radiometrically. To this effect, A measuring setup consisting of a Beta radiation source (C-14) and a Geiger Mueller counter tube is used.

The measuring principle for determining the dust mass is based on the fact that Beta rays are attenuated as they pass through matter. The intensity of the radiation (pulses/measuring time) is initially assessed after the rays pass through the unused filter paper. Once it has collected the dust, the intensity of the radiation is measured again. The ratio of the two intensity values is a measure of the quantity of dust collected on the filter spot (assuming homogeneous distribution on the filter surface) and, with a constant cross-sectional area of the loaded filter spot, a measure of the absolute dust mass. The absolute dust mass divided by the quantity of air taken in then gives the dust concentration.

The radiometric measuring method is universally applicable, as it determines the mass of the dust within wide limits irrespective of the chemical and physical properties of the dust and the carrier gas.

With homogeneous distribution of dust precipitation of the mass m on a filter area A_F, up to 5 mg/cm² the relationship is approximately linear:

$$\ln (n_0/n) = (\mu/\rho) * d$$

Where: $d = m/A_F$ in µg/cm² is the dust surface density with dust precipitation in µg on the constant precipitation area in cm²

is the constant precipitation area in cm²

μ/ρ in cm²/g is the mass attenuation coefficient

μ in cm-1 is the linear attenuation coefficient of the Beta radiation used

ρ in g/cm³ is the density of the absorber material

n_0 and n are the Beta particles detected by the counter per minute, without or with the dust, registered electronically as voltage pulses. The pulse rate is a measure of the radiation intensity. The pulse rate is a measure for the radiation intensity.

The mass attenuation coefficient μ/ρ of the Beta radiation used depends on the electron density of the absorber and is thus proportional to the ratio (Z/A).

Where: Z is the chemical atomic number

A is the mass number

However, as the ratio (Z/A) = 0.45… 0 .5 is approximately constant for most dusts that occur, in practical terms the Beta radiation attenuation is independent of the chemical composition and particle size distribution of the dust.

If the filter area remains constant, because (μ/ρ) = constant the dust mass precipitated on the filter A can be calculated from the radiation attenuation using the following equation:

$$m = A_F * (\rho/\mu) * \ln (n_0/n)$$

Where: m is the absolute dust mass in g

A_F is the filter area in cm²

As the mass attenuation coefficient (μ/ρ) increases as the maximum Beta energy decreases, determination of mass by Beta absorption measurement is more sensitive the weaker the energy of the Beta radiation used.

he dust concentration is calculated from the absolute mass divided by the air volume taken in:

$$c = m/Q$$

Where: c is the dust concentration in g/m³

Q is the intake air volume in m³

3.2 Functioning of the measuring system

The F-701-20 ambient air quality measuring system uses beta-attenuation as its measurement principle.

The particulate sample passes the $PM_{2.5}$ sampling head at a flow rate of 1 m³/h (=16,67 l/min) and reaches the F-701-20 analyser through the intake pipe.

During performance testing, the AMS was tested with an actively ventilated intake tube and without an auxiliary pipe heating. When using the actively ventilated intake tube, ambient air is steadily transported through the outer cladding tube with a ventilation unit in order to keep the sampling tube proper situated on the inside upstream of the measurement section at ambient temperature. Power supply for the ventilator unit is provided by the instrument itself. An additional passive isolation of the outer tube might be helpful if extreme temperature differences between ambient air and installation space exist.

The AMS itself has a compact design (Figure 1). For the instrument version with internal pump, all components except for the sampling probe (intake tube, sampling head), the meteorological sensor to measure air pressure and ambient temperature and the installation for the active ventilation of the intake tube are built in one unit. Furthermore, there is an instrument version with an external pump. It is in fact the same pump which has simply been relocated by removing it from the existing assembly and having the tubing and power supply adapted accordingly to allow for operating the pump outside of the instrument housing.

The AMS is controlled with the help of a micro controller board.

A step motor transports the filter belt from the supply roll to the take-up roll. The Geiger-Müller tube determines the mass increase on the filter belt on the basis of the attenuation of radiance emitted by the C-14 source. A pump sucks in air. A flow meter measures the flow and a by-pass valve keeps it at a constant flow rate of 1000 l/h. Electronics save the data and control the measurement procedure, which enables a user-optimised handling via a touchscreen.

Optionally, a cover foil protects the instrument from contamination or loss to allow for subsequent laboratory testing. This option was outside the scope of the performance test.

In a regular test sequence, an unloaded filter spot is inserted in between the C-14 source and the counter tube at the beginning of the sequence. Radiance intensity is measured over a period of 300s. This implies that pulses generated by the counter tube are used as a measure of beta attenuation.

Subsequently, the filter adapter is opened and the filter belt is transported until the assessed filter spot reaches the extraction position. The filter adapter is then closed and the extraction process starts. Once sampling is completed, the filter adapter is opened again and the filter paper is brought into its original position under the counter tube. The filter adapter is closed and the radiance intensity is measured for 300 s again.

Dust load is then determined from the count rates before and after the extraction and dust concentration is calculated from setting it off from extracted air as described in Chapter 3.1.

Extraction time corresponds to the cycle time fixed in each case and the number of times set for a filter spot to be sampled minus measurement time and the time required to move the filter tape. The number of times a filter spot is sampled serves as a setting for multiple filter spot uses. It can parameterised to between 1 (i.e. a new filter spot is used for every cycle) to 24 (i.e. a filter spot is sampled 24 times).

Thus, the extraction time is:

For a cycle time of 60 min and a single sample per filter spot:

60 min – (2 x 300 s measurement time + 120 s filter tape movement) = 48 min

For any number of samples taken on a single filter spot > 1, the measurement after a suction serves both the calculation of the measured value for the completed cycle and the start measurement for the subsequent cycle. In other words, every cycle requires only a single radiometric measurement of 300 s.

During performance testing, the cycle time was set to 60 min and the number of samples per filter spot was set to 24. Extraction time in that case is:

Cycle 1: 60 min – (2 x 300 s measurement time + 120 s filter tape movement) = 48 min

60 min – (1 x 300 s measurement time + 120 s filter tape movement) = 53 min

The measured values determined are shown in the display and are available both as 4-20 mA analogue signals and via a serial RS232 interface (e.g. using the Bayern-Hesse or Gesytec protocol). The instrument stores all measured values of the past 9 months. They can be retrieved via the display or the serial interface. It is easy to download measured values, error messages or instrument parameters via a terminal software. It is also possible to print out information on the filter tape to label the collected particulate sample. This option was outside the scope of the performance test.

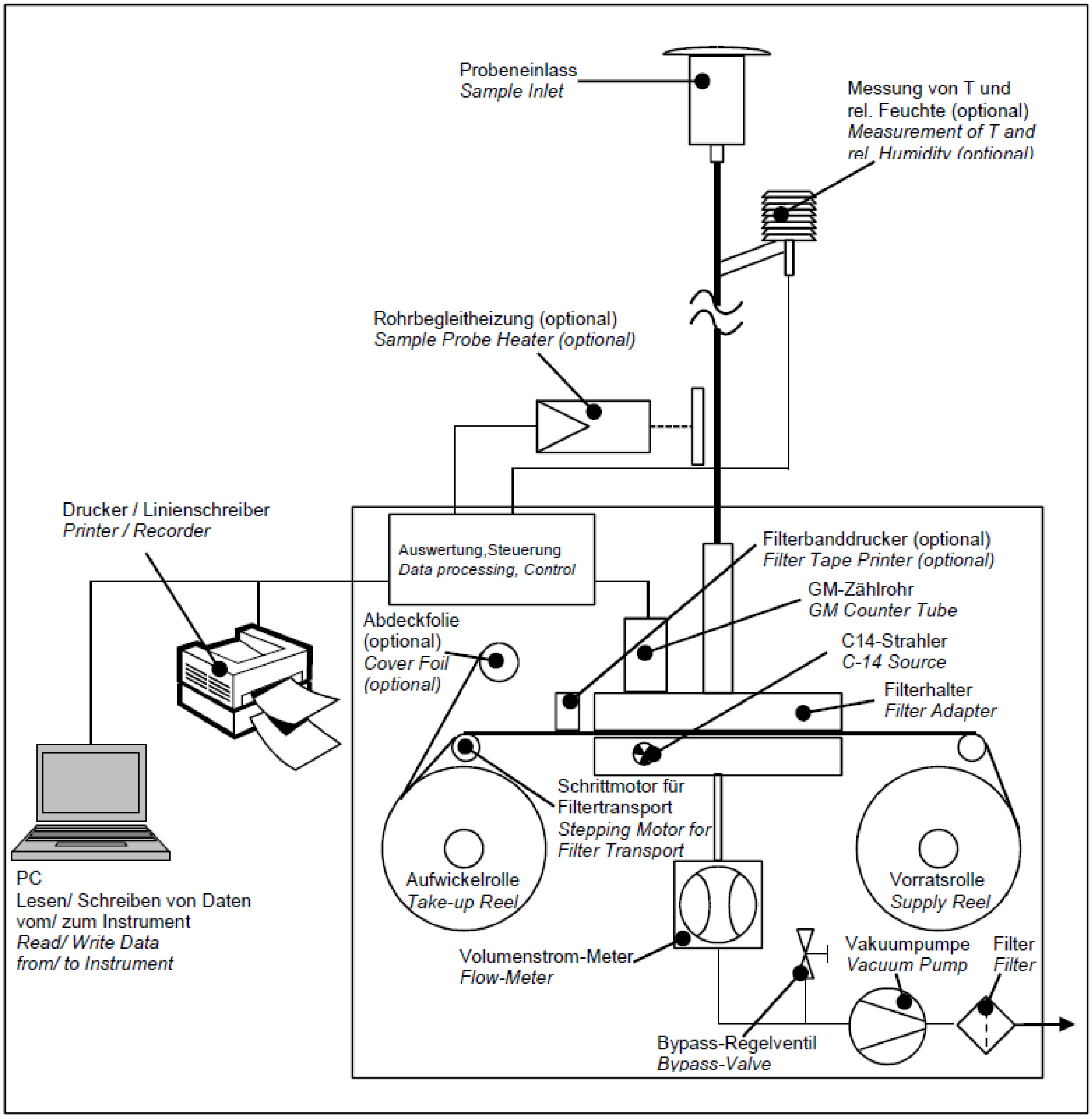


Figure 1: Schematic diagramme – Set-up of the F-701-20 measuring system, without actively ventilated sample inlet tube and with internal pump

3.3 AMS scope and set-up

The F-701-20 ambient air quality measuring system consists of the $PM_{2,5}$ sampling head, the meteorology sensor, the intake tube with active ventilation, the F-701-20 analyser itself incl. glass fibre filter tape, the required connecting tubes and cables as well as adapters, the roof flange as well as the manual in German.

Figure 2 shows an overview of the F-701-20 measuring system

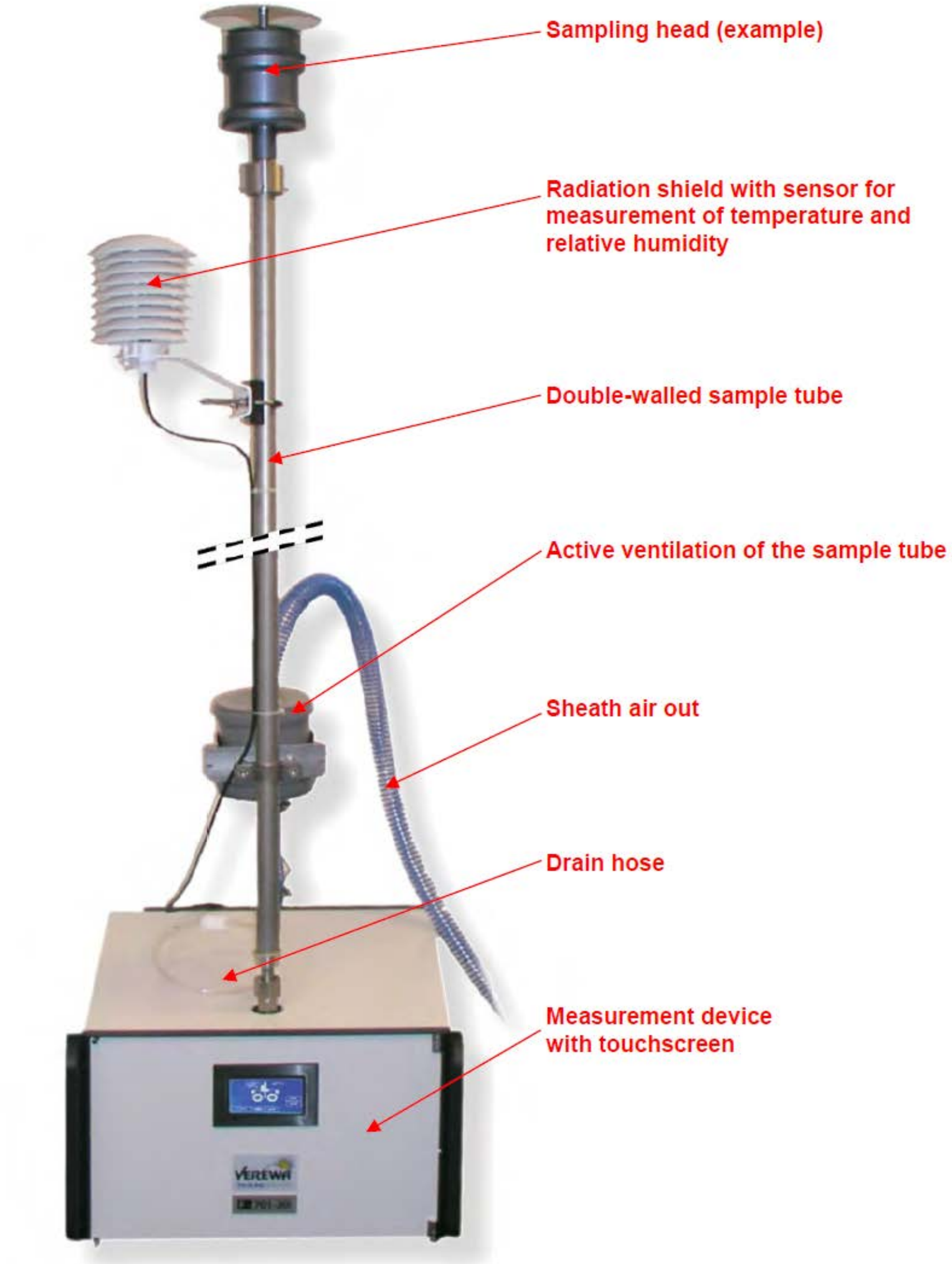


Figure 2: Presentation of the F-701-20

A $PM_{2,5}$ sampling head (manufactured by Comde-Derenda GmbH) serves as a sampling head. It is also possible to use TSP or PM_{10} sampling inlets instead.

Figure 3: $PM_{2,5}$ sampling head

An actively ventilate sampling inlet tube connects the sampling head to the measuring system. When using the actively ventilated intake tube, ambient air is steadily transported through the outer cladding tube with a ventilation unit in order to keep the sampling tube proper situated on the inside upstream of the measurement section at ambient temperature. During the performance test, a 2 m long probe inlet tube was used. Default lengths of 1 and 3 m are also available.

Figure 4: Active ventilation of the sampling system used for field testing

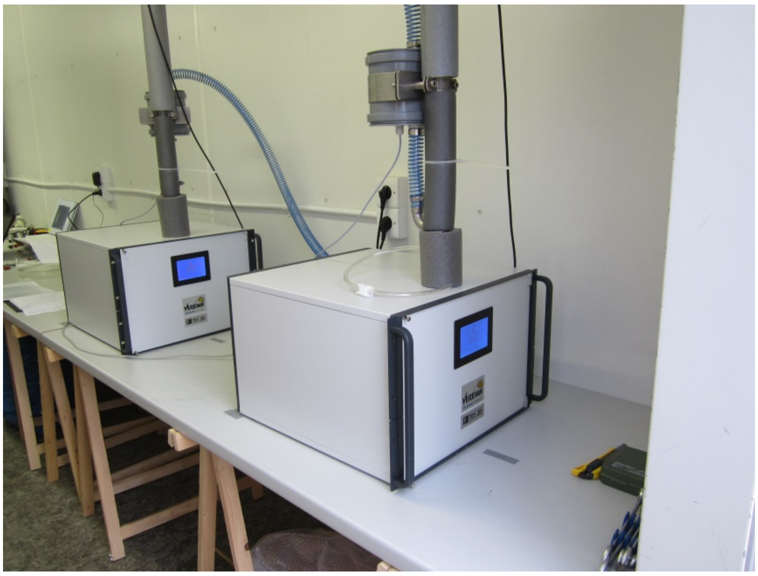


Figure 5: F-701-20 installed at the field test site

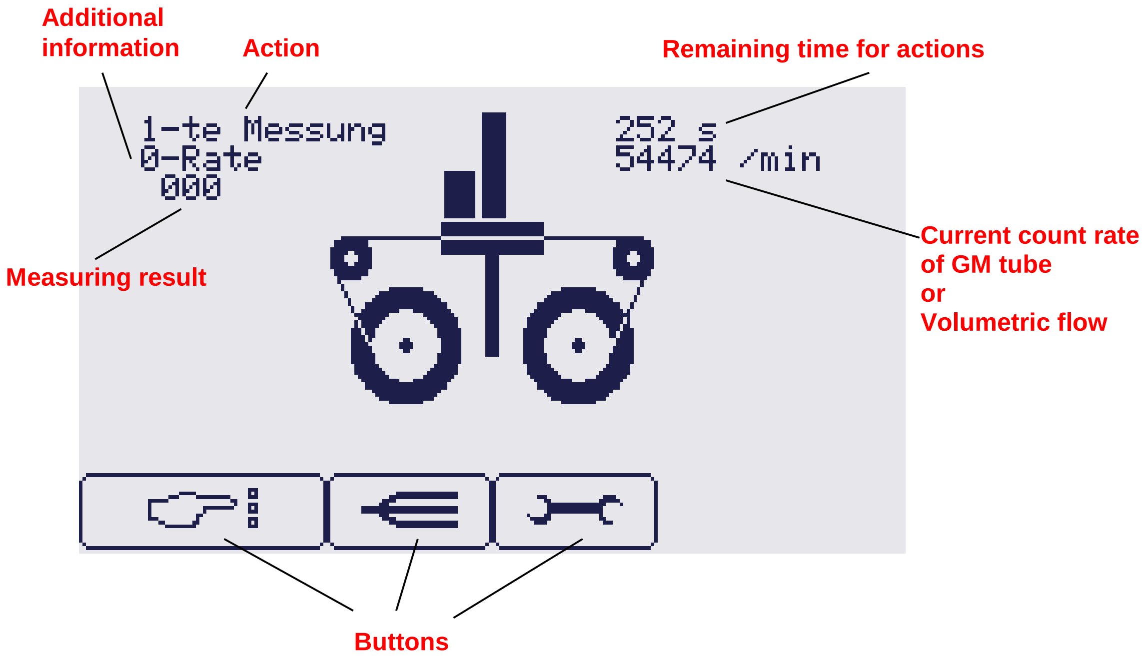
A zero filter is mounted to the instrument inlet for the purpose of external zero checks. The use of this filter allows the provision of PM-free air.

Figure 6: Zero filter for generating particle-free air, field test use

The manufacturer has provided a span foil for the purpose of external checks of the radiometric measurement.

Figure 7: Span foil

A touchscreen display at the front of the measuring system controls the measuring system. The user may retrieve measurement data and system information, change parameters and perform functionality tests of the measuring system.

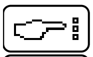


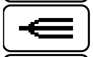
F-701-20 8: Main menu F-701-20

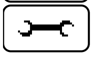
The main menu appears after the instrument has started. It displays various pieces of information such as

- Current instrument status (measurement, *i*th measurement (cycle count for multiple sampling, stand-by)
- Additional information such as status within the current measurement cycle (0 rate ...)

Buttons provide access to the following features:

 Switch between measuring, data display and setup mode.

 Go to a submenu

 Open maintenance menu

In normal operating mode,  switches between the following menus.

Measurement mode: Dust measurement and display of results, display of on-going activities, performance of servicing tasks

Display mode: Display of measured values as graphs or tables and of status and error messages

Parameterisation mode: Display and change of instrument parameters

The parameterisation mode allows to look up any parameter and change them after having entered a password Figure 9 shows an overview of the entire parameter menu structure Chapter 5 of the operation manual provides a detailed description of all parameters.

Password	Password entry
Measurement	Display the measured / saved values
Parameter	Display and enter the main parameters
Sub parameter	Display and enter the secondary parameters
Adjust	Correct the input and output signals
Interface	Set the interface parameters
Date/Time	Set the date and time
Service	Basic operating functions, troubleshooting

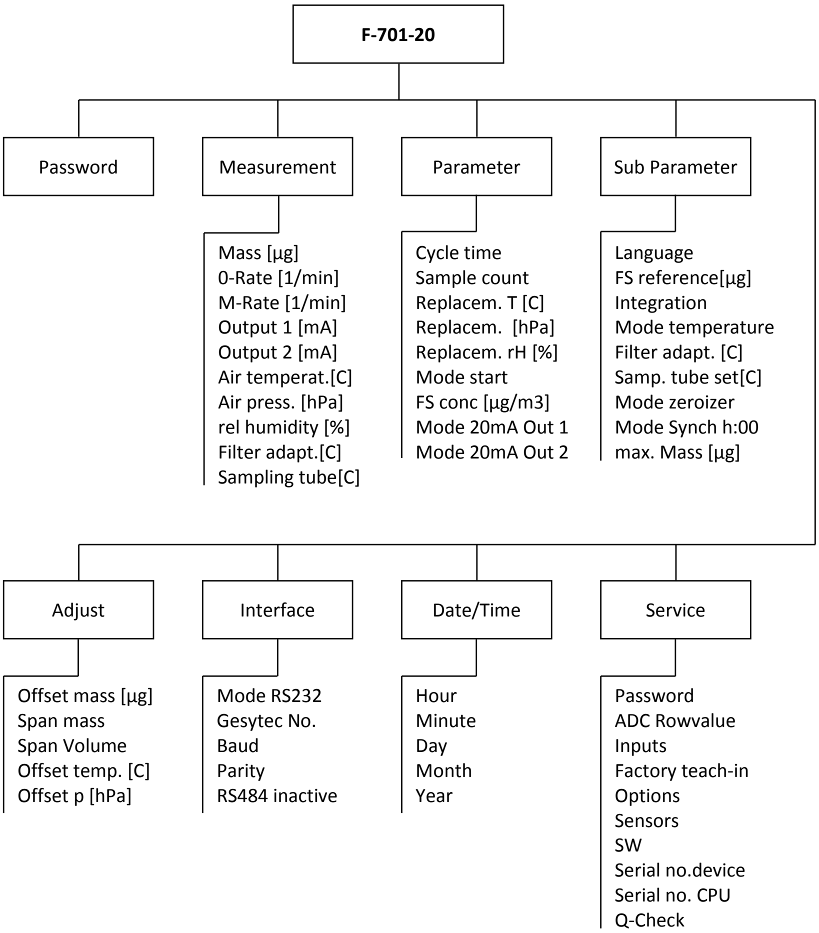
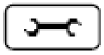
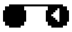
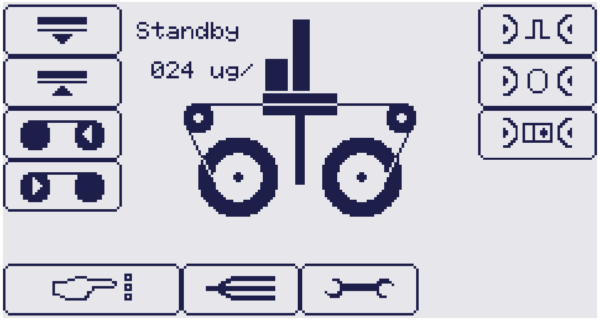


Figure 9: Flow chart – parameter menu structure (Software version 3.11R0008 and later)

Pressing [key symbol] retrieves additional information. Thus, the measurement mode provides additional information on the standardised volumetric flow rate, ambient air temperature, rel. humidity and ambient air pressure.

Pressing  activates the maintenance menu provided that the correct password is entered. The following actions can be carried out.

 Open filter housing
 Close filter housing
 Filter tape forwards
 Filter tape backwards
 Start reference measurement
 Start zero measurement
 Start reference foil measurement



In manual mode, also:

-  Start measurement

In addition to using the touchscreen display for communication with the instrument, the RS232 interface can be used. In the context of performance testing, the instrument was primarily accessed via the RS232 interface and the Hyper Terminal software, especially for downloading internally saved measurement data.

Figure 10provides an overview of all instrument parameters relevant during performance testing (taking instrument SN 1512361 as an example).

```
                                  P_1512361.TXT
Parameter Ausdruck  15.10.13 14:33
-------------------------  Stammdaten:  -------------------------------------
Beta Staubmeter  F 701-20
Serien Nr.Geraet  1512361  Serien Nr.CPU      1227716
Silicon Serial Number      8A-70-00-00-00-0C-E9-68
SW 3.10

-------------------------  Parameter:  --------------------------------------
Zykluszeit            1 h  Belegzahl              24  Ersatzwert T [C]       20
Ersatzwert [hPa]     1013  Ersatzwert rF[%]       50  Modus Start        60 Min
MBE/20mA [ug/m3]      200  Modus 20mA Ausg1     conc  Modus 20mA Ausg2     mass

Sprache           Deutsch  MBE Ref/20mA[ug]     1000  Integral                1
Modus Temperatur humidity  Filterh.Soll [C]        3  Rohr    Soll [C]        3
Modus Nullrueck. inactive  Modus Synch h:00       10  Max. Masse [ug]       250

Offset Masse[ug]        0  Span   Masse            1  Span Volumen        0.982
Offset Temp. [C]        1  Offset Druck hPa       -8

Modus RS232      terminal  Gesytec Nr.           123  Baud               9600bd
Parity/Bit         no   8  RS485 inactive

-------------------------  Fertigungseinstellungen:  -------------------------
Offset sc1  [ug]        0  Offset sc2-n[ug]        0  Span Service            1
Offs Fi-Ha[0.1C]        0  Filter adapt.100     4258  Filter adapt.120     9001
Tube heater 100      4240  Tube heater 120      9019  Temperature 100      4271
Temperature 120      9022  Volumesensor 1 V     3278  Volumesensor 5 V    15613
Pressure   4 mA      4024  Pressure 20 mA      15679  Reserve   4 mA       4000
Reserve 20 mA       15000  b 20 mA Out1        0.998  c 20 mA Out1        0.016
b 20 mA Out2        1.001  c 20 mA Out2        0.021

Meldung debounce        0  Beta Sensor       GM tube  Geraetetyp       F701- 20
Filter Motor        micro  Abstand Qu./Rohr     1600  Abstand Flecken      1600
Intell. Korr.    Active 1  ICC Wert             0.39  Vol. GM Quelle        780
Filter Drucker   inactive

Sensor Luft T     meteor.  Sensor Luft p      4/20mA  Druck b             31.25
Druck c               675  Sensor Luft rF    meteor.
```

Figure 10: Print out of F-701-20 parameters

Table 2 lists a number of important instrument characteristics of the F-701-20 monitor for suspended particulate matter.

Table 3: F-701-20 instrument characteristics (manufacturer's specifications)

Dimension/weight	**F-701-20**
Measuring device	482 x 530 x 320 mm / 31 kg (version with internal pump), 26 kg + 8 kg pump (version with external pump)
Sampling tube	Single or double-walled sampling tube, length 1 , 2 m or 3 m
Sampling head	depending on the manufacturer, during performance test Comde-Derenda GmbH, $PM_{2,5}$ sampling head 1.0m³/h for 16 mm tube connection
Power supply	Analyser: 230 V / 50 Hz or 115 V / 60 Hz
Power requirement	~400 W
Ambient conditions	
Temperature	+5 to +40 °C (during performance test)
Moisture	non-condensing
Sample flow rate (inlet)	16.67 l/min = 1 m³/h
Radiometry Light source	^{14}C surface radiator < 450 kBq (< 12.5 µCi)
Detector	End-window Geiger-Müller tube
Parameters of filter replacement	
Filter Tape	Glass fibre filter, 30 or 45 m
Measurement cycle (cycle time)	15 min - 24 h During performance testing: 1 h (24 replacements per day)
Times sampled (multiple sampling)	1 – 24 During performance testing: 24 (max. 24 cycles per filter spot)
Max. Dust mass per filter spot	Depending on the composition of dust, parameterisable, 400 µg during performance testing
Parameters: Sample conditioning	
Sample inlet tube conditioning	Active ventilation
Date storage capacity (internal)	Depending on the size of the SD chip, direct access to data of the past 9 months via instrument menu

	F-701-20
Instrument inputs/outputs	Outputs: Analogue 4–20 mA Digital RS232
Protocols	PC communication via RS232 Bavaria-Hesse, Gesytec
Status signals/error messages	available, see Chapter 6, Table 6.4 (Error messages) or Chapter 5.7 (Status messages) of the manual for an overview

4. Test programme

4.1. General

The original performance test [9] was performed using two identical instruments, type F-701-20, serial numbers S/N 1512361 and S/N 1512401 in accordance with the minimum requirements specified in [1; 2; 3; 4].

The tests were performed with software versions 3.07 and 3.10.

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.

New tests for items 6.1 4 Flow rate accuracy (7.4.4), 6.1 9 Dependence of span on supply voltage (7.4.8) and 11 Effect of humidity on measured value (7.4.9) were performed with two identical F-701-20 instruments, serial numbers SN 1274509 and SN 1274510.

The software version most recently announced publically is 4.11R0009. Software version 4.11R0010 was installed during the additional tests. In this new updated software version, a bug relating to the application of "intelligent correction" has been fixed. So far, the intelligent correction has only been applied when the number of filter spots sampled exceeded 1. The updated software version now allows for application to a single filter spot sampling. In line with the requirements of EN 15267-2, this change has been documented and classified correctly. No influence on instrument performance was identified, especially since the number of times a filter spot was sampled was set to 24 (as during performance testing) and the change did therefore not affect measurement in the first place. A separate notification is prepared for the relevant body.

Concentrations are indicated as µg/m³ (operating conditions).

The present addendum presents an assessment of the F-701-20 measuring system with $PM_{2,5}$ pre-separator regarding compliance with the requirements defined in standard EN 16450 [8].

In this report, the heading for each performance criterion cites the requirements according to [8] including its chapter number and wording.

4.2 Laboratory test

A large portion of the laboratory test is taken from the original performance test [9]. 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 2018.

- Flow rate accuracy
- 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
- Span foil

The measured values were recorded internally. Stored measured values were retrieved using a HyperTerminal connected to the RS232 interface.

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 [9] with 2 identical measuring systems. These were:

Instrument 1:	S/N 1512361
Instrument 2:	S/N 1512401

For the present report, test results were either taken from the previous report or re-assessed. No further testing was required.

The following instruments were used during the field test.

- Measurement container provided by TÜV Rheinland, air-conditioned to about 20 °C
- Weather station (WS 500 manufactured by ELV Elektronik AG) for collecting meteorological data such as temperature, air pressure, humidity, wind speed, wind direction and precipitation.
- Two LVS3 reference measuring systems for $PM_{2.5}$ according to item 5
- 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
- Span foil

Two F-701-20 systems and two reference measuring systems for $PM_{2.5}$ were simultaneously operated for 24 h each during the field test. The reference system is a discontinuous system: the filter has to be replaced manually after sampling.

Impaction plates of the $PM_{2.5}$ 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. $PM_{2,5}$ sampling inlets of the tested instruments were cleaned every four weeks. 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 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 4: Field test sites

No.	Measurement site	Period	Description
1	Bonn, crossroads, winter	02/2013 – 05/2013	Affected by traffic
2	Bornheim, parking lot at motorway, summer	05/2013 – 07/2013	Rural area + traffic
3	Cologne parking lot, autumn	09/2013 – 12/2013	Urban area
4	Cologne parking lot, winter	01/2014 – 03/2014	Urban area

Figure 11 to Figure 14 show the $PM_{2,5}$ concentrations measured with the reference systems at the field test sites.

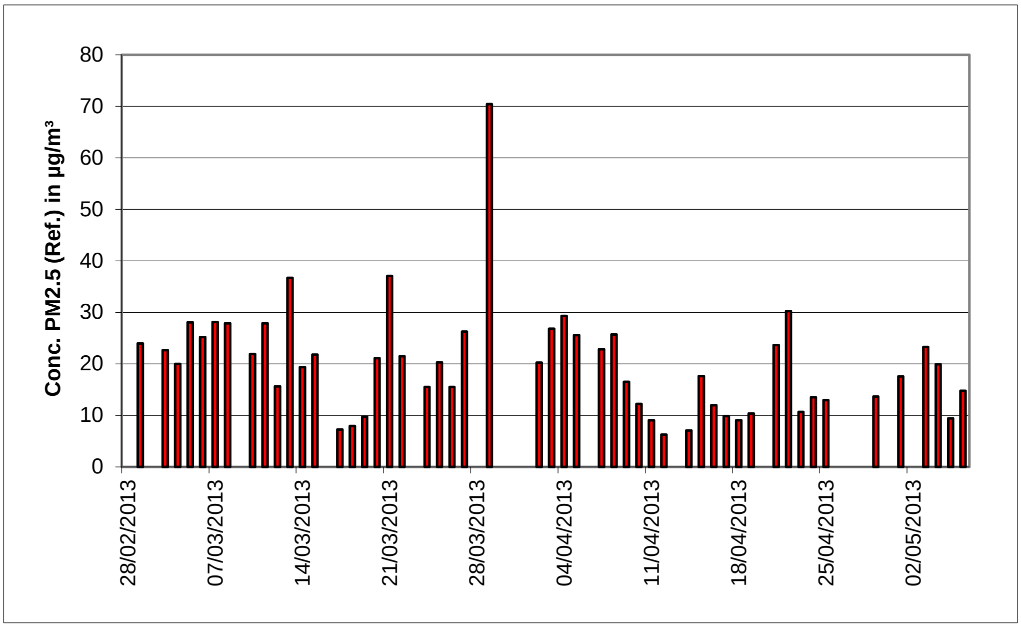


Figure 11: $PM_{2,5}$ concentrations (reference) in Bonn, crossroads, winter"

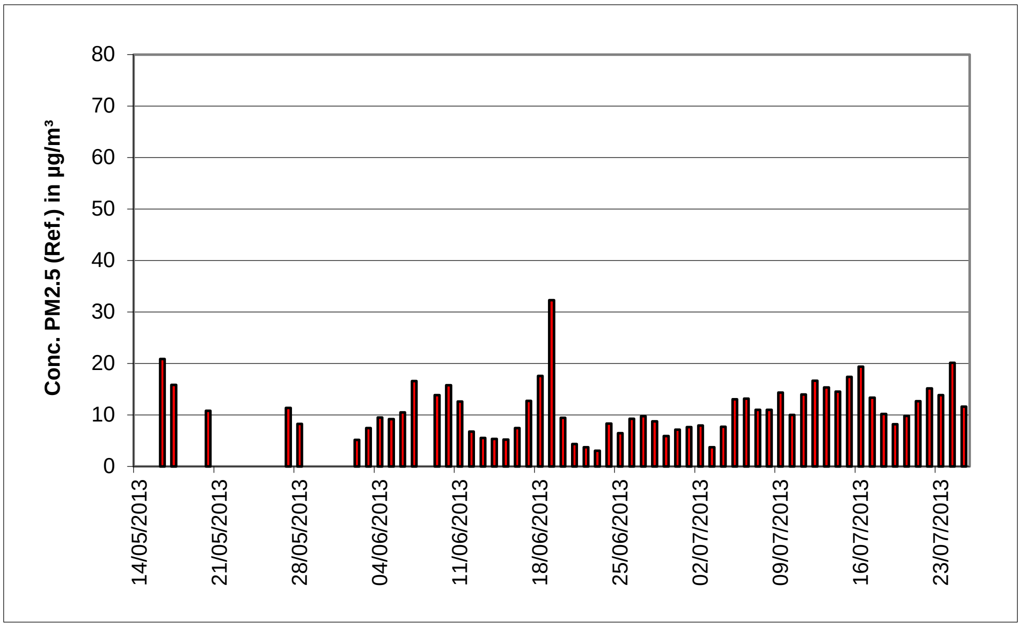


Figure 12: $PM_{2,5}$ concentrations (reference) in "Bornheim, parking lot at motorway, summer"

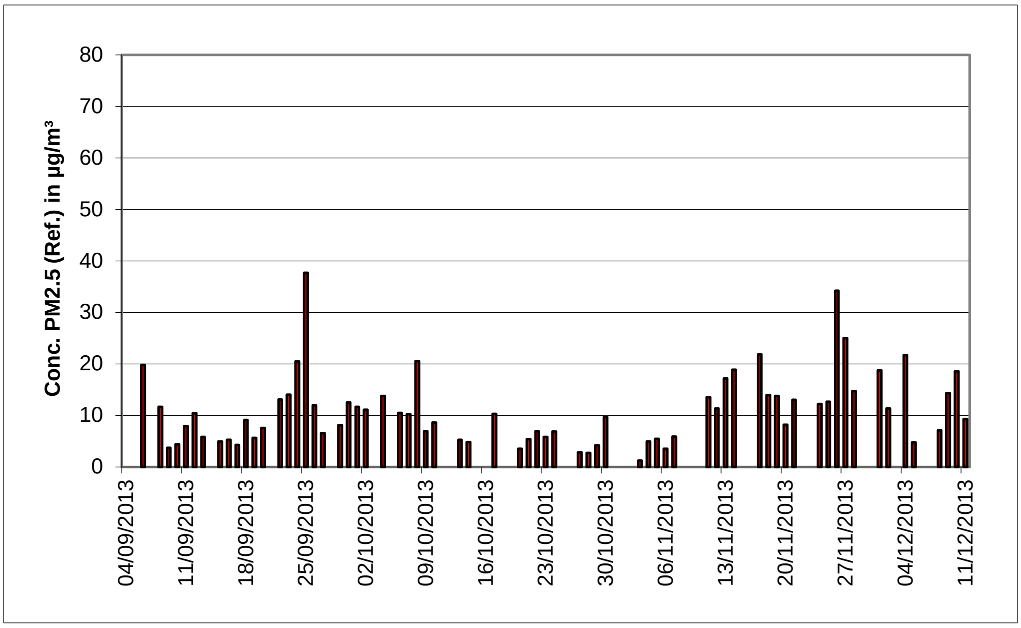


Figure 13: $PM_{2,5}$ concentrations (reference) in Cologne, winter parking lot, autumn"

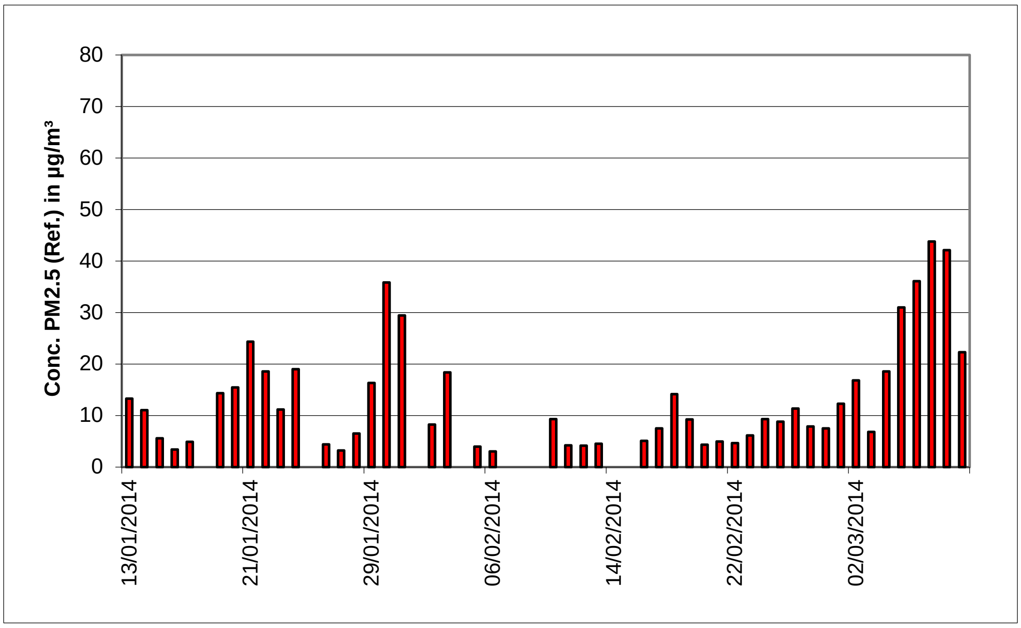


Figure 14: $PM_{2,5}$ concentrations (reference) in Cologne, winter parking lot, winter"

The following pictures show the measurement container at the various field test sites in Bonn (cross-roads), Bornheim (parking lot at a motorway) and Cologne.

Figure 15: Field test site in Bonn, cross-roads

Figure 16: Field test site Bornheim, motorway parking lot

Figure 17: Field test site Cologne, parking lot

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.

- Height of cabinet roof. 2.50m
- Height of the sampling system for test/roof 0.50 m/1.2 m above container
- Reference system 3.00 / 3.01 m over ground level
- Height of the wind vane: 4.5 m above ground level

In addition to an overview of the meteorological conditions determined during measurements at the 4 field test sites, the following Table 5 therefore provides information on the concentrations of suspended particulate matter. All individual values are presented in appendices 5 and 6.

Table 5: Ambient conditions at the field test sites as daily averages

	Bonn, Junction Winter	Bornheim, Motorway parking lot Summer	Cologne Parking lot autumn	Cologne Parking lot Winter
number of measurements Reference	51	58	68	47
Ratio of $PM_{2.5}$ to PM_{10} [%] Range Average	42.2 – 96.5 70.5	39.1 – 84.6 60.5	28.6 – 90.7 61.7	32.0 – 90.9 68.8
Air temperature [°C] Range Average	-3.4 – 20.0 8.0	6.4 – 27.6 17.7	1.1 – 25.5 10.9	2.5 – 13.1 6.5
Air pressure [hPa] Range Average	985 – 1018 1004	989 – 1020 1008	986 – 1027 1008	984 – 1022 1000
Rel. Humidity [%] Range Average	42.8 – 85.8 63.0	52.2 – 89.1 69.2	56.3 – 89.8 79.5	46.8 – 87.2 74.4
Wind speed [m/s] Range Average	0.4 – 4.2 1.6	0.2 – 4.7 1.4	0.0 – 2.5 0.4	0.0 – 3.0 0.7
Precipitation rate [mm/d] Range Average	0.0 – 13.2 0.9	0.0 – 34.6 3.3	0.0 – 35.8 3.4	0.0 – 18.9 1.7

Sampling duration

Standard EN 14907 [3] 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) 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 [4] 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.

The Grubb's test for outliers did not identify any value pairs considered significant outliers (99%) for any of the test sites. Consequently, none of the value pairs obtained from reference measurements for $PM_{2,5}$ were discarded.

Filter handling – Mass measurement

The following filters were used during performance testing:

Table 6: Filter materials used

Measuring device	Filter material, type	Manufacturer
Reference devices LVS3	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 during the field test in accordance with EN 14907:

1. as $PM_{2.5}$ reference system: Low Volume Sampler LVS3
Manufacturer: Engineering office Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007 and 2010
$PM_{2.5}$ sampling inlet

During the tests, two reference systems for $PM_{2.5}$ 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 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 $PM_{2.5}$ 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 shall 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 measuring system allows for a measuring range of up to 0–10,000 µg/m³. By default, the measuring range is set to 0–1,000 µg/m³.

For typical European conditions, a measuring range of 0 –200 µg/m³ or 0–1,000 µg/m³ is recommended as a useful standard setting for the analogue output.

(recommended) measuring range: 0–200 or 0–1,000 µg/m³

6.5 Assessment

The measuring range is set to 0–1,000 µg/m³ by default. Supplementary measuring ranges are possible up to 0–10,000 µg/m³.

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.

6.5 Assessment

Negative signals are directly displayed and correctly output by the measuring system.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 3 Zero level and detection limit (7.4.3)

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 1512361 and SN 1512401 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 test specimen. It is equal to the standard deviation of the average x_0 of the measured values x_{0i} multiplied by 3.3 for each test specimen.

$$X = 3.3 \cdot s_{x0} \qquad \text{where} \cdot s_{x0} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1,n} (x_{0i} - \overline{x_0})^2}$$

6.5 Assessment

On the basis of testing both instruments, the zero level was determined at a maximum of 0.34 µg/m³ and the detection limit at a maximum of 1.15 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 7: Zero level and detection limit $PM_{2.5}$

		Device SN 1512401	Device SN 1512361
Number of values n		15	15
Average of the zero values (Zero level) $\overline{x}_0$	µg/m³	0.28	0.34
Standard deviation of the values s_{x0}	µg/m³	0.31	0.35
Detection limit x	µg/m³	**1.01**	**1.15**

Schedule 1 in the annex 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 +5°C to +40°C; a reference flow meter in accordance with item 4 was provided.

6.3 Testing

The F-701-20 measuring system operates at a flow rate of 16.67 l/min (1 m³/h).

At a temperature of +5 °C and +40 °C the flow rate was measured with the help of a reference flow meter for both measuring systems 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.

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 +5°C and at +40°C did not exceed -1.53%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 8 summarises the results of the flow rate measurements.

Table 8: Flow rate accuracy at +5°C and +40°C

		Device SN 1274509	Device SN 1274510
Nominal value flow rate	l/min	16.67	16.67
Mean value at 5°C	l/min	16.43	16.41
Dev. from nominal value	%	-1.44	-1.53
Mean value at 40°C	l/min	16.91	16.90
Dev. from nominal value	%	1.44	1.36

Schedule 2 in the annex contains the individual measured values for the determination of the flow rate accuracy.

6.1 5 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 F-701-20 measuring system operates at a flow rate of 16.67 l/min (1 m³/h).

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 in the field, 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 9 presents the results of the flow rate checks performed at every field test site.

Table 9: Results of the flow rate checks

Flow rate check before:	SN 1512361		SN 1512401	
Field test site:	[l/min]	Dev. from target [%]	[l/min]	Dev. from target [%]
Bonn, winter	16.67*	-	16.67*	-
Bornheim, Summer	16.69	0.12	16.72	0.30
Cologne, autumn	16.35	-1.92	16.42	-1.50
Cologne, Winter	16.58	-0.54	16.68	0.06

* adjusted 27/02/2013

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%. At 16.67 l/min, the deviation of the 24h-mean for the overall flow rate also remains well below the required maximum of ±2.0% from the rated 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

Table Table 10 lists the characteristics determined for the flow rate. Figure 18 to Figure 19 provide a chart of the flow rate measurement for both instruments - SN 1512361 and SN 1512401.

Table 10: Characteristics of the overall flow rate measurement (24h mean), SN 1512361 and SN 1512401

		Device SN 1512361	Device SN 1512401
Mean value	l/min	16.66	16.64
Dev. from nominal value	%	-0.05	-0.20
Standard deviation	l/min	0.12	0.12
Minimum value	l/min	16.27	16.18
Maximum value	l/min	17.22	17.03

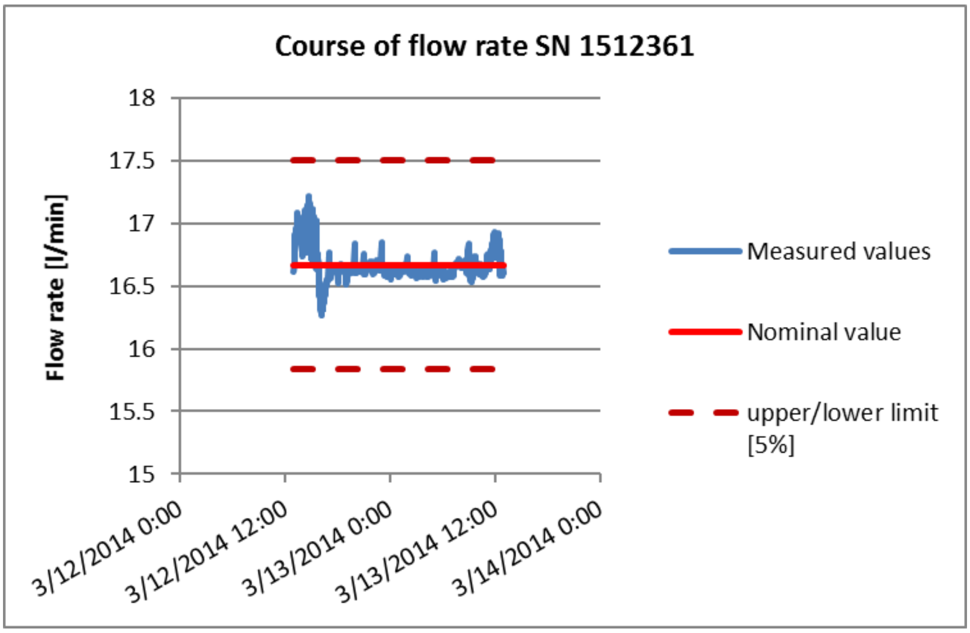


Figure 18: Flow rate of tested instrument SN 1512361

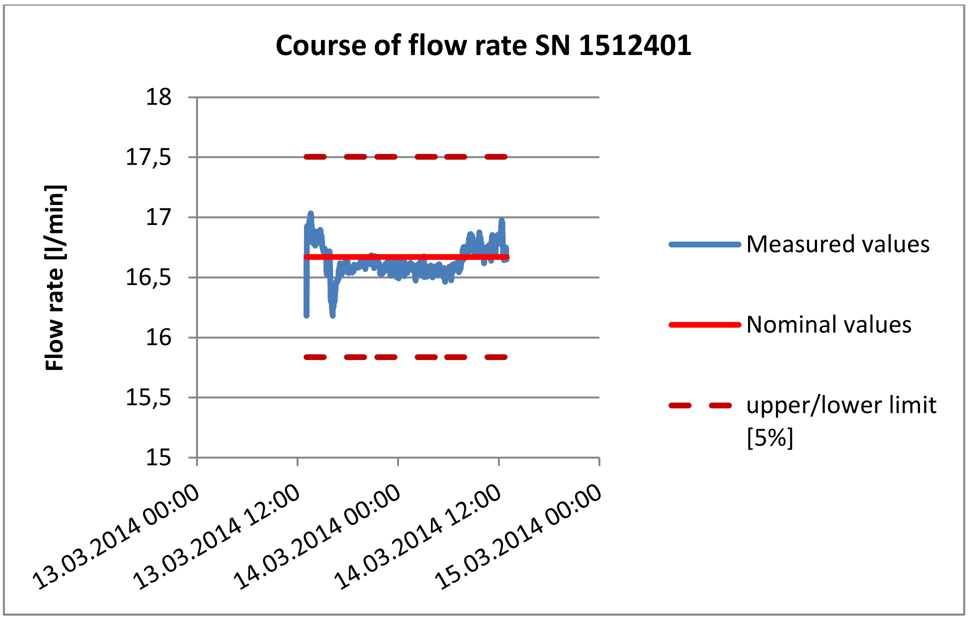


Figure 19: Flow rate of tested instrument SN 1512401

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 manufacturer'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 F-701-20 measuring system is located immediately upstream of the pump. In order to determine the leak tightness of the measuring system, the latter was started in accordance with Chapter 5.3.3 of the instruction manual. Once the operational flow rate of 1,000 l/h was reached, the inlet of the sample tube was blocked with a thumb or a plug. As specified by the manufacturer, the flow rate measured by the instrument must then drop below 10 l/h, ideally even to 0 l/h.

This procedure was followed at the beginning of the tests at each field test site.

It is re recommended to test the instrument's leak tightness with 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 10 l/min when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness.

At 1 l/m, the maximum leak rate determined remained below 2.0% of the nominal flow rate of 1,000 l/h (16.67 l/m).

6.5 Assessment

The criterion for passing the leak test as specified by the AMS manufacturer – maximum flow rate of 10 l/min when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness.

At 1 l/m, the maximum leak rate determined remained below 2.0% of the nominal flow rate of 1000 l/h (16.67 l/m).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 11 lists the result from the leak test.

Table 11: Results of the leak test during the field test

Leak check before	SN 1512361		SN 1512401	
Test site:	Nominal [l/h]	Actual [l/h]	Nominal [l/h]	Actual [l/h]
Bonn, Winter	< 10	0	< 10	0
Bornheim, Summer	< 10	1	< 10	0
Köln, Autumn	< 10	0	< 10	0
Köln, Winter	< 10	0	< 10	0

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 +5 and +40 °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 $T_{S,1}$ = +5 °C;

c) at a maximum temperature $T_{S,2}$ = +40 °C.

The complete measuring systems were operated inside a climatic chamber in order to evaluate the influence of ambient temperature on the zero point.

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 24h 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 tested temperature range at the site of installation was +5 °C to +40 °C. Taking into account at the values displayed by the instrument, we determined a maximum dependence of the zero point on the on surrounding temperature of -1.0 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 12: Dependence of the zero point on surrounding temperature, F-701-20, Deviation as µg/m³, mean from three measurements S/N 1512361 & S/N 1512401

Temperature	SN 1512361		SN 1512401	
	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	0.7	0.1	0.3	0.0
5	0.8	0.1	-0.1	-0.4
20	0.8	0.2	0.3	0.0
40	-0.3	-1.0	-0.2	-0.5
20	0.4	-0.2	0.3	0.0
Mean value at 20°C	0.7	-	0.3	-

Schedule 3 in the annex 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 adjusted to +5 °C to +40 °C, span foil used to check the span point.

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 $T_{S,1}$ = +5 °C;

c) at a maximum temperature $T_{S,2}$ = +40 °C.

For the purpose of testing the dependence of the AMS sensitivity on the surrounding temperature, the complete measuring system was operated in the climatic chamber without the outdoor rack.

For the purpose of span checks the sensitivity of the internal span foil was verified for the tested instruments SN 1512361 and SN 1512401 in order to test the stability of the sensitivity.

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 span foil were recorded at different temperatures 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 tested temperature range at the site of installation was +5 °C to +40 °C. At span point, the deviations determined did not exceed -1.9%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 13: Dependency of the sensitivity (span foil) to ambient temperature F-701-20, deviation in %, average from three measurements, S/N 1512361 & S/N 1512401

Temperature	SN 1512361		SN 1512401	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	[µg]	%	[µg]	%
20	291.0	0.4	274.3	1.6
5	289.0	-0.3	270.0	0.0
20	294.0	1.5	267.3	-1.0
40	284.3	-1.9	266.0	-1.5
20	284.3	-1.9	268.7	-0.5
Mean value at 20°C	289.8	-	270.1	-

Schedule 3 in the annex 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, span foil 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 sensitivity of the span foil was verified for the tested instruments SN 1274509 and SN 1274510 in order to test the stability of the sensitivity.

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 result in deviations > 2.3% compared to the initial value of 230 V.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table14 shows a summary of the test results.

Table14: Influence of mains voltage on measured value, deviation in %
S/N 1274509 & S/N 1274510

Supply voltage	SN 1274509		SN 1274510	
	Measured value	Deviation to start value at 230 V	Measured value	Deviation to start value at 230 V
V	[µg]	%	[µg]	%
230	320.3	-	333.3	-
195	324.3	1.2	330.7	-0.8
230	326.3	1.9	332.7	-0.2
253	326.3	1.9	337.7	1.3
230	327.7	2.3	338.7	1.6

Schedule 4 in the annex 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

In the event of a failure in mains voltage, the measuring system automatically starts a new measuring cycle (during performance testing: at the next full hour) and thus resumes normal operation.

6.5 Assessment

Buffering protects all instrument parameters against loss. On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring as soon as the start time for the next measurement cycle is reached (this was set to the next full hour during performance testing).

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 measuring system 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 1274509 and SN 1274510 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 24h-averaging period at 40% relative humidity was recorded. Relative humidity was then increased to 90% at a constant pace. The time needed until an equilibrium was reached (ramp) and the measured value over an averaging time of 24h at 90% relative humidity were recorded. Subsequently, humidity was decreased to 40% at a constant pace. Again, the time needed until an equilibrium was reached (ramp) and the reading over an averaging time of 24h at 40% relative humidity were recorded.

6.4 Evaluation

The measured value for the zero level of 24-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 -1.1 µg/m³. Various water vapour concentrations were not observed to cause any significant effect on zero readings.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 15: Dependence of reading on water vapour concentration. dev. in µg/m³. $PM_{2.5}$. SN 1274509 & SN 1274510

rel. Humidity	SN 1274509		SN 1274510	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	-1.5	-	-0.9	-
90	-0.5	1.0	-0.2	0.7
40	-1.2	-0.7	-1.3	-1.1
Maximum deviation	1.0		-1.1	
40 → 90*	-0.3		0.4	
90 → 40*	-1.1		-1.7	

* only informative

6.1 12 Zero checks (7.5.3)

During the tests, the absolute measured value of the AMS shall not exceed the following 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 12 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 measured value determined for $PM_{2,5}$ at zero point was 1.8 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 16 shows the determined measured values for the zero point in µg/m³.

Figure 20 and Figure 21 illustrate the zero drift observed during the test period.

Table 16: Zero point checks SN 1512361 & SN 1512401, $PM_{2.5}$, with zero filter

Date	SN 1512361		Date	SN 1512401	
	Measured Value µg/m³	Measured value (absolute) > 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) > 3.0 µg/m³
2/28/2013	0.1	ok	2/28/2013	1.0	ok
3/30/2013	0.5	ok	3/30/2013	0.7	ok
3/31/2013	1.0	ok	3/31/2013	0.4	ok
4/1/2013	0.5	ok	4/1/2013	0.4	ok
4/26/2013	0.8	ok	4/26/2013	0.3	ok
4/27/2013	0.3	ok	4/27/2013	0.6	ok
4/28/2013	1.8	ok	4/28/2013	1.6	ok
5/14/2013	0.9	ok	5/14/2013	0.6	ok
5/15/2013	0.8	ok	5/15/2013	0.6	ok
6/22/2013	1.2	ok	6/22/2013	0.8	ok
6/23/2013	0.6	ok	6/23/2013	1.4	ok
7/26/2013	1.8	ok	7/26/2013	-0.1	ok
9/4/2013	0.7	ok	9/4/2013	0.6	ok
10/16/2013	0.1	ok	10/16/2013	0.7	ok
11/8/2013	0.3	ok	11/8/2013	0.4	ok
11/9/2013	0.1	ok	11/9/2013	0.2	ok
11/10/2013	0.3	ok	11/10/2013	0.2	ok
12/14/2013	0.1	ok	12/14/2013	0.6	ok
12/15/2013	0.3	ok	12/15/2013	0.3	ok
1/13/2014	0.3	ok	1/13/2014	0.0	ok
2/7/2014	0.4	ok	2/7/2014	1.0	ok
2/8/2014	0.0	ok	2/8/2014	0.4	ok
2/9/2014	0.4	ok	2/9/2014	0.3	ok
3/10/2014	0.4	ok	3/10/2014	0.6	ok

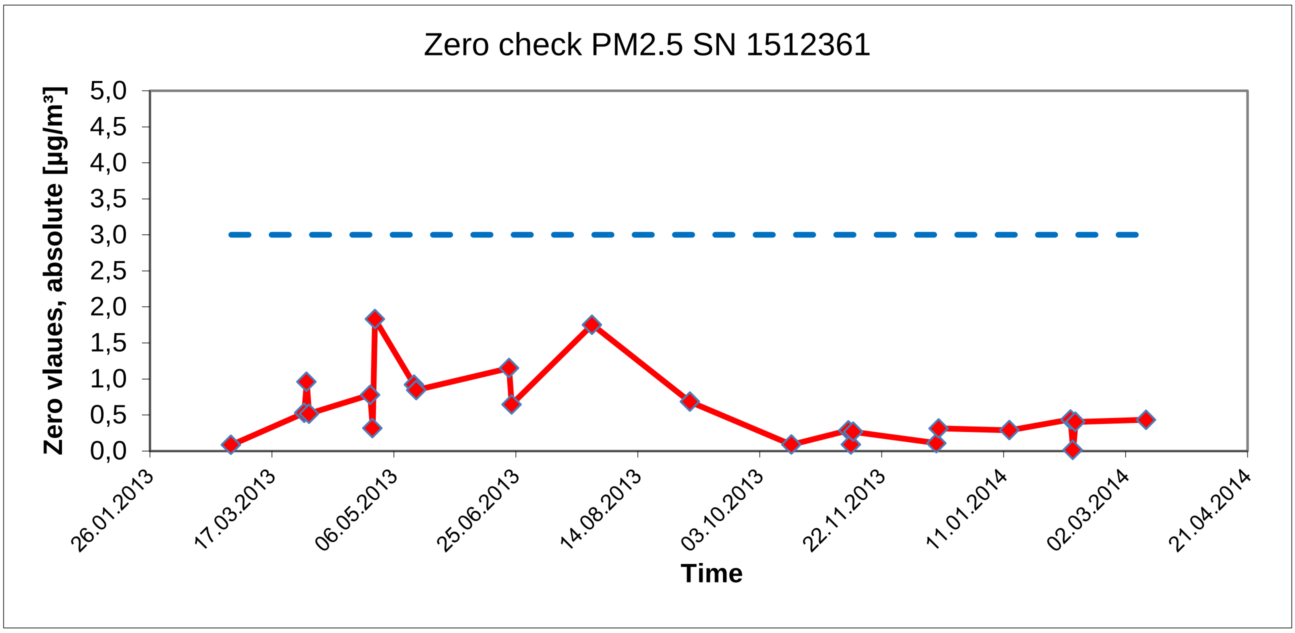


Figure 20: Zero drift SN 1512361, measured component $PM_{2.5}$

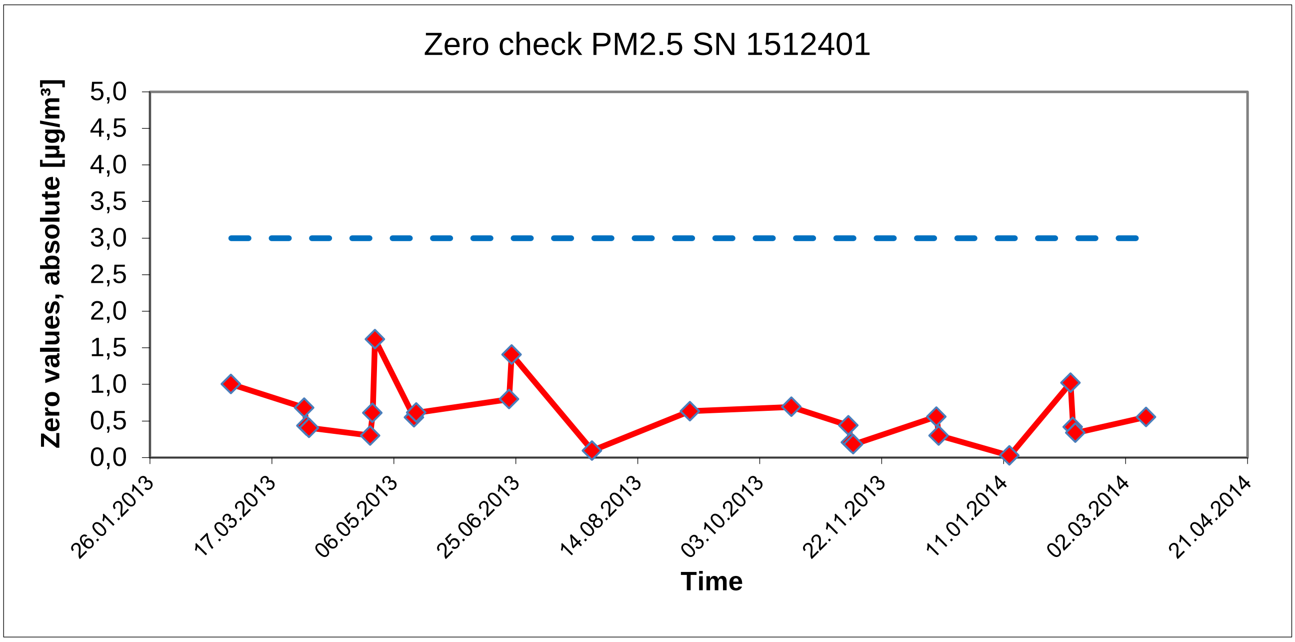


Figure 21: Zero drift SN 1512401, measured component $PM_{2.5}$

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 remote monitoring and control e.g. via an RS232 or RS485 interfaces. It can communicate measured values and status information via the Gesytec protocol.

It is possible to communicate the operating statuses and relevant parameters including:

- Concentration measurement value
- Sampled volume,
- Sampled mass,
- Ambient air temperature, pressure, humidity,
- Temperature of the filter adapter.
- ….

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 or are covered by other parameters (such as maximum load of a filter spot).

Remote monitoring and control is easily possible via routers or modems.

Access to the instrument and the data during the performance test was ensured by terminal software.

6.4 Evaluation

The measuring system allows for comprehensive remote monitoring and control via various connectors (RS232, RS485). The instrument provides operating statuses and all relevant parameters.

6.5 Assessment

The measuring system allows for comprehensive remote monitoring and control via various connectors (RS232, RS485). 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 measuring system operates in measurement cycles of 15 min to 24 h.

Extraction or sampling time corresponds to the cycle time fixed in each case and the number of times set for a filter spot to be sampled minus measurement time and the time required to move the filter tape. The number of times a filter spot is sampled serves as a setting for multiple filter spot uses. It can parameterised to between 1 (i.e. a new filter spot is used for every cycle) to 24 (i.e. a filter spot is sampled 24 times).

Thus, the extraction time is:

For a cycle time of 60 min and a single sample per filter spot:

60 min – (2 x 300 s measurement time + 120 s filter tape movement) = 48 min

For any number of samples taken on a single filter spot > 1, the measurement after a suction serves both the calculation of the measured value for the completed cycle and the start measurement for the subsequent cycle. In other words, every cycle requires only a single radiometric measurement of 300 s.

During performance testing, the cycle time was set to 60 min and the number of samples per filter spot was set to 24. Extraction time in that case is:

Cycle 1: 60 min – (2 x 300 s measurement time + 120 s filter tape movement) = 48 min

60 min – (1 x 300 s measurement time + 120 s filter tape movement) = 53 min

The time available for sampling per cycle is 80% to 88.3% of the total cycle time.

Thus, the formation of daily averages is ensured.

6.5 Assessment

The instrument configuration described and a measurement cycle set to 1 h and filter spots sampled 24 times allow the formation of valid daily averages based on 24 measurement cycles.

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. 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

Table 17 establishes the operation, maintenance and outage times. During the field test, the measuring systems were operated for a total of 296 measuring days (see annex 5). This period includes a total of 22 days in zero filter operation, audits as well as days which had to be disregarded because of changing to the zero filter (again, see annex 5).

In light of the checks performed to identify the cause of the unusual deviation between the two instruments on 15 October 2013, the measured values obtained for both instruments, including those of the unaffected SN 1512361, were discarded because of the long outage time caused by maintenance.

Outages caused by external events not attributed to the measuring system occurred between 5 September 2013 and 12 September 2013. Measured values obtained by both instruments had to be discarded for the entire period, since the flow rate was systematically adjusted incorrectly before commissioning as a result of incorrect parameterisation of the reference flow sensor. Consequently, the flowrates were checked and re-adjusted on 12 September 2013.

This reduces the total time of operation to 288 (SN 1512361) and 288 measuring days (SN 1512401).

The following errors in functioning were observed:

SN 1512361:

No instrument malfunctions were observed for this AMS.

SN 1512401:

Instrument SN 1512401 at the site in Cologne, winter was observed to provide considerably higher measured values than provided by SN 1512361 and than the initial reference values observed at the site. As a result, the manufacturer thoroughly inspected the instrument on-site on 15 October 2013 and observed the cover foil of the Geiger Müller counter to be very ripply. The cause could not be identified. It was decided to replace the Geiger Müller counter tube. Past measured value were not discarded, however, values obtained on 15 October 2013 could not be used.

No further errors in functioning were observed:

Maintenance times (without zero filter operation), e.g. for maintaining the sampling heads or for checking the flow rate / tightness, typically result in outages of one measuring cycle (i.e. 1 h per day). This is why affected daily averages were not discarded.

6.5 Assessment

The availability for SN 1512361 was 100%, for SN 1512401 it was 99.7%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 17: Determination of the availability

		System 1 (SN 1512361)	System 2 (SN 1512401)
Operation time (t_{field})	d	288	288
Outage time	d	0	1
Maintenance time incl. zero filter ($t_{cal,maint}$)	d	23	22
Actual operating time (t_{valid})	d	265	265
Availability	%	100	99.7

6.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8)

The January 2010 Guide [4] 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 [7], i.e. 28 µg/m³ for PM_{10} and 17 µg/m³ for $PM_{2.5}$. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.
2. Between-AMS uncertainty shall remain below 2.5 µg/m³ for the overall data and for data sets with data larger than/equal to 30 µg/m³ PM_{10} and 18 µg/m³ $PM_{2.5}$.
3. The uncertainty between reference systems shall not exceed 2.0 µg/m³.
4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and at 30 µg/m³ for $PM_{2.5}$ for every individual test specimen and checked against the average of the reference method. For each of the following cases, the expanded uncertainty shall not exceed 25%:
   - Full data set:
   - datasets representing PM concentrations greater than/equal to 30 µg/m³ for PM_{10}, or concentrations greater than/equal to 18 µg/m³ for $PM_{2.5}$, provided that the set contains 40 or more valid data pairs
   - Datasets for each individual site
5. Preconditions for acceptance of the full dataset are that the slope b is insignificantly different from 1 $|b-1| \leq 2 \cdot u(b)$ and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept.

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 four separate comparison campaigns. Different seasons as well as different concentrations of $PM_{2.5}$ 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 [7]. The assessment threshold for $PM_{2.5}$ is 17 µg/m³.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full dataset, (4 locations, 213 valid pairs of measured values for SN 1512361, 213 valid pairs for SN 1512401) a total of 27.2% of the measured values exceed the upper assessment threshold of 17 µg/m³ for $PM_{2,5}$. The concentrations measured were related to the ambient conditions.

6.4 Evaluation

Chapter 7.5.8.4 of standard EN 16450 specifies that:

The between-AMS uncertainty u_{bs} shall be ≤ 2.5 µg/m³. A between-AMS uncertainty > 2.5 µg/m³ is an indication of unsuitable performance of one or both instruments, and equivalence should not be stated.

Uncertainty is determined for:

- All locations or comparisons together (full data set)
- 1 data set with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)

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)

The between-AMS uncertainty u_{bs} is calculated from the differences of all daily averages (24h-values) of the AMS which are operated simultaneously as:

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

Where: $y_{i,1}$ and $y_{i,2}$ = Results of the parallel measurements of individual 24h-values i

n = Number of 24h-values

6.5 Assessment

At no more than 0.84 µg/m³ for $PM_{2.5}$, the between-AMS uncertainty u_{bs} remains well below the permissible maximum of 2.5 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 18 lists the calculated values for the between-AMS uncertainties u_{bs}. A corresponding chart is provided in Figure 22 to Figure 28.

Table 18: In-between-instrument uncertainty u_{bs} for the instruments SN 1512361 and S/N 1512401, measured component $PM_{2,5}$

Tested instruments	Location	Number of measurements	Uncertainty u_{bs}
SN			µg/m³
SN 1512361 / SN 1512401	**All locations**	**265**	**0.61**
Individual locations			
SN 1512361 / SN 1512401	Bonn, winter	61	0.62
SN 1512361 / SN 1512401	Bornheim, Summer	67	0.45
SN 1512361 / SN 1512401	Cologne, autumn	85	0.81
SN 1512361 / SN 1512401	Cologne, Winter	52	0.33
Classing over reference values			
SN 1512361 / SN 1512401	**Values ≥ 18 µg/m³**	**53**	**0.84**
SN 1512361 / SN 1512401	Values < 18 µg/m³	160	0.50

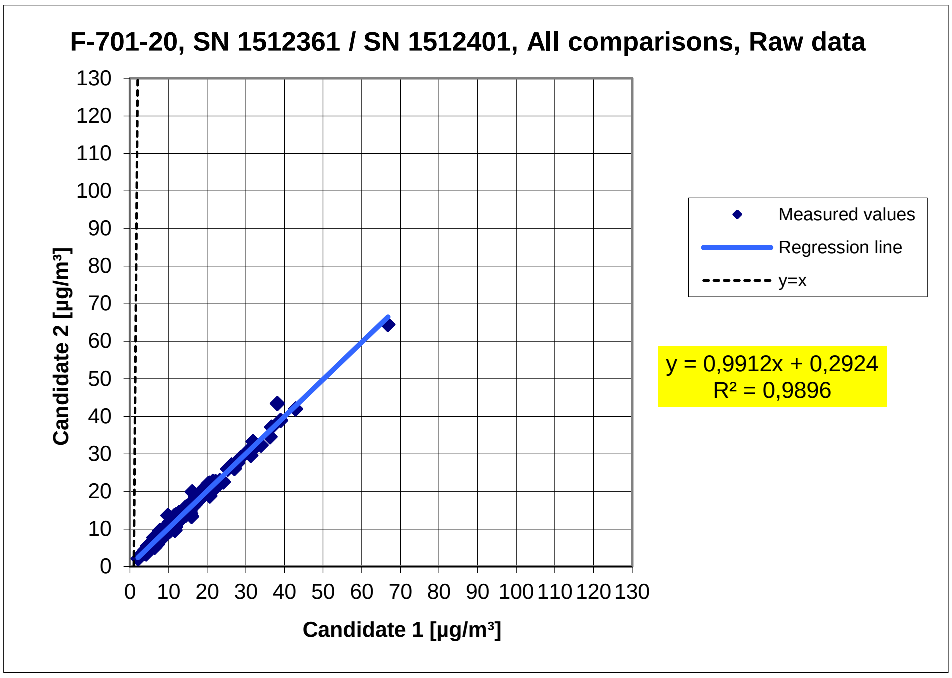


Figure 22: Results of the parallel measurements for instruments SN 1512361 / SN 1512401, Measured component $PM_{2.5}$, all locations

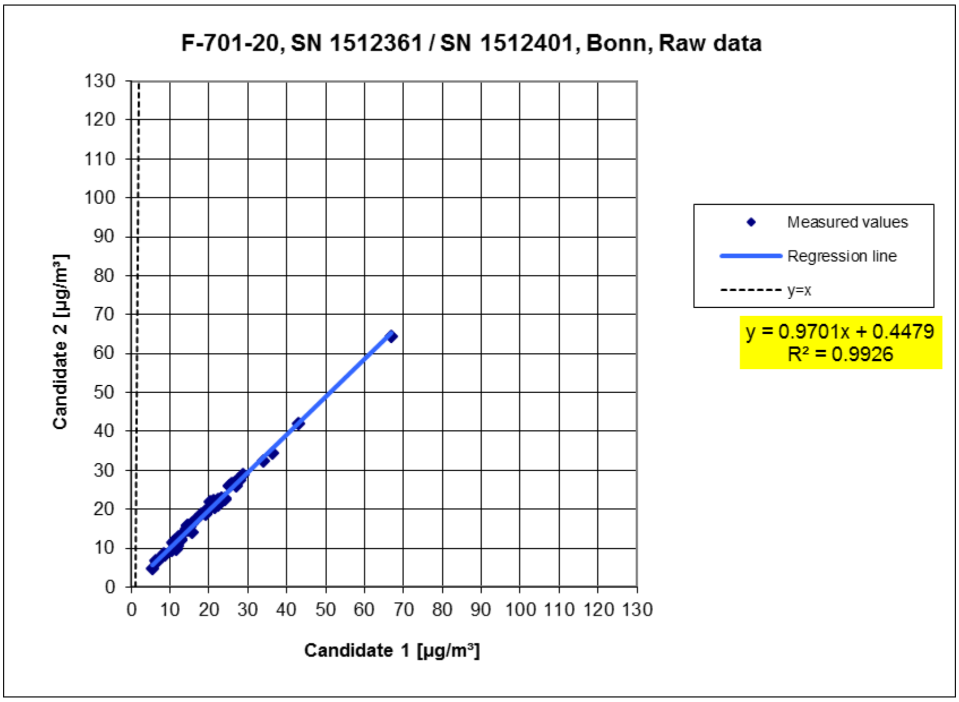


Figure 23: Results of the parallel measurements for instruments SN 1512361 / SN 1512401, Measured component $PM_{2.5}$, Bonn, winter

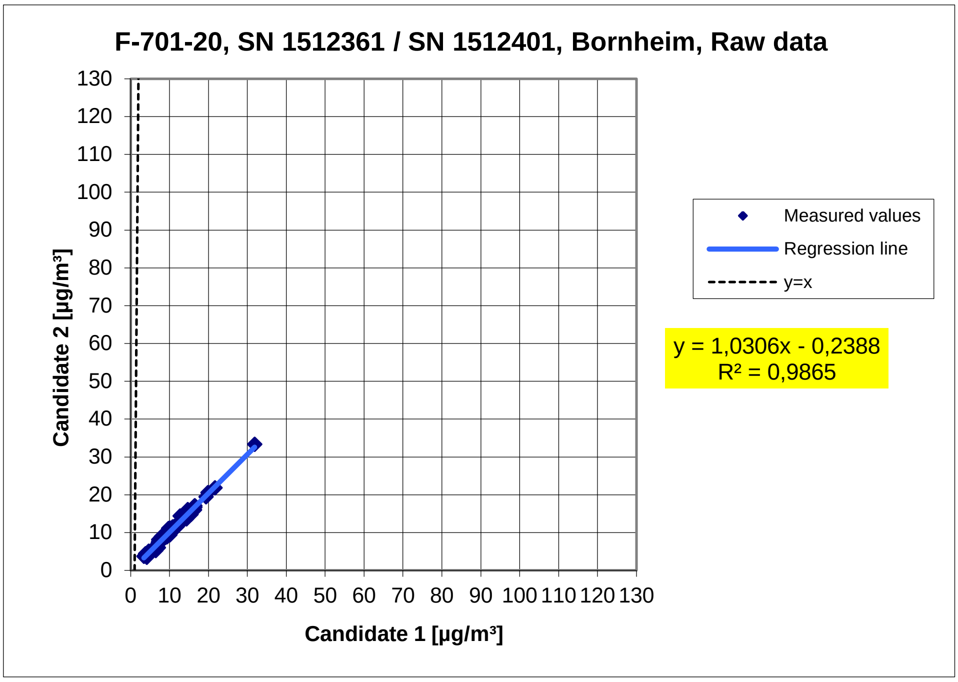


Figure 24: Results of the parallel measurements for instruments SN 1512361 / SN 1512401, Measured component $PM_{2.5}$, location: Bornheim, Summer

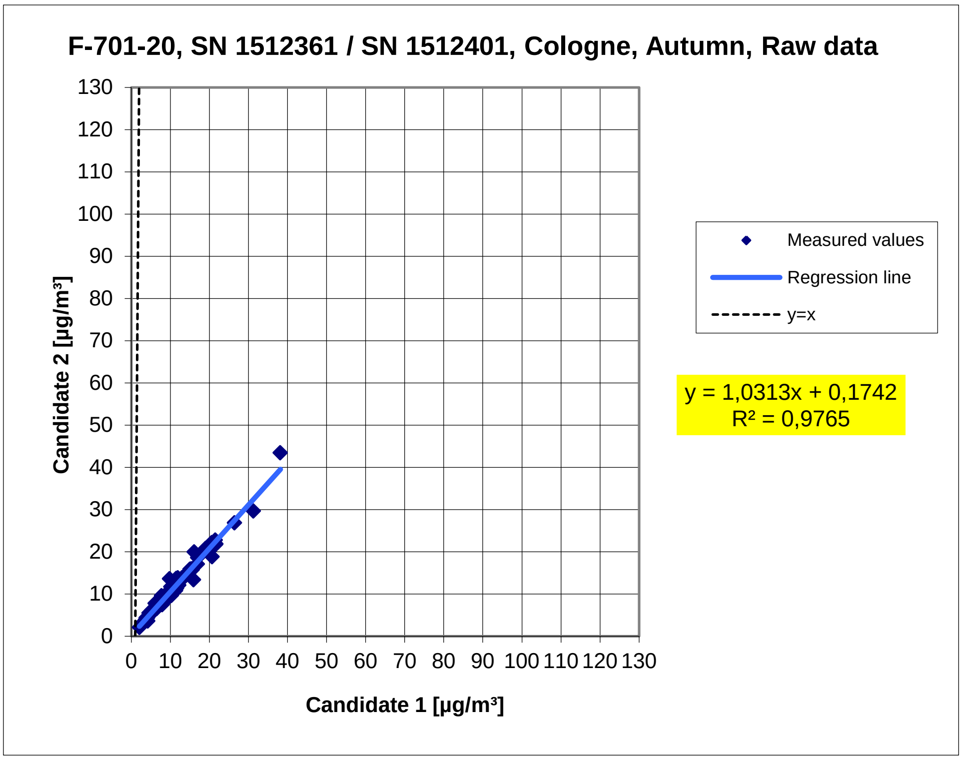


Figure 25: Results of the parallel measurements for instruments SN 1512361 / SN 1512401, Measured component $PM_{2.5}$, Cologne, winter

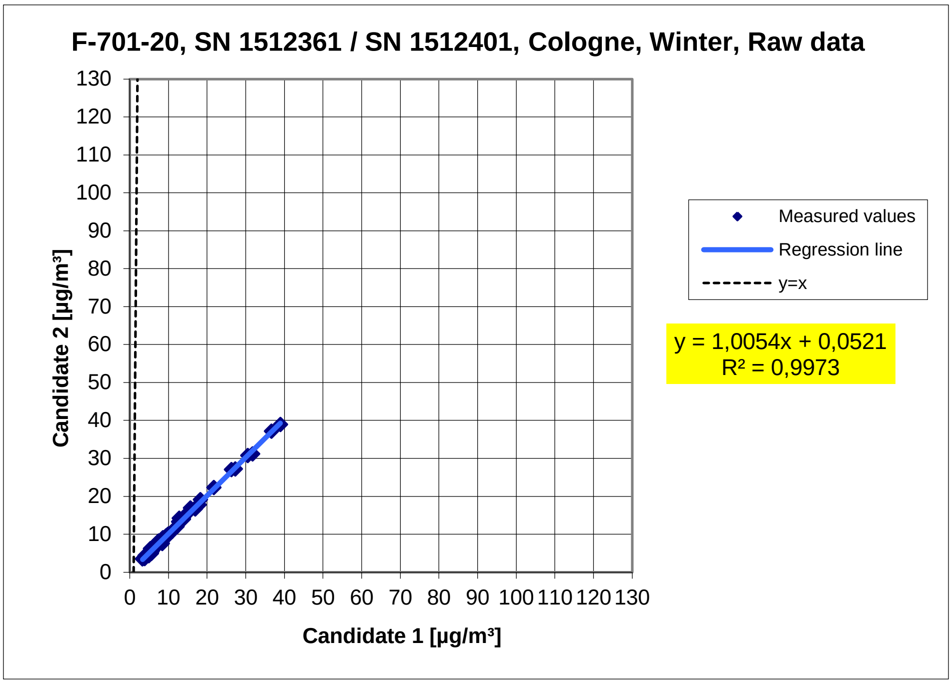


Figure 26: Results of the parallel measurements for instruments SN 1512361 / SN 1512401, Measured component $PM_{2.5}$, location: Cologne, Winter

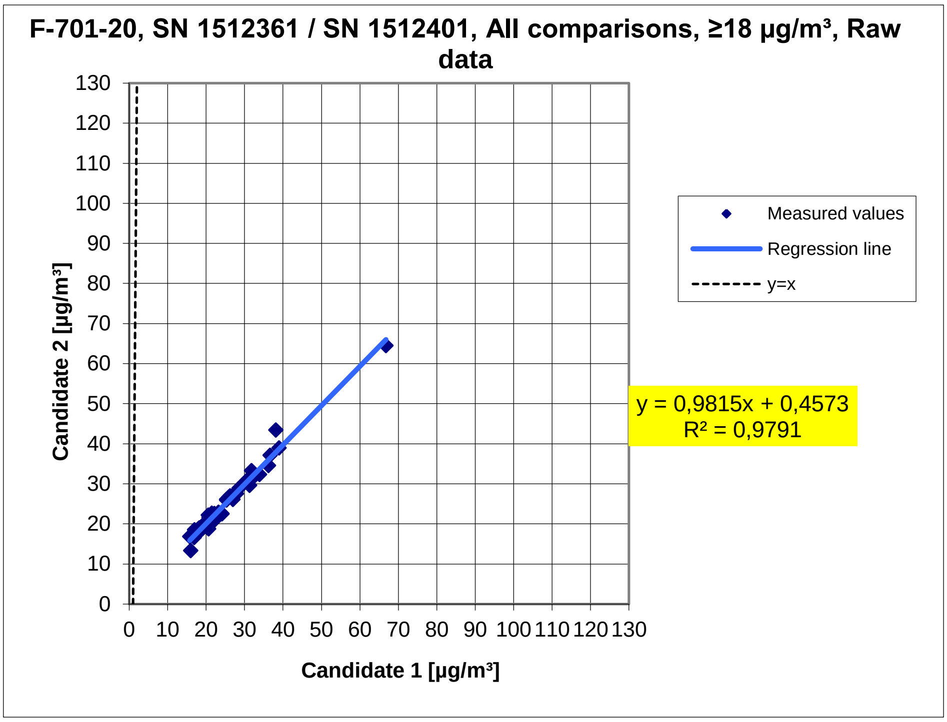


Figure 27: Results of the parallel measurements for instruments SN 1512361 / SN 1512401, Measured component $PM_{2.5}$, all locations, values ≥ 18 µg/m³

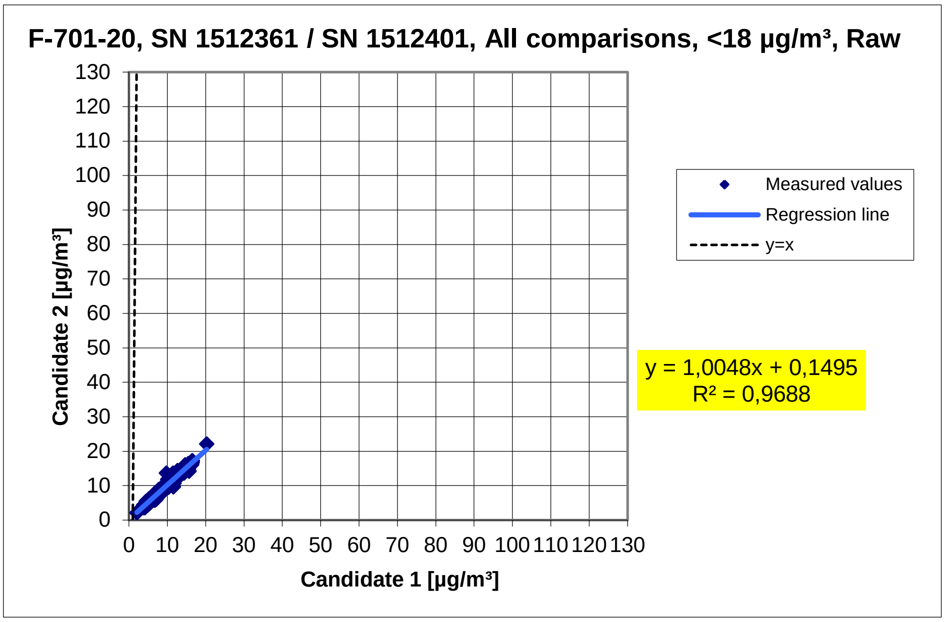


Figure 28: Results of the parallel measurements for instruments SN 1512361 / SN 1512401, Measured component $PM_{2.5}$, all locations, values < 18 µg/m³

6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

The expanded uncertainty shall be ≤ 25% at the level of the relevant limit value related to the 24-hour average results – after a calibration where necessary.

6.2 Equipment

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 four separate comparison campaigns. Different seasons as well as different concentrations of $PM_{2.5}$ 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 [7]. The assessment threshold for $PM_{2.5}$ is 17 µg/m³.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full dataset, (4 locations, 213 valid pairs of measured values for SN 1512361, 213 valid pairs for SN 1512401) a total of 27.2% of the measured values exceed the upper assessment threshold of 17 µg/m³ for $PM_{2,5}$. The concentrations measured were related to the ambient conditions.

6.4 Evaluation

[EN 16450, 7.5.8.3]

Before calculating the expanded uncertainty of the test specimens, uncertainties were established between the simultaneously operated reference measuring systems (u_{ref})

Uncertainties between the simultaneously operated reference measuring systems $u_{bs,RM}$ were established similar to the between-AMS uncertainties and shall be ≤ 2.0 µg/m³.

Results of the evaluation are summarised in section 6.6.

[EN 16450, 7.5.8.5 & 7.5.8.6]

In order to assess comparability of the tested instruments y with the reference method x, a linear relationship $y_i = a + bx_i$ between the measured values of both methods is assumed. The association between the means of the reference systems and each individual test specimen to be assessed is established by means of orthogonal regression.

The regression is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- 1 data set with measured values $PM_{2.5}$ ≥ 18 µg/m³ (basis: averages of reference measurement)

For further assessment, the uncertainty u_{c_s} resulting from a comparison of the test specimens with the reference method is described in the following equation which defines u_{CR} as a function of the fine dust concentration x_i.

$$u_{yi}^2 = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [a + (b-1)L]^2$$

Where RSS is the sum of the (relative) residuals from orthogonal regression

u_{RM} = random uncertainty of reference method results; u_{RM} is calculated from $u_{bs,RM}/\sqrt{2}$, where $u_{bs,RM}$ is the between-RM uncertainty.

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 [8].

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)

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 $PM_{2.5}$.

[EN 16450 7.5.8.8] For each data set the expanded relative uncertainty of the results measured with the test specimen is calculated by multiplying w_{AMS} by an coverage factor k according to the following equation:

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

In practice, k is specified at k=2 for large n.

[Item 9.6]

The largest resulting uncertainty W_{AMS} is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive [7]. Two situations are conceivable:

1. $W_{AMS} \leq W_{dqo}$ → The test is deemed equivalent to the reference method.
2. $W_{AMS} > W_{dqo}$ → The tested instrument is not deemed equivalent to the reference method.

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

7.5 Assessment

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 fine particulate matter.

Criterion satisfied? yes

Given the significance of the slope and the axis intercept for the total set of data, a correction factor is applied according to Chapter 6.1 17 Use of correction factors/terms .

The following Table 19 shows an overview on all results of the equivalence test for the F-701-20 for $PM_{2,5}$. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 19: Overview of F-701-20 equivalence testing for $PM_{2,5}$

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	F-701-20		SN	SN 1512361 / SN 1512401	
			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	**0.61**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**213**				
Slope b	**0.917**	**significant**			
Uncertainty of b	**0.009**				
Ordinate intercept a	**0.587**	**significant**			
Uncertainty of a	**0.153**				
Expanded meas. uncertainty W_{CM}	**14.89**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.70**	**µg/m³**			
Uncertainty between Candidates	**0.84**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**53**				
Slope b	**0.922**				
Uncertainty of b	**0.025**				
Ordinate intercept a	**0.368**				
Uncertainty of a	**0.700**				
Expanded meas. uncertainty W_{CM}	**16.66**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.50**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**160**				
Slope b	**0.936**				
Uncertainty of b	**0.022**				
Ordinate intercept a	**0.431**				
Uncertainty of a	**0.224**				
Expanded meas. uncertainty W_{CM}	**12.08**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	F-701-20		SN	SN 1512361 / SN 1512401	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Bonn					
Uncertainty between Reference	0.62	µg/m³			
Uncertainty between Candidates	0.62	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	51			51	
Slope b	0.925			0.903	
Uncertainty of b	0.018			0.020	
Ordinate intercept a	0.882			1.105	
Uncertainty of a	0.400			0.457	
Expanded meas. uncertainty W_{CM}	12.32	%		15.39	%
Bornheim					
Uncertainty between Reference	0.52	µg/m³			
Uncertainty between Candidates	0.45	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	54			54	
Slope b	1.020			1.045	
Uncertainty of b	0.031			0.030	
Ordinate intercept a	-0.429			-0.611	
Uncertainty of a	0.377			0.365	
Expanded meas. uncertainty W_{CM}	7.13	%		8.44	%
Cologne, Autumn					
Uncertainty between Reference	0.65	µg/m³			
Uncertainty between Candidates	0.81	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	62			62	
Slope b	0.922			0.962	
Uncertainty of b	0.021			0.029	
Ordinate intercept a	0.284			0.315	
Uncertainty of a	0.270			0.386	
Expanded meas. uncertainty W_{CM}	15.37	%		11.93	%
Cologne, Winter					
Uncertainty between Reference	0.49	µg/m³			
Uncertainty between Candidates	0.33	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	46			46	
Slope b	0.852			0.856	
Uncertainty of b	0.010			0.009	
Ordinate intercept a	0.775			0.875	
Uncertainty of a	0.165			0.155	
Expanded meas. uncertainty W_{CM}	24.76	%		23.23	%
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	0.70	µg/m³			
Uncertainty between Candidates	0.84	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	53			53	
Slope b	0.929			0.920	
Uncertainty of b	0.023			0.030	
Ordinate intercept a	0.195			0.422	
Uncertainty of a	0.629			0.85	
Expanded meas. uncertainty W_{CM}	15.83	%		18.29	%
All comparisons, <18 µg/m³					
Uncertainty between Reference	0.53	µg/m³			
Uncertainty between Candidates	0.50	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	160			160	
Slope b	0.930			0.950	
Uncertainty of b	0.022			0.023	
Ordinate intercept a	0.396			0.395	
Uncertainty of a	0.233			0.236	
Expanded meas. uncertainty W_{CM}	13.54	%		10.41	%
All comparisons					
Uncertainty between Reference	0.58	µg/m³			
Uncertainty between Candidates	0.61	µg/m³			
	SN 1512361			SN 1512401	
Number of data pairs	213			213	
Slope b	0.921	significant		0.915	significant
Uncertainty of b	0.009			0.010	
Ordinate intercept a	0.457	significant		0.689	significant
Uncertainty of a	0.151			0.172	
Expanded meas. uncertainty W_{CM}	14.85	%		15.26	%

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: All expanded uncertainties remained below 25%.

Criterion 5: Both the slope and the axis intercept obtained from evaluating the full data set for instruments SN 1512361 and SN 1512401 significantly exceed the permissible limits.

The evaluation of the full data set for both test specimen shows that the measuring system provides good correlation with the reference method: the slope is 0.917 and the intercept is 0.587 at an expanded total uncertainty of 14.9%.

The January 2010 version of the Guideline does not specify clearly which axis intercept and which slope to use for correcting test specimens if a test specimen does not meet the requirements for equivalence testing. After double-checking with the chair of the EU working group responsible for issuing the Guideline (Mr Theo Hafkenscheid), we decided to apply the requirements of the November 2005 version of the Guideline and to use the slope and the intercept determined by means of orthogonal regression for the full data set. These are listed for each criterion under “Additional”

As a result of the significance determined, the axis intercept and the slope have to be corrected for $PM_{2,5}$ for both tested instruments according to Table 19.

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 $PM_{2.5}$.

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 recommends that the expanded uncertainty of the entire data set (in the present case, the uncorrected raw data) be used for this purpose: 14.9% for $PM_{2.5}$, implying annual checks at three measurement sites (Guideline [4], Chapter 9.9.2, Table 6 or EN 16450 [8], 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 20 provides an overview of the between-RM uncertainties $u_{bs,RM}$ determined during the field tests.

Table 20: 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	Bonn, winter	51	0.62
1 / 2	Bornheim, Summer	54	0.52
1 / 2	Cologne, autumn	62	0.65
1 / 2	Cologne, Winter	46	0.49
1 / 2	All locations	213	0.58

At all sites, between-RM uncertainty $u_{bs,RM}$ was < 2.0 µg/m³.

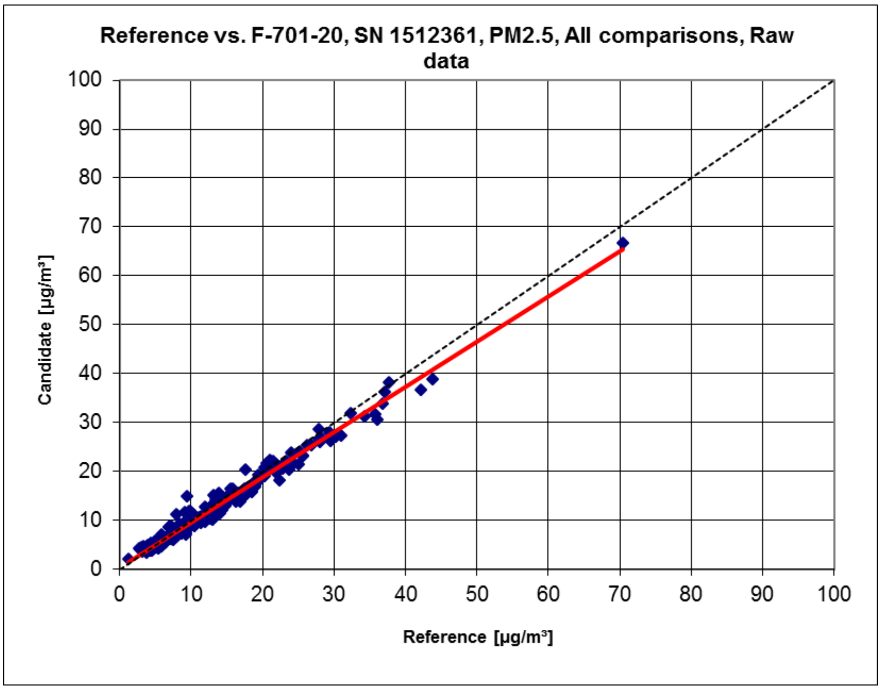


Figure 29: Reference vs. tested instrument, SN 1512361, component $PM_{2.5}$, all sites

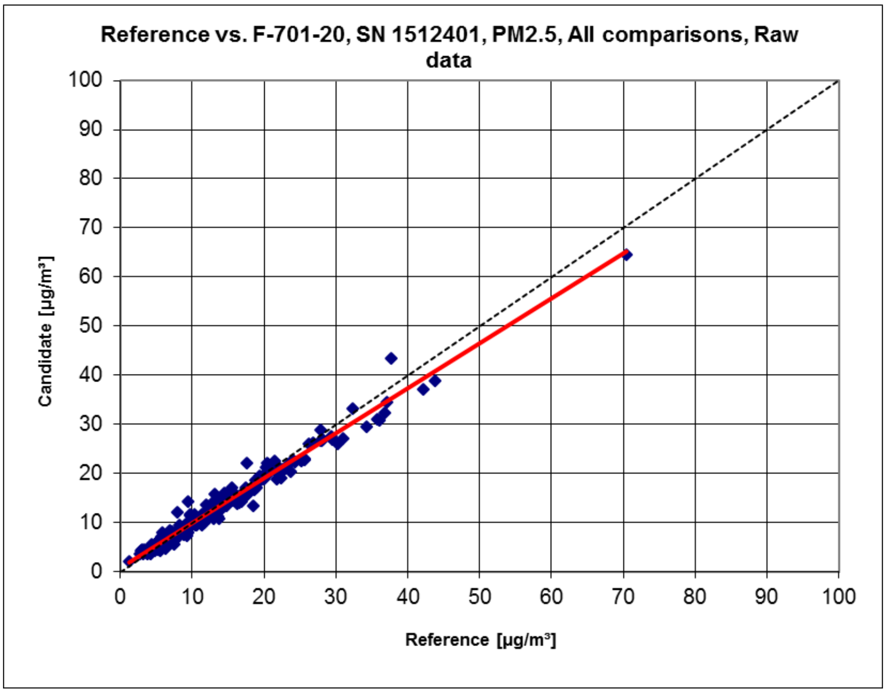


Figure 30: Reference vs. tested instrument, SN 1512401, component $PM_{2.5}$, all sites

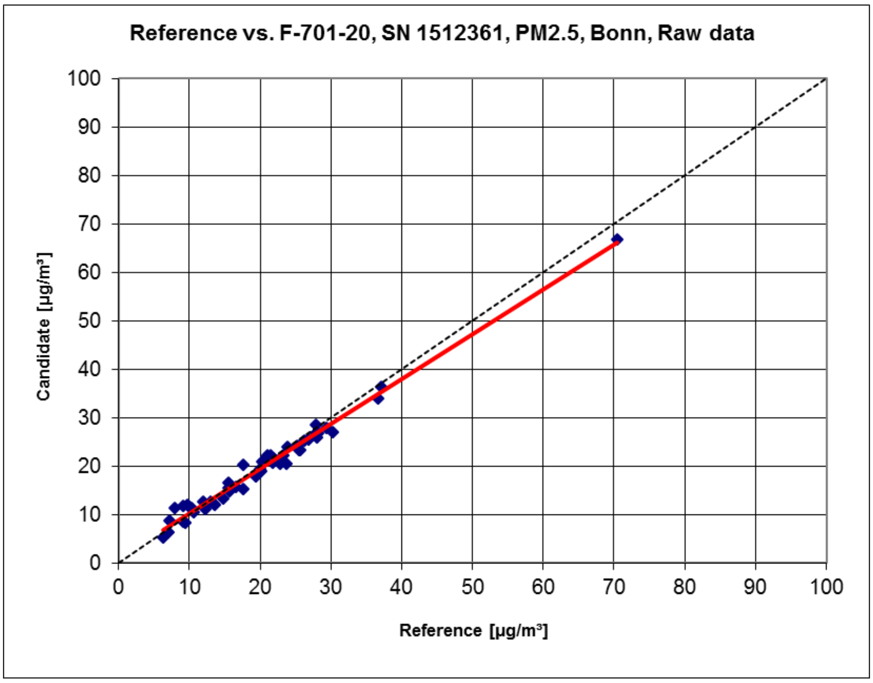


Figure 31: Reference vs. tested instrument, SN 1512361, component $PM_{2.5}$, Bonn, winter,

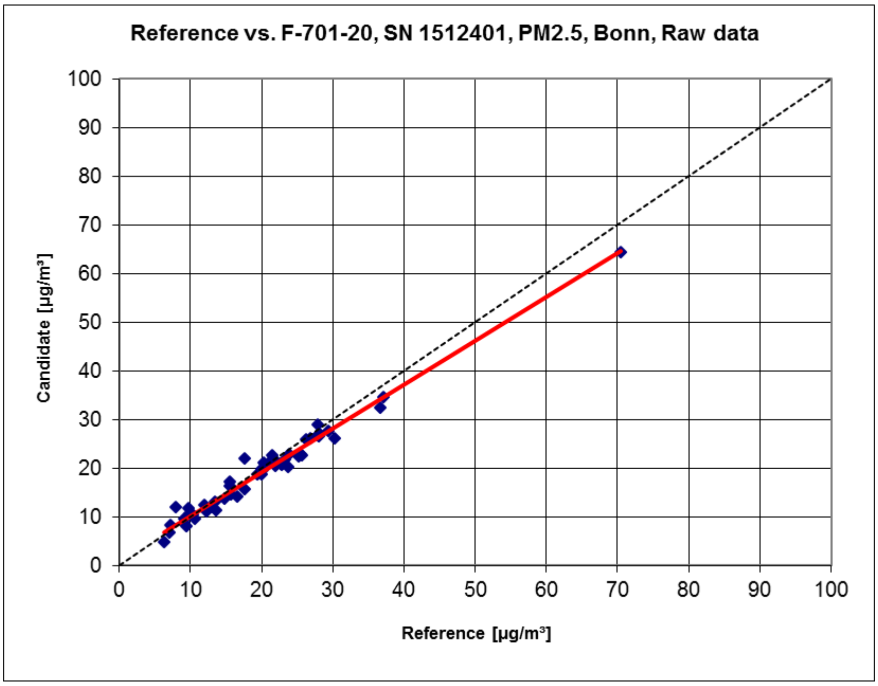


Figure 32: Reference vs. tested instrument, SN 1512401, component $PM_{2.5}$, Bonn, winter,

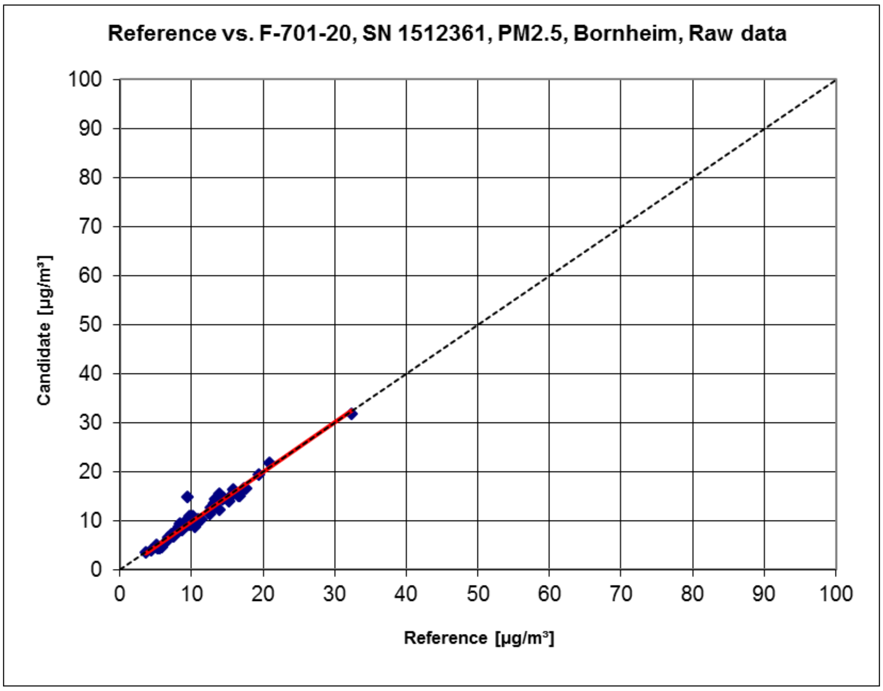


Figure 33: Reference vs. tested instrument, SN 1512361, component $PM_{2.5}$, Bornheim, summer,

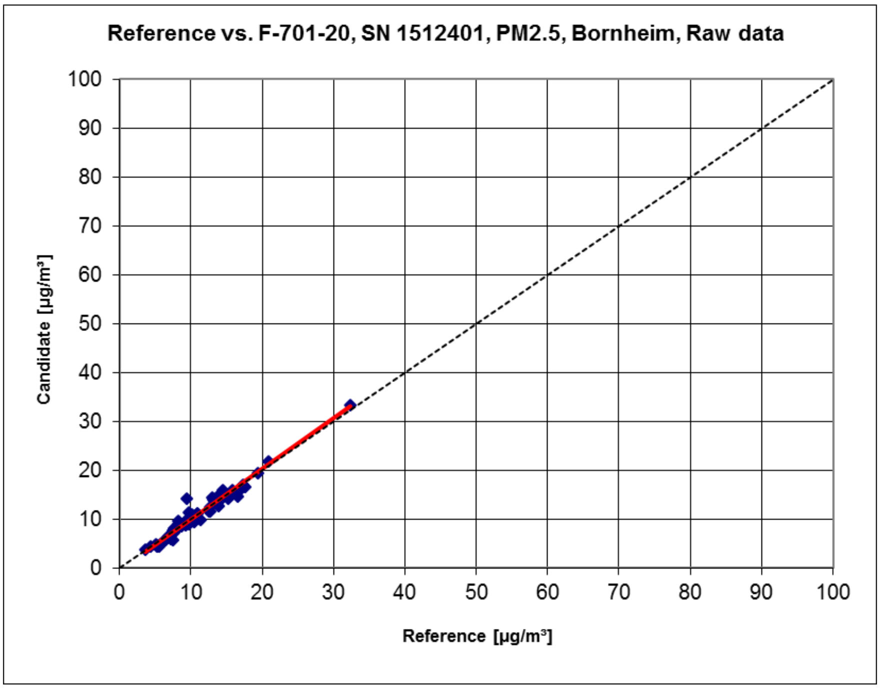


Figure 34: Reference vs. tested instrument, SN 1512401, component $PM_{2.5}$, Bornheim, summer,

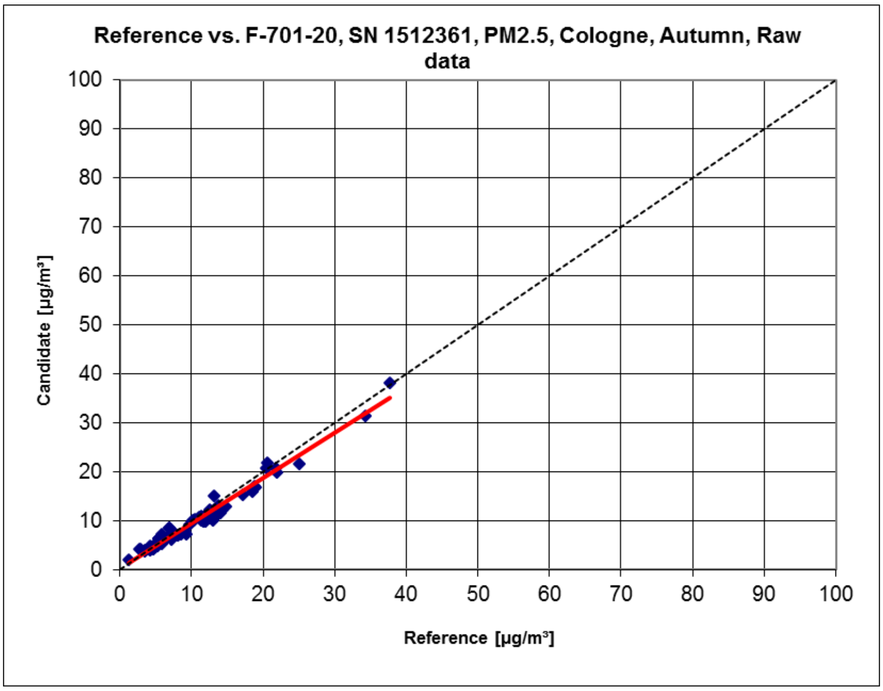


Figure 35: Reference vs. tested instrument, SN 1512361, component $PM_{2.5}$, Cologne, autumn

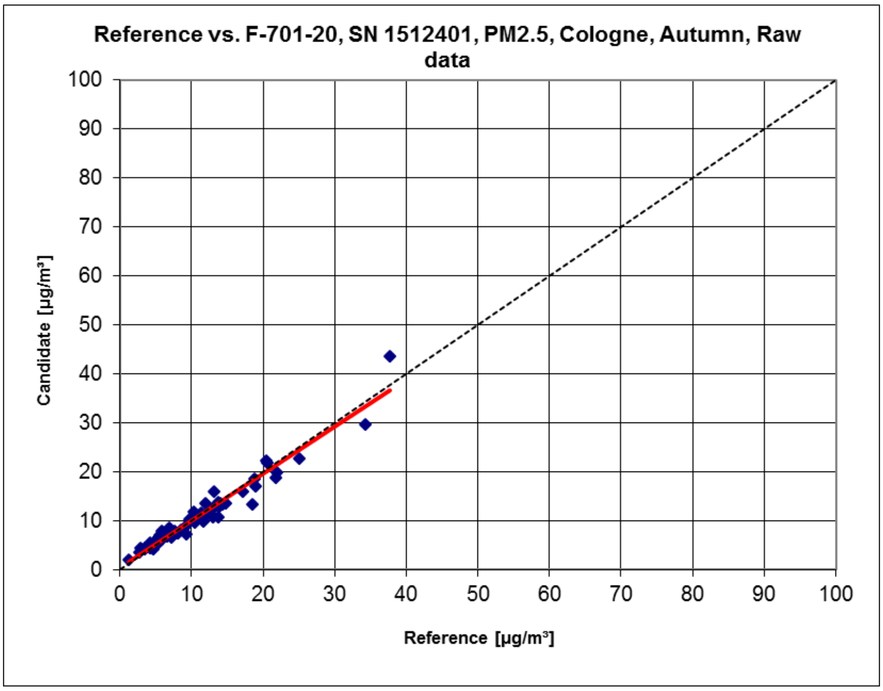


Figure 36: Reference vs. tested instrument, SN 1512401, component $PM_{2.5}$, Cologne, autumn

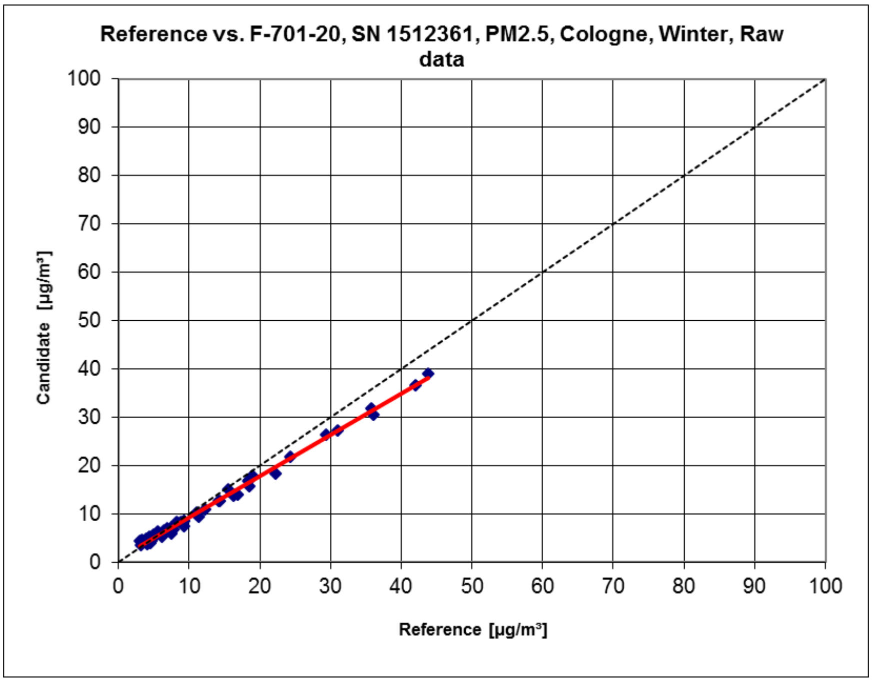


Figure 37: Reference vs. tested instrument, SN 1512361, component $PM_{2.5}$, Cologne, winter

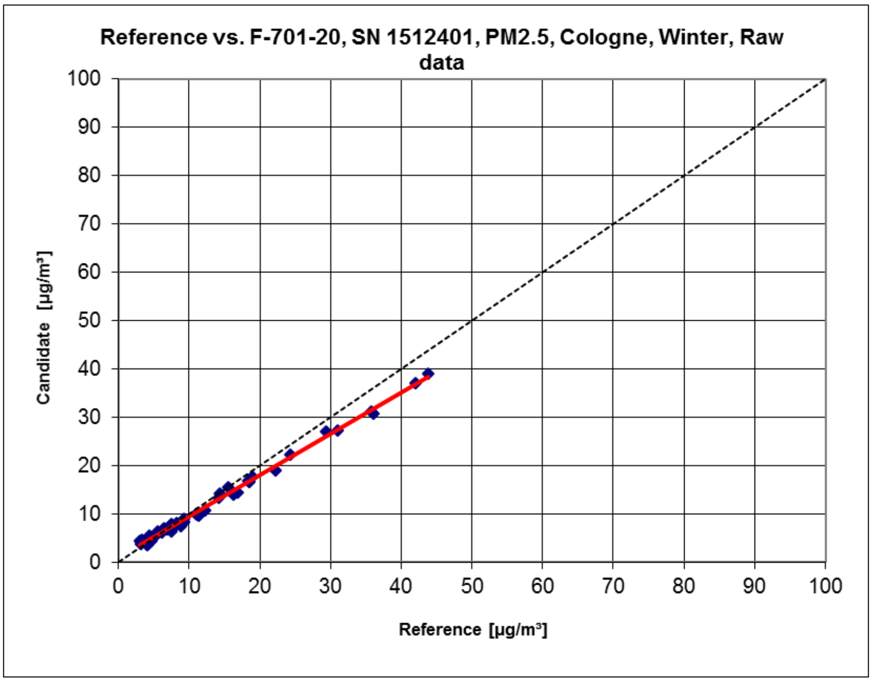


Figure 38: Reference vs. tested instrument, SN 1512401, component $PM_{2.5}$, Cologne, winter

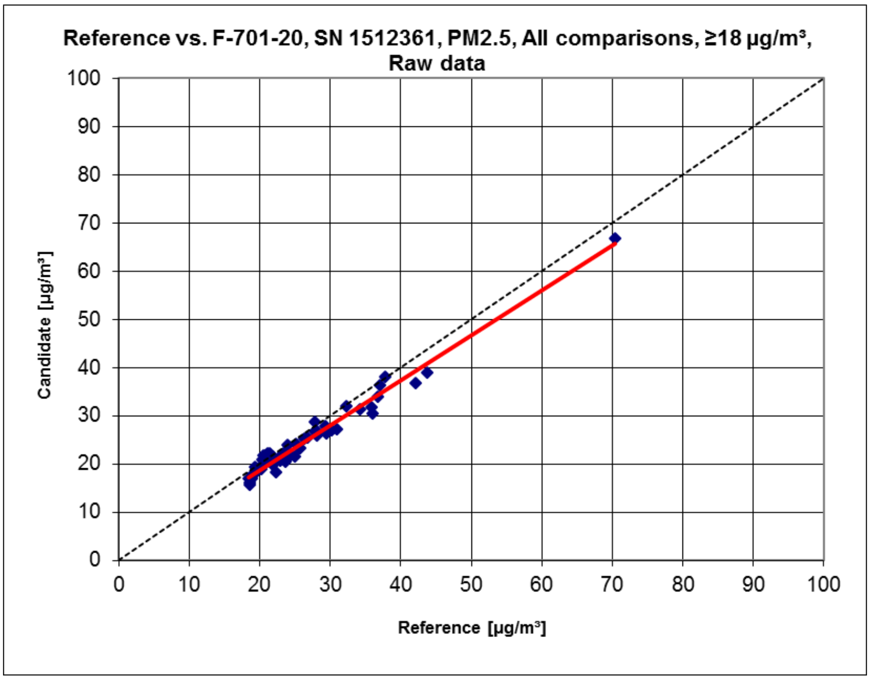


Figure 39: Reference vs. tested instrument, SN 1512361, component $PM_{2.5}$, values ≥ 18 µg/m³

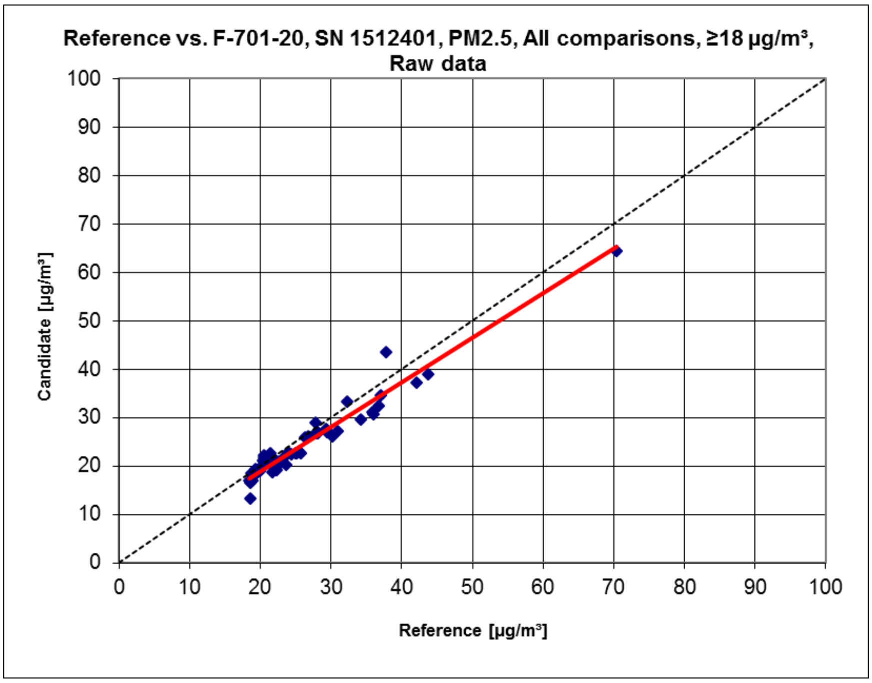


Figure 40: Reference vs. tested instrument, SN 1512401, component $PM_{2.5}$, values ≥ 18 µg/m³

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 <u>the full data set</u>. The corrected values have to meet the requirements for all data sets or sub data sets. Moreover, a correction may also be used for the case that $W_{AMS} \leq W_{dqo}$ in order to improve the accuracy of the tested instruments.

Three different situations may occur:

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

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

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

concerning a)

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

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

The corrected values $y_{i,corr}$ may then serve to calculate the following new terms using linear regression:

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

and

$$u^2_{yi,corr} = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [c + (d-1)L]^2 + u^2(a)$$

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 [8].

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

$$u^2_{yi,corr} = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [c + (d-1)L]^2 + L^2u^2(b)$$

where u(b) = uncertainty of the original slope b, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [8].

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

$$u_{yi,corr}^2 = \frac{RSS}{(n-2)} - u_{RM}{}^2 + [c + (d-1)L]^2 + L^2u^2(b) + u^2(a)$$

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 [8].

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 [7]. 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% [7].

6.5 Assessment

During the test, the test samples met the requirements for data quality of air quality measurements without applying a correction factor. The correction of the slope and intercept results in a significant improvement of the expanded uncertainty of the complete dataset.

Criterion satisfied? yes

The evaluation of the full data set for both test specimen results in a significant slope and intercept for the component $PM_{2,5}$.

The slope for the entire data set is 0.917. The intercept for the full data set is 0.587 (see Table 19)

For the component $PM_{2,5}$, 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. Only for the site in Bornheim was a significant deterioration observed. The expanded uncertainty, however, remains below the permissible maximum of 25%.

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 [8], 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 of 20–25%.

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: 14.9% ($PM_{2.5}$ uncorrected data set) and 8.9% ($PM_{2.5}$ data set after correcting slope/intercept). This would in turn require annual tests at 3 (uncorrected) or 2 (corrected) sites.

6.6 Detailed presentation of test results

Table 21 shows the evaluation results of the equivalence test after applying the correction factor to the full data set.

Table 21: Overview of results of the equivalence test, SN 1512361 S/N 1512401, component $PM_{2,5}$ after correcting the slope and intercept

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	F-701-20		SN	SN 1512361 / SN 1512401	
			Limit value	30	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**213**				
Slope b	**1.001**	**not significant**			
Uncertainty of b	**0.010**				
Ordinate intercept a	**-0.013**	**not significant**			
Uncertainty of a	**0.167**				
Expanded meas. uncertainty W_{CM}	**8.89**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.70**	**µg/m³**			
Uncertainty between Candidates	**0.92**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**53**				
Slope b	**1.007**				
Uncertainty of b	**0.027**				
Ordinate intercept a	**-0.283**				
Uncertainty of a	**0.763**				
Expanded meas. uncertainty W_{CM}	**11.59**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.54**	**µg/m³**			
	SN 1512361 / SN 1512401				
Number of data pairs	**160**				
Slope b	**1.025**				
Uncertainty of b	**0.024**				
Ordinate intercept a	**-0.209**				
Uncertainty of a	**0.244**				
Expanded meas. uncertainty W_{CM}	**8.73**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	F-701-20		SN	SN 1512361 / SN 1512401	
			Limit value	30	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
Bonn					
Uncertainty between Reference	**0.62**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**51**			**51**	
Slope b	**1.010**			**0.986**	
Uncertainty of b	**0.019**			**0.022**	
Ordinate intercept a	**0.306**			**0.544**	
Uncertainty of a	**0.436**			**0.499**	
Expanded meas. uncertainty W_{CM}	**10.22**	**%**		**10.86**	**%**
Bornheim					
Uncertainty between Reference	**0.52**	**µg/m³**			
Uncertainty between Candidates	**0.49**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**54**			**54**	
Slope b	**1.114**			**1.142**	
Uncertainty of b	**0.033**			**0.032**	
Ordinate intercept a	**-1.134**			**-1.330**	
Uncertainty of a	**0.411**			**0.398**	
Expanded meas. uncertainty W_{CM}	**17.24**	**%**		**21.02**	**%**
Cologne, Autumn					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.89**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**62**			**62**	
Slope b	**1.007**			**1.051**	
Uncertainty of b	**0.022**			**0.032**	
Ordinate intercept a	**-0.345**			**-0.327**	
Uncertainty of a	**0.295**			**0.421**	
Expanded meas. uncertainty W_{CM}	**8.13**	**%**		**14.30**	**%**
Cologne, Winter					
Uncertainty between Reference	**0.49**	**µg/m³**			
Uncertainty between Candidates	**0.36**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**46**			**46**	
Slope b	**0.929**			**0.934**	
Uncertainty of b	**0.011**			**0.010**	
Ordinate intercept a	**0.201**			**0.311**	
Uncertainty of a	**0.180**			**0.169**	
Expanded meas. uncertainty W_{CM}	**13.75**	**%**		**12.12**	**%**
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.70**	**µg/m³**			
Uncertainty between Candidates	**0.92**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**53**			**53**	
Slope b	**1.014**			**1.006**	
Uncertainty of b	**0.025**			**0.033**	
Ordinate intercept a	**-0.464**			**-0.246**	
Uncertainty of a	**0.686**			**0.92**	
Expanded meas. uncertainty W_{CM}	**10.35**	**%**		**14.18**	**%**
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.54**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**160**			**160**	
Slope b	**1.018**			**1.040**	
Uncertainty of b	**0.025**			**0.025**	
Ordinate intercept a	**-0.250**			**-0.251**	
Uncertainty of a	**0.254**			**0.257**	
Expanded meas. uncertainty W_{CM}	**8.53**	**%**		**10.55**	**%**
All comparisons					
Uncertainty between Reference	**0.58**	**µg/m³**			
Uncertainty between Candidates	**0.67**	**µg/m³**			
	SN 1512361			**SN 1512401**	
Number of data pairs	**213**			**213**	
Slope b	**1.005**	**not significant**		**0.999**	**not significant**
Uncertainty of b	**0.010**			**0.011**	
Ordinate intercept a	**-0.155**	**not significant**		**0.095**	**not significant**
Uncertainty of a	**0.165**			**0.187**	
Expanded meas. uncertainty W_{CM}	**8.77**	**%**		**10.01**	**%**

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.

Moreover, the results of the zero drift tests in accordance with 6.1 12 Zero checks (7.5.3) were taken into account when determining the maintenance interval .

6.4 Evaluation

Over the entire period of the field test, no unacceptable drift was observed.

The maintenance interval is thus determined by the necessary maintenance works.

1. Checking the operational status
   The instrument status can be verified by checking the AMS; alternatively it can be monitored online via the RS232 interface and Gesytec protocol.
2. The sampling inlet must in principle be cleaned in accordance with the manufacturer's instructions, taking into account the local suspended particulate concentrations (every 4 weeks in the performance test).
3. Check of filter tape stock –
   With the cycle time set to 1 h and the filter spot being 24 times (setting during performance testing), a 45m long filter tape will last, in theory, for 30,000 measurement cycles which corresponds to 1,250 days. In practice and given actual particle concentration levels, however, it is possible that a filter spot reaches the maximum permissible load of 400 µg earlier than after 24 times of sampling, a clean filter spot may be required at that earlier point. The time in which the filter tape is consumed is reduced accordingly.
   With a cycle time of 1 h and a filter spot being sampled a single time (i.e. a new filter spot is used for each cycle), there are 1,250 measurement cycles which corresponds to 52 days. It is therefore recommended to check the stock of the filter tape each time the measuring system is visited for regular maintenance (e.g. during cleaning of the sampling head).
4. According to the manufacturer, the pump must be serviced approx. every 6 weeks after one year of operation. This implies the filters must be blown out, the fin height checked and the fins changed if necessary.
5. According to DIN EN 16450 [8], the sensors for ambient temperature and pressure should be checked every 3 months.
6. EN 16450 [8] requires a check of the flow rate every three months.
7. The leak tightness should also be checked every 3 months as part of the flow rate check.
8. Clean the filter adapter, the conveyer and the pressure roller every 6 months.
9. Check and, if necessary, blow out exhaust air filters and hose connectors every 6 months.
10. Replace the pump filter and the seal once a year.

11. Return the meteorological sensor to manufacturer for re-calibration once a year. It is also recommended to check the radiometric measurement with the help of a span foil once a year.
12. During annual basic maintenance, care must also be taken to clean the sampling tube.

The instructions in the manual (chapter 6) must be observed when carrying out maintenance work. All work can generally be carried out with standard tools. During operation times, maintenance may be limited to contamination and plausibility checks and potential status/error messages.

6.5 Assessment

The period of unattended operation is determined by the necessary maintenance works. It is 4 weeks.

Criterion satisfied? yes

6.6 Detailed presentation of test results

The necessary maintenance works are listed in chapter 6 of the operation manual.

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.

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.

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.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Available status signals are listed in chapter 5 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

To determine ambient air temperature, pressure and relative humidity, the F-701-20 measuring system uses meteorological sensors.

The manufacturer of the meteorological sensors indicates the sensors' accuracy as follows: ±0.1°K (ambient temperature), ±0.8% (relative humidity) < 0.5 kPa (air pressure).

Relying on transfer standards, it is easily possible to perform comparison measurements on-site at any time and to adjust the sensors in the event of any deviation with the help of offset factors (temperature, pressure) or slope factors (rel. humidity).

6.5 Assessment

It is easy to check and adjust the sensors for determining ambient temperature, ambient pressure and relative humidity on-site.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

7. Recommendations for use in practice

7.1 Tasks to be performed in the maintenance interval (4 weeks)

The tested measuring systems require regular performance of the following tasks:

- Regular visual inspections/telemetric inspections
- Instrument status ok
- No error messages
- No contaminations
- Check of the instrument functions according to the instructions of the manufacturer
- Check of filter tape stock
- Maintenance of the sampling inlet according to the manufacturer's instructions

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.

- Check of filter tape stock –
  With the cycle time set to 1 h and the filter spot being 24 times (setting during performance testing), a 45m long filter tape will last, in theory, for 30,000 measurement cycles which corresponds to 1,250 days. In practice and given actual particle concentration levels, however, it is possible that a filter spot reaches the maximum permissible load of 400 µg earlier than after 24 times of sampling, a clean filter spot may be required at that earlier point. The time in which the filter tape is consumed is reduced accordingly.
  With a cycle time of 1 h and a filter spot being sampled a single time (i.e. a new filter spot is used for each cycle), there are 1,250 measurement cycles which corresponds to 52 days. It is therefore recommended to check the stock of the filter tape each time the measuring system is visited for regular maintenance (e.g. during cleaning of the sampling head).
- According to the manufacturer, the pump must be serviced approx. every 6 weeks after one year of operation. This implies the filters must be blown out, the fin height checked and the fins changed if necessary.
- According to CEN/TS 16450 [9], the sensors for ambient temperature and pressure should be checked every 3 months.
- EN 16450 [9] requires a check of the flow rate every three months.
- The leak tightness should also be checked every 3 months as part of the flow rate check.
- Clean the filter adapter, the conveyer and the pressure roller every 6 months.
- Check and, if necessary, blow out exhaust air filters and hose connectors every 6 months.
- Replace the pump filter and the seal once a year.

- Return the meteorological sensor to manufacturer for re-calibration once a year. It is also recommended to check the radiometric measurement with the help of a span foil once a year.
- During annual basic maintenance, care must also be taken to clean the sampling tube.

Further details are provided in the operation manual.

Environmental Protection/Air Pollution Control

Dipl.-Ing. Guido Baum	Dipl.-Ing. Karsten Pletscher

Cologne, 14 September 2018
936/21243589/A

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] 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] Guideline "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated January 2010

[5] Operation manual F-701-20, last updated 2018

[6] Operation manual LVS3 of 2000

[7] 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

[8] 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)

[9] TÜV Report No. 936/21220478/A of 17 March 2014 on the performance test of the F-701-20 ambient air quality measuring system with $PM_{2,5}$ pre-separator for suspended particulate matter $PM_{2,5}$ manufactured by DURAG GmbH.

[10] Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 13 October 2016

[11] Statement issued by TÜV Rheinland Energy GmbH dated 29 September 2017

Statement issued by TÜV Rheinland Energy GmbH dated 2 May 2018

3.1 F-701-20 mit $PM_{2,5}$-Vorabscheider für Schwebstaub $PM_{2,5}$

Hersteller:

DURAG GmbH, Hamburg

Eignung:

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

Messbereich in der Eignungsprüfung:

Komponente	Zertifizierungsbereich	Einheit
$PM_{2,5}$	0 – 1 000	µg/m³

Softwareversion: 3.10

Einschränkungen:

Keine

Hinweise:

1. Die Anforderungen gemäß des Leitfadens „Demonstration of Equivalence of Ambient Air Monitoring Methods" werden für die Messkomponente $PM_{2,5}$ eingehalten.
2. Während der Eignungsprüfung betrug die Zykluszeit 1 h und die Belegzahl betrug 24; d. h. jede Stunde wurde ein automatischer Filterwechsel durchgeführt, wobei jeder Filterfleck bis zu maximal 24 Mal beprobt wurde.
3. Die Messeinrichtung ist mit einem aktiv belüfteten Probenahmesystem ohne Rohrbegleitheizung zu betreiben.
4. Die Messeinrichtung ist in einem verschließbaren Messcontainer zu betreiben.
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.: 936/21220478/A vom 17. März 2014

Figure 41: First published in BAnz AT 05.08.2014 B11, chapter III number 3.1

3 Mitteilung zu der Bekanntmachung des Umweltbundesamtes vom 17. Juli 2014 (BAnz AT 05.08.2014 B11, Kapitel III Nummer 3.1)

Die aktuelle Softwareversion der Messeinrichtung F-701-20 mit $PM_{2,5}$-Vorabscheider für Schwebstaub $PM_{2,5}$ der Firma DURAG GmbH lautet: 03.11R0005.

Darüber hinaus ist auch die Version V03.10R0001 zugelassen.

Die Messeinrichtung kann jetzt auch mit SD-Karten neueren Typs (Spec. V4.10, 22. Januar 2013) genutzt werden.

Stellungnahme der TÜV Rheinland Energy GmbH vom 13. Oktober 2016

Figure 42: UBA announcement BAnz AT 15.03.2017 B6 chapter V 3rd Notification

4 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 17. Juli 2014 (BAnz AT 05.08.2014 B11, Kapitel III Nummer 3.1) und vom 22. Februar 2017 (BAnz AT 15.03.2017 B6, Kapitel V 3. Mitteilung)

Die aktuelle Softwareversion der Messeinrichtung F-701-20 mit $PM_{2,5}$-Vorabscheider für Schwebstaub $PM_{2,5}$ der Firma DURAG GmbH lautet: 03.11R0008.

Die Messeinrichtung kann statt mit dem Regelventil Buschjost 8288200.9624.02400 jetzt auch mit dem Regelventil Buschjost 8288200.9638.02400 ausgerüstet werden.

Stellungnahme der TÜV Rheinland Energy GmbH vom 29. September 2017

Figure 43: UBA announcement BAnz AT 26.03.2018 B8 chapter V 4th Notification

27 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 17. Juli 2014 (BAnz AT 05.08.2014 B11, Kapitel III Nummer 3.1) und vom 21. Februar 2018 (BAnz AT 26.03.2018 B8, Kapitel V 4. Mitteilung)

Die aktuelle Softwareversion der Messeinrichtung F-701-20 mit $PM_{2,5}$-Vorabscheider für Schwebstaub $PM_{2,5}$ der Firma DURAG GmbH lautet:

04.11R0009

Das Gehäuse der Messeinrichtung wurde für den Einbau in ein 19“ Rack angepasst.

Die Messeinrichtung ist auch in einer Gerätevariante mit externer Pumpe verfügbar. Die Variante ist in der Typenschlüsselstruktur F-701-20 PM xx2-xxxxxF durch den Buchstaben „F“ eindeutig gekennzeichnet und identifizierbar.

Stellungnahme der TÜV Rheinland Energy GmbH vom 2. Mai 2018

Figure 44: UBA announcement BAnz AT 17.07.2018 B9 chapter III 27th Notification

9. Appendices

Annex 1 Measured and calculated values

Schedule 1: Zero level and detection limit

Schedule 2: Flow rate accuracy

Schedule 3: Temperature dependence of the zero point and sensitivity

Schedule 4: Independence of supply voltage

Annex 5: Measured values from the field test sites

Schedule 6: Ambient condition at the field test locations

Annex 2: Methods used for filter weighing

Annex 3 Operation manuals

Annex 1 **Zero level and Detection limit** **Page 1 of 1**

Manufacturer DURAG GmbH

Type F-701-20 Standards ZP Measured values with zero filter

Serial-No. SN 1512401 / SN 1512361

No.	Date	Measured values [µg/m³] SN 1512401	Date	Measured values [µg/m³] SN 1512361
1	12/20/2012	0.4	12/20/2012	0.3
2	12/21/2012	0.6	12/21/2012	0.1
3	12/22/2012	0.3	12/22/2012	0.7
4	12/23/2012	0.1	12/23/2012	0.0
5	12/24/2012	0.3	12/24/2012	0.8
6	12/25/2012	0.7	12/25/2012	-0.4
7	12/26/2012	-0.3	12/26/2012	0.5
8	12/27/2012	0.0	12/27/2012	0.7
9	12/28/2012	0.9	12/28/2012	-0.1
10	12/29/2012	0.1	12/29/2012	0.4
11	12/30/2012	0.0	12/30/2012	0.2
12	12/31/2012	0.2	12/31/2012	0.6
13	1/1/2013	0.5	1/1/2013	0.5
14	1/2/2013	0.5	1/2/2013	0.0
15	1/3/2013	0.0	1/3/2013	0.6
	No. of values	15	No. of values	15
	Mean (Zero level)	0.28	Mean (Zero level)	0.34
	Standard deviation s_{x0}	0.31	Standard deviation s_{x0}	0.35
	Detection limit x	1.01	Detection limit x	1.15

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

Annex 2 **Flow rate accuracy** **Page 1 of 1**

Manufacturer	DURAG GmbH
Type	F-701-20
Serial-No.	SN 1274509 / SN 1274510
Nominal flow rate [l/min]	16.67

		SN 1274509			SN 1274510		
Temperature 1 5°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
	1	8/15/2018 7:06	16.45	1	8/15/2018 7:08	16.44
	2	8/15/2018 7:10	16.43	2	8/15/2018 7:12	16.42
	3	8/15/2018 7:14	16.43	3	8/15/2018 7:16	16.41
	4	8/15/2018 7:18	16.42	4	8/15/2018 7:20	16.42
	5	8/15/2018 7:22	16.42	5	8/15/2018 7:24	16.44
	6	8/15/2018 7:26	16.40	6	8/15/2018 7:28	16.43
	7	8/15/2018 7:30	16.41	7	8/15/2018 7:32	16.40
	8	8/15/2018 7:34	16.43	8	8/15/2018 7:36	16.40
	9	8/15/2018 7:38	16.42	9	8/15/2018 7:40	16.40
	10	8/15/2018 7:42	16.49	10	8/15/2018 7:44	16.39
		Mean	**16.43**		**Mean**	**16.41**

		SN 1274509			SN 1274510	
Temperature 2 40°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
	1	8/16/2018 7:04	16.83	1	8/16/2018 7:06	16.86
	2	8/16/2018 7:08	16.91	2	8/16/2018 7:10	16.90
	3	8/16/2018 7:12	16.92	3	8/16/2018 7:14	16.91
	4	8/16/2018 7:16	16.90	4	8/16/2018 7:18	16.90
	5	8/16/2018 7:20	16.92	5	8/16/2018 7:22	16.89
	6	8/16/2018 7:24	16.92	6	8/16/2018 7:26	16.90
	7	8/16/2018 7:28	16.91	7	8/16/2018 7:30	16.90
	8	8/16/2018 7:32	16.91	8	8/16/2018 7:34	16.91
	9	8/16/2018 7:36	16.92	9	8/16/2018 7:38	16.91
	10	8/16/2018 7:40	16.97	10	8/16/2018 7:42	16.90
		Mean	**16.91**		**Mean**	**16.90**

Annex 3 — Dependence of zero point on surrounding temperature — Page 1 of 2

Manufacturer	DURAG GmbH						
Type	F-701-20						
Serial-No.	SN 1512361 / SN 1512401						
Test period:	24.01.2013 - 11.02.2013		Measurement 1	Measurement 2	Measurement 3		
SN 1512361	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	1.0	0.5	0.7	0.7	0.7
	2	5	1.2	0.8	0.4	0.8	
	3	20	1.4	0.4	0.7	0.8	
	4	40	0.0	-0.5	-0.4	-0.3	
	5	20	0.7	0.5	0.1	0.4	
SN 1512401	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	0.5	0.1	0.3	0.3	0.3
	2	5	-0.1	-0.2	0.0	-0.1	
	3	20	-0.2	0.7	0.4	0.3	
	4	40	-0.5	-0.4	0.2	-0.2	
	5	20	0.2	0.4	0.2	0.3	

Annex 3 **Dependence of span on surrounding temperature** **Page 2 of 2**

Manufacturer: DURAG GmbH

Used test standard: Reference foil

Type: F-701-20

Serial-No.: SN 1512361 / SN 1512401

Test period: 07.01.2014 - 09.01.2014

			Measurement 1	Measurement 2	Meaurement 3		
SN 1512361	No.	Temperature [°C]	Measured value [µg]	Measured value [µg]	Measured value [µg]	Mean value of 3 measurements [µg]	Mean value at 20°C [µg]
Span	1	20	294.0	289.0	290.0	291.0	289.8
	2	5	292.0	292.0	283.0	289.0	
	3	20	292.0	292.0	298.0	294.0	
	4	40	288.0	285.0	280.0	284.3	
	5	20	284.0	284.0	285.0	284.3	
SN 1512401	No.	Temperature [°C]	Measured value [µg]	Measured value [µg]	Measured value [µg]	Mean value of 3 measurements [µg]	Mean value at 20°C [µg]
Span	1	20	277.0	272.0	274.0	274.3	270.1
	2	5	267.0	270.0	273.0	270.0	
	3	20	262.0	275.0	265.0	267.3	
	4	40	261.0	263.0	274.0	266.0	
	5	20	267.0	268.0	271.0	268.7	

Annex 4 **Dependence of span on supply voltage** **Page 1 of 1**

Manufacturer DURAG GmbH

Used test standard Reference foil

Type F-701-20

Serial-No. SN 1274509 / SN 1274510

Test period: 7/4/2018

SN 1274509	No.	Mains voltage [V]	Measurement 1 Measured value [µg]	Measurement 2 Measured value [µg]	Measurement 3 Measured value [µg]	Mean value of 3 measurements [µg]
Span	1	230	327.0	322.0	312.0	320.3
	2	195	335.0	320.0	318.0	324.3
	3	230	317.0	325.0	337.0	326.3
	4	253	332.0	331.0	316.0	326.3
	5	230	327.0	327.0	329.0	327.7
SN 1274510	**No.**	**Mains voltage [V]**	**Measured value [µg]**	**Measured value [µg]**	**Measured value [µg]**	**Mean value of 3 measurements [µg]**
Span	1	230	340.0	336.0	324.0	333.3
	2	195	328.0	331.0	333.0	330.7
	3	230	321.0	345.0	332.0	332.7
	4	253	342.0	338.0	333.0	337.7
	5	230	342.0	340.0	334.0	338.7

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 1 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM2,5 [µg/m³]	SN 1512401 PM2,5 [µg/m³]	Remark	Test site
1	2/28/2013								Zero point	Bonn, Winter
2	3/1/2013	24.9	23.0	36.3	36.7	65.6	24.0	22.8		
3	3/2/2013						27.7	27.8		
4	3/3/2013	22.1	23.2	29.3	29.8	76.6	21.2	20.9		
5	3/4/2013	19.6	20.5	28.2	28.7	70.2	19.3	19.7		
6	3/5/2013	28.4	27.7	40.2	39.9	70.1	26.0	26.7		
7	3/6/2013	25.8	24.5	39.3	39.7	63.8	24.2	22.5		
8	3/7/2013	28.0	28.3	39.5	39.5	71.2	26.9	27.0		
9	3/8/2013	28.8	27.0	35.4	34.8	79.5	28.6	28.9		
10	3/9/2013						12.0	11.5		
11	3/10/2013	21.8	22.0	23.1	22.3	96.5	21.6	20.6		
12	3/11/2013	27.6	28.1	31.2	30.3	90.6	26.7	26.7		
13	3/12/2013	15.6	15.6	17.8	17.7	87.9	14.8	14.5		
14	3/13/2013	36.7	36.7	50.8	50.0	72.9	33.9	32.4		
15	3/14/2013	19.6	19.2	27.5	27.6	70.3	18.0	18.7		
16	3/15/2013	22.0	21.5	31.7	31.7	68.7	20.8	21.7		
17	3/16/2013						14.4	15.7		
18	3/17/2013	7.0	7.4	11.0	10.5	67.2	8.8	8.3		
19	3/18/2013	7.7	8.2	17.4	17.2	45.9	11.4	12.0		
20	3/19/2013	9.5	9.9	17.1	16.8	57.5	11.9	11.7		
21	3/20/2013	21.3	20.9	25.2	24.5	84.7	22.3	21.1		
22	3/21/2013	37.5	36.6	46.3	45.9	80.5	36.2	34.6		
23	3/22/2013	21.4	21.6	26.0	26.3	82.2	22.2	22.6		
24	3/23/2013						23.4	22.5		
25	3/24/2013	15.1	15.9	19.7	18.8	80.6	16.5	17.2		
26	3/25/2013	20.1	20.6	26.0	25.6	78.9	20.9	21.2		
27	3/26/2013	15.7	15.3	21.1	20.4	74.7	15.6	16.4		
28	3/27/2013	26.6	25.9	33.3	32.8	79.5	25.3	26.0		
29	3/28/2013						42.9	42.0		
30	3/29/2013	71.1	69.8	76.5	76.3	92.2	66.8	64.5		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 2 of 10**

Manufacturer: DURAG
Type of instrument: F701-20
Serial-No.: SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
31	3/30/2013								Zero point	Bonn, Winter
32	3/31/2013								Zero point	
33	4/1/2013								Zero point	
34	4/2/2013	20.2	20.2	24.7	25.2	81.0	19.0	19.5		
35	4/3/2013	27.2	26.5	31.4	30.8	86.3	25.4	26.2		
36	4/4/2013	29.5	29.1	33.5	33.2	88.0	27.9	27.6		
37	4/5/2013	25.8	25.4	30.8	30.0	84.1	23.2	22.9		
38	4/6/2013						21.3	22.1		
39	4/7/2013	23.0	22.8	30.9	30.2	74.9	20.6	20.7		
40	4/8/2013	26.3	25.1	31.7	31.7	81.0	23.3	22.7		
41	4/9/2013	16.5	16.5	21.6	21.0	77.4	15.7	14.1		
42	4/10/2013	12.2	12.2	17.9	17.8	68.4	11.1	11.1		
43	4/11/2013	9.4	8.8	15.9	15.7	57.4	8.5	8.7		
44	4/12/2013	6.2	6.3	10.4	10.4	60.4	5.3	4.8		
45	4/13/2013						6.5	6.6		
46	4/14/2013	7.2	6.9	11.9	11.1	61.4	6.4	6.9		
47	4/15/2013	18.5	16.8	31.2	30.2	57.3	20.3	22.1		
48	4/16/2013	12.7	11.2	21.1	20.7	57.2	12.7	12.4		
49	4/17/2013	9.9	9.8	19.5	19.7	50.2	11.8	10.7		
50	4/18/2013	9.4	8.7	21.4	21.5	42.2	11.7	9.7		
51	4/19/2013	10.3	10.3	21.0	20.8	49.4	11.3	10.5		
52	4/20/2013						10.6	11.5		
53	4/21/2013	24.4	23.0	36.7	37.6	63.8	20.4	20.3		
54	4/22/2013	31.0	29.4	44.7	43.9	68.3	27.0	26.1		
55	4/23/2013	11.0	10.4	18.2	18.8	57.6	10.4	9.5		
56	4/24/2013	14.3	12.7	24.2	24.4	55.6	12.2	13.0		
57	4/25/2013	13.8	12.1	23.3	23.6	55.3	12.6	12.0		
58	4/26/2013								Zero point	
59	4/27/2013								Zero point	
60	4/28/2013								Zero point	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 3 of 10**

Manufacturer	DURAG	PM2,5 Measured values in µg/m³ (ACT)
Type of instrument	F701-20	
Serial-No.	SN 1512361 / SN 1512401	

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
61	4/29/2013	14.3	12.9	20.6	21.4	64.9	11.9	11.2		Bonn, Winter
62	4/30/2013						14.1	15.0		
63	5/1/2013	16.9	18.2	21.4	22.2	80.7	15.2	15.6		
64	5/2/2013						14.5	15.8		
65	5/3/2013	23.2	23.4	33.7	34.4	68.5	22.2	21.7		
66	5/4/2013	20.2	19.7	30.1	30.6	65.7	19.1	18.8		
67	5/5/2013	9.6	9.3	14.0	14.8	65.4	8.2	8.0		
68	5/6/2013	14.5	15.0	23.3	22.9	63.9	13.4	13.8		
69	5/14/2013								Zero point	Bornheim, Summer
70	5/15/2013								Zero point	
71	5/16/2013	21.0	20.7	24.5	24.7	84.6	21.7	21.8		
72	5/17/2013	16.1	15.5	18.3	19.4	83.8	16.4	16.0		
73	5/18/2013						8.8	9.3		
74	5/19/2013						19.9	20.5		
75	5/20/2013	11.3	10.3	13.9	14.7	75.2	9.5	10.2		
76	5/21/2013		5.4	8.3	8.8		5.1	4.9	Power loss Ref. PM2,5 G#1	
77	5/22/2013						6.4	5.2		
78	5/23/2013						5.3	4.8		
79	5/24/2013			10.1	10.7		6.6	6.1	Power loss Ref. PM2,5	
80	5/25/2013						10.4	10.8		
81	5/26/2013		6.6	12.9	13.4		7.2	7.0	Power loss Ref. PM2,5 G#2	
82	5/27/2013	11.7	11.0	16.9	17.6	65.7	10.3	9.9		
83	5/28/2013	8.7	7.7	12.8	12.2	65.8	7.9	8.9		
84	5/29/2013						4.2	3.4		
85	5/30/2013						9.8	11.0		
86	5/31/2013						16.4	16.9		
87	6/1/2013						13.3	13.0		
88	6/2/2013	5.3	5.0	10.8	10.7	47.7	5.0	4.8		
89	6/3/2013	8.0	7.0	14.5	14.5	51.5	7.2	7.6		
90	6/4/2013	9.5	9.5	18.2	18.4	51.9	10.1	9.3		

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

Manufacturer	DURAG	PM2,5
Type of instrument	F701-20	Measured values in µg/m³ (ACT)
Serial-No.	SN 1512361 / SN 1512401	

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
91	6/5/2013	9.1	9.3	17.2	18.8	51.2	8.9	8.7		Bornheim, Summer
92	6/6/2013	10.8	10.2	17.0	17.5	60.8	8.8	9.4		
93	6/7/2013	17.0	16.1	28.6	29.9	56.6	15.1	14.7		
94	6/8/2013						15.0	15.7		
95	6/9/2013	14.0	13.6	20.1	21.3	66.9	15.6	14.8		
96	6/10/2013	16.1	15.4	26.1	27.1	59.1	15.4	15.0		
97	6/11/2013	13.0	12.2	20.8	20.7	60.7	11.3	11.6		
98	6/12/2013	7.1	6.4	14.6	14.0	47.4	6.7	6.3		
99	6/13/2013	5.6	5.4	13.4	12.7	42.1	4.4	4.3		
100	6/14/2013	5.0	5.7	10.8	10.8	49.3	4.3	4.4		
101	6/15/2013	5.1	5.3	10.6	10.2	50.0	4.5	4.6		
102	6/16/2013	7.3	7.6	16.7	16.6	44.8	6.8	5.7		
103	6/17/2013	12.2	13.3	21.3	20.9	60.3	12.0	11.6		
104	6/18/2013	17.8	17.3	28.6	29.1	60.9	16.5	16.7		
105	6/19/2013	31.9	32.7	48.7	48.5	66.5	31.9	33.3		
106	6/20/2013	8.7	10.1	15.5	14.9	62.1	14.9	14.2		
107	6/21/2013	4.2	4.5	7.2	6.8	62.2	3.9	4.3		
108	6/22/2013	3.3	4.1	5.7	5.9	63.8			Zero point	
109	6/23/2013	3.1	3.0	4.6	5.5	59.8			Zero point	
110	6/24/2013	8.7	8.0	13.9	13.2	61.6	9.3	8.8		
111	6/25/2013	6.3	6.6	12.9	12.7	50.4	5.7	5.6		
112	6/26/2013	9.1	9.4	14.6	14.5	63.4	10.0	9.6		
113	6/27/2013	9.8	9.6	14.2	13.8	69.5	9.3	9.0		
114	6/28/2013	8.8	8.7	14.2	14.7	60.4	8.0	8.4		
115	6/29/2013	6.0	5.8	11.7	11.5	50.8	4.7	5.0		
116	6/30/2013	7.4	6.9	14.6	14.4	49.3	7.1	6.0		
117	7/1/2013	7.7	7.6	13.4	13.2	57.5	7.2	8.1		
118	7/2/2013	7.9	7.9	12.5	12.0	64.9	8.1	7.9		
119	7/3/2013	3.6	3.8	9.0	9.9	39.1	3.4	3.7		
120	7/4/2013	7.5	7.9	13.5	13.6	56.8	7.1	7.3		

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

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
121	7/5/2013	12.9	13.1	20.9	19.9	63.8	12.7	14.4		Bornheim, Summer
122	7/6/2013	13.3	13.1	18.7	18.5	71.0	13.5	13.9		
123	7/7/2013	11.3	10.7	14.9	14.4	75.0	10.1	11.1		
124	7/8/2013	11.3	10.6	16.3	16.1	67.7	10.2	11.1		
125	7/9/2013	14.2	14.5	24.9	22.6	60.5	14.4	14.4		
126	7/10/2013	9.7	10.2	19.1	17.5	54.6	9.6	9.9		
127	7/11/2013	13.6	14.3	26.6	24.9	54.1	12.3	12.6		
128	7/12/2013	16.5	16.8			53.6	15.0	15.7	Outlier Ref. PM10	
129	7/13/2013	15.3	15.3	20.4	20.7	74.5	14.5	15.1		
130	7/14/2013	14.5	14.5	22.2	21.5	66.5	14.7	16.0		
131	7/15/2013	17.4	17.4	26.2	25.6	67.1	16.6	17.1		
132	7/16/2013	20.4	18.4	30.2	28.9	65.5	19.4	19.4		
133	7/17/2013	13.6	13.2	18.7	18.0	72.9	14.4	13.8		
134	7/18/2013	11.3	9.0	17.0	17.3	59.2	10.9	10.9		
135	7/19/2013	9.0	7.3	16.3	14.8	52.7	8.8	9.6		
136	7/20/2013	10.1	9.5	17.3	16.0	58.7	10.8	11.4		
137	7/21/2013	12.9	12.3	18.0	17.7	70.7	12.7	12.5		
138	7/22/2013	15.5	14.8	23.2	22.0	67.2	13.9	14.2		
139	7/23/2013	14.1	13.6	25.4	24.5	55.3	14.4	13.6		
140	7/24/2013	20.3	20.0	31.5	30.3	65.2			Audits	
141	7/25/2013	11.1	12.1	21.3	20.3	55.7			Switch to zero filter	
142	9/4/2013								Zero point	Cologne, Autumn
143	9/5/2013								discarded due to faulty flow cal.	
144	9/6/2013	19.7	19.9	31.6	29.9	64.4			discarded due to faulty flow cal.	
145	9/7/2013								discarded due to faulty flow cal.	
146	9/8/2013	10.9	12.5	15.0	14.9	78.3			discarded due to faulty flow cal.	
147	9/9/2013	3.6	3.8	6.7	6.7	55.6			discarded due to faulty flow cal.	
148	9/10/2013	3.9	4.9	9.1	7.4	53.2			discarded due to faulty flow cal.	
149	9/11/2013	7.8	8.0	12.3	11.7	65.7			discarded due to faulty flow cal.	
150	9/12/2013	10.3	10.6	17.6	15.9	62.5			discarded due to faulty flow cal.	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 6 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
151	9/13/2013	6.3	5.3	9.0	7.7	69.4	7.2	8.0		Cologne, Autumn
152	9/14/2013						3.1	3.3		
153	9/15/2013	4.4	5.5	9.5	7.9	56.8	4.6	5.5		
154	9/16/2013	6.0	4.5	9.8	9.8	53.9	4.9	5.3		
155	9/17/2013	4.3	4.2	7.5	6.4	61.7	4.8	5.4		
156	9/18/2013	8.8	9.4	13.9	13.1	67.3	7.8	8.7		
157	9/19/2013	5.8	5.5	10.3	10.5	54.2	6.4	7.1		
158	9/20/2013	8.2	6.9	15.2	14.8	50.5	7.5	7.8		
159	9/21/2013						11.9	13.8		
160	9/22/2013	13.1	13.1	18.9	17.1	72.8	15.1	15.8		
161	9/23/2013	14.2	13.9	20.0	18.5	72.8	11.5	13.6		
162	9/24/2013	19.6	21.3	27.5	26.3	76.1	20.6	22.2		
163	9/25/2013	36.5	38.9	49.6	48.6	76.8	38.2	43.5		
164	9/26/2013	11.1	12.8	19.1	18.9	62.9	9.8	13.6		
165	9/27/2013	6.0	7.2	11.7	11.7	56.4	6.6	6.8		
166	9/28/2013						8.2	8.5		
167	9/29/2013	7.3	8.9	11.7	11.6	69.7	7.0	7.4		
168	9/30/2013	11.9	13.2	18.5	17.9	69.0	12.2	12.1		
169	10/1/2013	11.2	12.1	16.2	16.6	70.9	9.9	9.9		
170	10/2/2013	10.6	11.6	17.1	16.4	66.3	10.6	10.7		
171	10/3/2013						7.8	9.6		
172	10/4/2013	13.1	14.5	18.3	18.4	75.3	13.0	13.8		
173	10/5/2013						16.1	19.9		
174	10/6/2013	9.9	11.1	14.1	14.6	73.2	10.3	9.6		
175	10/7/2013	9.9	10.6	15.7	15.1	66.4	10.0	10.0		
176	10/8/2013	19.9	21.2	28.9	28.8	71.3	21.7	21.8		
177	10/9/2013	7.1	6.8	12.6	11.7	57.3	6.8	7.8		
178	10/10/2013	8.4	8.8	12.6	12.4	68.8	7.3	8.1		
179	10/11/2013						7.9	8.2		
180	10/12/2013						13.4	13.7		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 7 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
181	10/13/2013	5.0	5.6	7.7	8.2	66.8	5.5	5.7		Cologne, Autumn
182	10/14/2013	5.0	4.6	8.3	7.8	59.5	5.0	5.4		
183	10/15/2013								Maintenance SN 1512401	
184	10/16/2013								Zero point	
185	10/17/2013	9.5	11.1	25.4	25.4	40.6	10.1	11.7		
186	10/18/2013						8.9	9.3		
187	10/19/2013						9.3	9.5		
188	10/20/2013	3.8	3.3	8.3	8.1	43.1	4.0	4.3		
189	10/21/2013	5.4	5.3	13.7	13.6	39.4	6.3	6.5		
190	10/22/2013	6.8	7.1	15.5	15.2	45.2	8.6	8.3		
191	10/23/2013	5.5	6.1	11.3	11.9	50.1	6.5	6.6		
192	10/24/2013	6.9	6.9	14.9	15.4	45.2	8.6	8.5		
193	10/25/2013						6.9	7.0		
194	10/26/2013						4.9	5.2		
195	10/27/2013	3.0	2.7	6.9	7.2	40.3	4.2	4.4		
196	10/28/2013	3.0	2.4	7.1	7.4	37.3	4.2	3.6		
197	10/29/2013	4.1	4.3	7.9	8.6	51.2	4.0	4.4		
198	10/30/2013	9.6	9.8	17.0	16.6	57.5	9.3	10.2		
199	10/31/2013						8.1	8.0		
200	11/1/2013						6.3	6.7		
201	11/2/2013						3.7	3.9		
202	11/3/2013	1.9	0.5	3.9	4.6	28.6	2.1	2.1		
203	11/4/2013	5.5	4.4	10.5	11.0	46.2	5.1	5.8		
204	11/5/2013	5.8	5.1	12.8	12.3	43.6	6.3	6.6		
205	11/6/2013	3.7	3.4	8.0	9.2	41.0	3.8	4.3		
206	11/7/2013	5.8	6.0	9.8	10.3	58.6	5.3	6.1		
207	11/8/2013								Zero point	
208	11/9/2013								Zero point	
209	11/10/2013								Zero point	
210	11/11/2013	13.2	13.8	21.5	21.4	63.0	12.5	13.2		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 8 of 10**

Manufacturer	DURAG
Type of instrument	F701-20
Serial-No.	SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
211	11/12/2013	11.3	11.3	18.1	18.7	61.6	10.9	11.6		Cologne, Autumn
212	11/13/2013	17.3	17.1	28.2	29.1	59.9	15.4	15.9		
213	11/14/2013	18.8	19.0	24.0	25.1	76.9	16.9	17.1		
214	11/15/2013						21.6	21.7		
215	11/16/2013						26.4	26.9		
216	11/17/2013	21.8	21.9	24.9	26.0	86.0	19.8	19.9		
217	11/18/2013	13.8	14.1	18.6	19.1	74.0	12.2	12.9		
218	11/19/2013	13.7	13.8	19.4	19.8	70.4	11.4	10.8		
219	11/20/2013	8.3	8.0	12.7	12.5	64.7	7.1	7.4		
220	11/21/2013	12.7	13.4	15.8	16.3	81.4	10.1	10.8		
221	11/22/2013						15.6	15.7		
222	11/23/2013						13.8	14.5		
223	11/24/2013	12.3	12.1	18.1	18.6	66.6	11.7	11.3		
224	11/25/2013	13.0	12.4	18.3	18.9	68.2	10.4	11.3		
225	11/26/2013	33.8	34.7	42.4	41.8	81.3	31.3	29.6		
226	11/27/2013	24.5	25.5	32.3	32.6	77.2	21.5	22.7		
227	11/28/2013	14.1	15.3	23.1	22.9	64.0	13.0	13.5		
228	11/29/2013						8.0	7.5		
229	11/30/2013						14.9	15.2		
230	12/1/2013	18.3	19.3	30.0	29.9	62.7	17.0	18.6		
231	12/2/2013	10.7	12.0	21.7	21.4	52.7	10.1	10.6		
232	12/3/2013						19.1	20.8		
233	12/4/2013	21.2	22.3	32.4	31.7	67.8	20.7	18.8		
234	12/5/2013	4.3	5.2	9.2	9.0	52.1	4.2	4.3		
235	12/6/2013						6.2	7.7		
236	12/7/2013						10.5	10.1		
237	12/8/2013	6.7	7.6	10.2	10.7	68.2	6.2	6.7		
238	12/9/2013	13.9	14.8	22.3	22.5	63.9	12.2	13.3		
239	12/10/2013	18.1	19.0	22.2	22.3	83.3	16.0	13.4		
240	12/11/2013	8.7	9.9	9.9	10.6	90.7	7.2	7.3		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 9 of 10**

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
241	1/13/2014	12.9	13.6	18.2	18.9	71.5			Zero point	Cologne, Winter
242	1/14/2014	10.8	11.2	15.5	15.0	72.3	10.0	10.0		
243	1/15/2014	5.5	5.7	8.0	8.7	66.9	6.3	6.4		
244	1/16/2014	3.1	3.6	6.4	7.1	50.0	4.7	4.6		
245	1/17/2014	4.6	5.2	8.9	8.6	56.0	5.3	5.3		
246	1/18/2014						9.5	9.4		
247	1/19/2014	14.5	14.2	16.8	17.3	84.2	12.8	14.2		
248	1/20/2014	15.6	15.3	18.9	19.9	79.7	15.0	15.6		
249	1/21/2014	24.2	24.6	30.8	31.1	78.7	21.7	22.3		
250	1/22/2014	18.4	18.8	23.0	23.5	80.0	17.0	16.6		
251	1/23/2014	10.9	11.4	15.2	16.3	70.9	10.2	10.0		
252	1/24/2014	18.7	19.3	28.1	28.9	66.6	17.9	17.7		
253	1/25/2014						9.4	9.1		
254	1/26/2014	4.4	4.4	11.4	12.0	37.8	5.3	5.6		
255	1/27/2014	2.9	3.5	6.7	7.1	46.7	3.6	3.7		
256	1/28/2014	6.3	6.7	10.9	10.6	60.4	6.6	7.1		
257	1/29/2014	16.0	16.6	19.2	19.7	83.8	13.9	13.9		
258	1/30/2014	35.7	36.0	41.6	42.3	85.4	31.8	31.2		
259	1/31/2014	29.8	29.0	35.0	34.9	84.1	26.3	27.0		
260	2/1/2014						5.6	4.9		
261	2/2/2014	8.6	7.9	18.1	17.5	46.3	8.3	8.2		
262	2/3/2014	18.7	18.0	22.0	21.5	84.5	16.9	16.9		
263	2/4/2014						12.2	12.0		
264	2/5/2014	4.4	3.4	8.0	8.2	48.6	5.0	4.4		
265	2/6/2014	2.9	3.1	9.8	9.1	32.0	4.5	4.5		
266	2/7/2014								Zero point	
267	2/8/2014								Zero point	
268	2/9/2014								Zero point	
269	2/10/2014	9.8	8.8	12.9	13.1	71.4	8.6	9.1		
270	2/11/2014	4.5	3.8	9.6	8.0	47.6	3.9	3.9		

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

Manufacturer DURAG

Type of instrument F701-20

Serial-No. SN 1512361 / SN 1512401

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 1512361 PM10 [µg/m³]	SN 1512401 PM10 [µg/m³]	Remark	Test site
271	2/12/2014	4.5	3.8	8.2	7.9	51.3	3.9	3.6		Cologne, Winter
272	2/13/2014	4.8	4.3	10.3	10.0	44.8	3.9	4.4		
273	2/14/2014	0.0	0.0				3.3	3.5		
274	2/15/2014	0.0	0.0				3.7	3.6		
275	2/16/2014	5.2	4.9	8.8	9.2	56.2	5.2	5.3		
276	2/17/2014	8.0	7.0	12.7	12.5	59.7	7.2	7.9		
277	2/18/2014	14.5	13.8	19.8	19.6	71.7	12.7	13.3		
278	2/19/2014	9.6	8.9	13.2	8.9	83.8	8.5	8.3		
279	2/20/2014	4.3	4.4	6.6	6.2	67.5	5.2	4.9		
280	2/21/2014	4.8	5.0	7.8	7.8	63.2	5.8	5.4		
281	2/22/2014	4.2	5.0	4.7	5.4	90.9	4.3	4.4		
282	2/23/2014	5.6	6.6	7.1	7.0	87.0	5.3	6.2		
283	2/24/2014	9.3	9.3	13.7	12.7	70.6	7.5	8.2		
284	2/25/2014	9.0	8.6	12.8	12.1	70.5	8.4	7.5		
285	2/26/2014	11.3	11.3	19.4	17.3	61.7	9.4	9.6		
286	2/27/2014	7.5	8.2	12.0	10.4	70.3	6.8	7.2		
287	2/28/2014	7.7	7.3	10.3	9.9	74.3	6.0	6.3		
288	3/1/2014	12.1	12.4	14.7	14.7	83.5	11.0	10.7		
289	3/2/2014	16.8	16.9	18.3	19.6	88.6	13.9	14.4		
290	3/3/2014	6.8	6.9	9.9	11.8	63.0	7.0	6.9		
291	3/4/2014	19.5	17.6	25.6	24.3	74.4	15.7	16.9		
292	3/5/2014	30.8	31.2	43.5	43.7	71.0	27.3	27.2		
293	3/6/2014	36.5	35.6	44.2	43.5	82.2	30.6	30.7		
294	3/7/2014	43.6	44.0	56.7	55.5	78.0	39.0	38.9		
295	3/8/2014	42.8	41.4	49.7	50.0	84.4	36.7	37.1		
296	3/9/2014	23.2	21.4	28.1	27.2	80.7	18.3	19.0		

Annex 6 **Ambient conditions at the field test sites** **Page 1 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	2/28/2013	Bonn, Winter	4.1	1017	71.8	1.2	250	0.0
2	3/1/2013		3.5	1016	72.0	1.7	249	0.0
3	3/2/2013		3.0	1015	67.4	1.2	238	0.0
4	3/3/2013		3.1	1014	72.8	0.5	196	0.0
5	3/4/2013		6.6	1007	57.8	1.4	140	0.0
6	3/5/2013		8.5	999	56.5	1.2	136	0.0
7	3/6/2013		11.5	993	48.5	0.4	143	0.0
8	3/7/2013		12.3	990	67.5	0.5	144	2.1
9	3/8/2013		13.7	990	72.1	1.4	138	1.5
10	3/9/2013		10.6	991	72.2	1.2	178	3.6
11	3/10/2013		1.6	993	81.8	3.6	273	2.4
12	3/11/2013		-1.4	996	78.7	1.9	241	0.0
13	3/12/2013		-3.4	995	83.9	2.0	276	0.0
14	3/13/2013		-1.2	999	72.8	1.1	224	0.3
15	3/14/2013		-1.3	1004	75.3	1.1	209	2.1
16	3/15/2013		2.3	1006	58.8	1.0	132	2.1
17	3/16/2013		5.3	998	49.0	3.4	131	0.0
18	3/17/2013		4.7	988	78.3	2.2	131	0.9
19	3/18/2013		6.6	985	60.3	0.7	131	0.0
20	3/19/2013		5.8	991	74.5	0.6	157	1.2
21	3/20/2013		2.6	999	85.8	1.9	240	13.2
22	3/21/2013		0.6	1010	78.8	1.0	229	0.3
23	3/22/2013		2.9	1006	63.4	3.2	146	0.0
24	3/23/2013		1.1	1005	56.8	4.2	146	0.0
25	3/24/2013		1.0	1005	42.8	3.3	153	0.0
26	3/25/2013		0.9	1004	49.0	2.6	153	0.0
27	3/26/2013		1.6	1003	44.1	2.3	168	0.0
28	3/27/2013		2.6	1001	49.5	2.0	148	0.0
29	3/28/2013		3.0	999	58.9	1.2	243	0.0
30	3/29/2013		0.4	999	77.8	1.1	271	1.5

Annex 6 **Ambient conditions at the field test sites** **Page 2 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	3/30/2013	Bonn, Winter	1.8	1000	68.9	1.3	271	0.0
32	3/31/2013		1.7	1003	68.2	1.1	269	0.0
34	4/1/2013		3.2	1001	52.9	1.5	190	0.0
34	4/2/2013		3.6	1003	52.2	1.8	201	0.0
35	4/3/2013		3.0	1005	58.0	1.8	158	0.0
36	4/4/2013		4.4	1001	60.5	1.8	166	0.0
37	4/5/2013		3.8	1003	67.8	1.6	267	0.0
38	4/6/2013		3.6	1012	73.9	1.7	221	0.3
39	4/7/2013		6.4	1008	51.4	0.7	174	0.0
40	4/8/2013		7.0	996	63.9	1.4	130	0.9
41	4/9/2013		8.3	992	78.0	1.2	133	1.8
42	4/10/2013		9.7	996	77.3	1.4	154	6.0
43	4/11/2013		13.0	991	69.6	1.3	169	6.0
44	4/12/2013		12.2	997	69.0	1.1	154	4.4
45	4/13/2013		13.9	1011	56.8	1.4	152	0.6
46	4/14/2013		18.3	1011	57.0	1.5	136	0.0
47	4/15/2013		17.5	1011	67.0	1.5	214	2.7
48	4/16/2013		18.4	1011	54.4	0.9	149	0.0
49	4/17/2013		18.7	1009	54.3	0.6	141	0.0
50	4/18/2013		15.6	1009	46.2	3.1	210	0.0
51	4/19/2013		11.4	1017	57.7	3.5	260	0.0
52	4/20/2013		10.3	1018	51.5	3.3	274	0.0
53	4/21/2013		11.1	1009	57.4	1.1	253	0.0
54	4/22/2013		13.2	1009	46.5	1.4	217	0.0
55	4/23/2013		13.7	1014	63.6	1.7	187	0.0
56	4/24/2013		17.9	1016	56.5	1.0	167	0.0
57	4/25/2013		20.0	1010	51.5	0.4	146	0.0
58	4/26/2013		11.9	1000	77.3	2.2	230	9.9
59	4/27/2013		7.8	1003	70.3	3.2	293	0.0
60	4/28/2013		9.2	1007	68.3	0.7	169	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 3 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	4/29/2013	Bonn, Winter	12.0	1010	56.1	1.9	209	0.0
62	4/30/2013		11.8	1014	57.9	1.0	214	0.0
63	5/1/2013		14.6	1011	62.8	0.9	173	0.3
64	5/2/2013		16.5	1009	60.4	1.1	200	0.0
65	5/3/2013		16.0	1007	60.0	1.5	253	0.0
66	5/4/2013		15.7	1011	54.5	2.4	238	0.0
67	5/5/2013		16.4	1013	55.9	1.3	190	0.0
68	5/6/2013		19.8	1008	50.0	0.6	192	0.0
69	5/14/2013	Bornheim, Summer	no weather data available					
70	5/15/2013							
71	5/16/2013		12.6	989	85.5	0.7	263	8.6
72	5/17/2013		10.0	995	89.1	0.8	265	2.4
73	5/18/2013		12.0	1000	77.7	0.4	216	0.0
74	5/19/2013		16.7	998	66.5	2.7	273	7.4
75	5/20/2013		11.9	1000	83.1	0.3	175	6.2
76	5/21/2013		12.9	1001	78.8	1.8	239	13.1
77	5/22/2013		8.8	1004	82.4	2.4	258	7.4
78	5/23/2013		6.4	1000	81.9	1.8	255	2.4
79	5/24/2013		8.3	1003	69.9	0.7	192	0.9
80	5/25/2013		10.5	1005	70.9	2.8	270	3.0
81	5/26/2013		9.8	1002	79.9	3.2	271	5.7
82	5/27/2013		14.0	1000	61.4	1.6	244	0.0
83	5/28/2013		17.2	993	60.4	2.0	179	1.2
84	5/29/2013		9.7	995	88.4	0.6	207	15.0
85	5/30/2013		13.5	999	69.6	1.7	237	2.4
86	5/31/2013		16.1	1001	73.0	4.7	299	0.9
87	6/1/2013		11.9	1009	79.4	4.4	290	0.3
88	6/2/2013		13.3	1016	57.6	4.0	288	0.0
89	6/3/2013		12.9	1017	61.6	3.6	269	0.0
90	6/4/2013		15.6	1012	64.5	1.7	237	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 4 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	6/5/2013	Bornheim, Summer	19.9	1009	54.2	0.6	197	0.0
92	6/6/2013		20.9	1010	52.6	0.8	168	0.0
93	6/7/2013		21.7	1010	55.5	1.0	211	0.0
94	6/8/2013		21.1	1005	62.3	2.1	243	0.0
95	6/9/2013		15.6	1001	78.7	1.8	273	4.5
96	6/10/2013		14.4	1005	75.9	1.2	253	0.6
97	6/11/2013		18.8	1008	61.5	0.6	198	0.0
98	6/12/2013		21.1	1008	67.1	1.0	181	0.0
99	6/13/2013		17.0	1007	77.9	1.3	209	22.5
100	6/14/2013		16.1	1009	65.4	0.6	181	0.0
101	6/15/2013		17.2	1005	63.1	1.4	209	0.0
102	6/16/2013		17.7	1007	63.9	0.7	226	0.0
103	6/17/2013		23.3	1004	64.7	0.9	185	0.0
104	6/18/2013		27.2	1005	61.3	0.4	178	0.0
105	6/19/2013		26.9	1003	67.8	1.9	244	0.0
106	6/20/2013		20.5	1003	78.5	1.0	187	34.6
107	6/21/2013		19.0	1005	69.8	1.6	196	0.3
108	6/22/2013		19.0	1004	67.8	1.8	198	1.5
109	6/23/2013		16.2	1005	69.9	1.6	216	0.9
110	6/24/2013		14.2	1013	76.9	1.8	255	1.5
111	6/25/2013		13.4	1018	71.1	1.8	259	0.3
112	6/26/2013		13.9	1018	70.9	1.1	250	9.8
113	6/27/2013		13.2	1014	78.5	0.7	230	3.9
114	6/28/2013		14.1	1010	86.1	0.3	174	16.4
115	6/29/2013		14.8	1012	73.9	2.6	269	1.8
116	6/30/2013		17.7	1012	66.4	0.6	198	0.0
117	7/1/2013		18.8	1008	74.9	0.7	215	21.0
118	7/2/2013		21.6	1003	62.7	0.6	183	0.3
119	7/3/2013		17.5	1004	85.6	0.2	213	16.0
120	7/4/2013		20.0	1014	71.1	0.9	232	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 5 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
121	7/5/2013	Bornheim, Summer	19.8	1020	74.4	0.3	222	0.0
122	7/6/2013		22.4	1020	65.4	1.0	191	0.0
123	7/7/2013		23.1	1020	58.8	1.2	218	0.0
124	7/8/2013		23.0	1019	59.6	1.4	214	0.0
125	7/9/2013		23.4	1014	59.4	1.4	237	0.0
126	7/10/2013		19.5	1012	62.6	3.5	261	0.0
127	7/11/2013		15.7	1013	70.1	1.7	215	0.0
128	7/12/2013		16.5	1013	70.8	1.2	250	0.0
129	7/13/2013		17.7	1014	68.3	1.1	241	0.0
130	7/14/2013		18.9	1014	69.1	1.7	249	0.0
131	7/15/2013		21.3	1013	62.9	0.8	188	0.0
132	7/16/2013		22.5	1013	58.8	0.8	184	0.0
134	7/17/2013		23.2	1014	59.0	1.2	218	0.0
134	7/18/2013		24.5	1014	56.8	1.7	224	0.0
135	7/19/2013		23.5	1013	58.3	2.3	241	0.0
136	7/20/2013		21.1	1011	68.5	1.3	226	0.0
137	7/21/2013		25.3	1009	57.4	1.1	155	0.0
138	7/22/2013		27.6	1006	52.2	0.9	167	0.0
139	7/23/2013		25.5	1004	62.0	0.6	159	0.0
140	7/24/2013		21.7	1006	78.7	0.7	213	3.6
141	7/25/2013		22.5	1006	81.7	0.7	145	15.1
142	9/4/2013	Cologne, Autumn	22.5	1012	64.5	0.2	159	0.0
143	9/5/2013		25.5	1004	56.3	0.2	181	0.0
144	9/6/2013		24.3	1004	62.8	0.2	180	0.3
145	9/7/2013		17.7	1010	81.6	0.1	170	35.8
146	9/8/2013		14.4	1012	86.6	0.0	172	2.1
147	9/9/2013		14.9	1007	73.6	0.5	186	4.2
148	9/10/2013		13.6	1005	79.7	1.0	188	11.9
149	9/11/2013		14.0	1006	86.5	0.1	178	10.9
150	9/12/2013		15.2	1011	82.9	0.1	191	2.7

Annex 6 **Ambient conditions at the field test sites** **Page 6 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
151	9/13/2013	Cologne, Autumn	17.1	1010	76.6	0.1	190	3.0
152	9/14/2013		15.5	1005	82.7	0.2	182	4.1
153	9/15/2013		14.8	1000	74.7	0.4	198	11.6
154	9/16/2013		12.3	995	67.6	0.4	191	1.2
155	9/17/2013		12.3	992	79.7	0.5	196	7.5
156	9/18/2013		12.3	998	84.1	0.0	182	0.9
157	9/19/2013		14.1	1005	75.0	0.4	181	3.0
158	9/20/2013		14.5	1013	78.7	0.1	189	0.0
159	9/21/2013		14.4	1020	77.8	0.0	188	0.0
160	9/22/2013		16.9	1020	81.0	0.0	182	0.0
161	9/23/2013		15.9	1015	78.0	0.0	187	0.0
162	9/24/2013		15.8	1007	76.9	0.1	191	0.0
163	9/25/2013		16.8	1004	80.1	0.0	197	0.0
164	9/26/2013		13.2	1009	77.2	0.1	188	0.0
165	9/27/2013		12.5	1008	71.6	0.1	199	0.0
166	9/28/2013		14.0	1004	64.8	0.4	164	0.0
167	9/29/2013		13.4	1002	61.9	0.6	187	0.0
168	9/30/2013		13.9	1003	62.8	0.2	177	0.0
169	10/1/2013		15.2	1006	57.0	0.4	153	0.0
170	10/2/2013		no weather data available					
171	10/3/2013							
172	10/4/2013							
173	10/5/2013							
174	10/6/2013							
175	10/7/2013							
176	10/8/2013							
177	10/9/2013		12.7	1005	84.1	0.2	207	6.9
178	10/10/2013		7.8	1003	86.9	0.1	180	7.1
179	10/11/2013		6.5	1009	89.2	0.0	190	6.3
180	10/12/2013		7.1	1009	88.6	0.1	187	2.7

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No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
181	10/13/2013	Cologne, Autumn	9.5	1009	78.9	0.5	194	0.0
182	10/14/2013		12.2	1004	82.3	0.3	183	12.4
183	10/15/2013		10.7	1002	82.5	0.2	187	10.6
184	10/16/2013		11.8	1006	83.2	0.1	206	0.6
185	10/17/2013		13.0	1008	83.5	0.4	191	0.3
186	10/18/2013		12.9	1009	79.7	0.0	166	0.0
187	10/19/2013		16.8	1004	78.4	0.1	184	0.6
188	10/20/2013		15.7	1006	81.9	0.3	174	3.3
189	10/21/2013		16.5	1005	79.6	0.2	195	0.0
190	10/22/2013		18.3	998	79.6	0.3	198	9.2
191	10/23/2013		16.6	1003	76.4	0.9	206	0.3
192	10/24/2013		14.3	1009	79.3	0.1	185	0.6
193	10/25/2013		15.9	1005	87.5	0.0	163	8.9
194	10/26/2013		18.1	1002	77.0	0.6	185	2.4
195	10/27/2013		15.7	996	69.5	2.5	217	4.8
196	10/28/2013		13.7	997	68.9	2.2	212	2.4
197	10/29/2013		10.5	1009	73.2	1.0	215	0.3
198	10/30/2013		8.2	1018	76.7	0.2	188	0.0
199	10/31/2013		11.1	1013	71.9	0.3	190	0.3
200	11/1/2013		10.0	1002	89.8	0.0	180	20.9
201	11/2/2013		11.9	995	86.3	0.2	195	7.7
202	11/3/2013		10.2	992	72.9	1.9	210	1.2
203	11/4/2013		8.9	986	82.5	0.7	186	15.1
204	11/5/2013		8.4	989	81.4	0.6	185	13.4
205	11/6/2013		13.5	997	80.2	1.1	202	8.3
206	11/7/2013		12.4	1001	89.2	0.3	174	21.2
207	11/8/2013		11.1	1000	77.6	0.9	197	1.5
208	11/9/2013		8.7	998	77.8	0.7	193	2.7
209	11/10/2013		5.4	1016	85.6	0.0	177	2.7
210	11/11/2013		6.0	1020	81.3	0.0	196	0.0

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No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
211	11/12/2013	Cologne, Autumn	7.8	1021	89.1	0.0	163	3.6
212	11/13/2013		4.4	1018	89.5	0.0	192	0.0
213	11/14/2013		7.0	1015	84.0	0.1	186	0.3
214	11/15/2013		3.4	1024	84.9	0.1	183	0.0
215	11/16/2013		2.6	1020	87.8	0.0	195	0.3
216	11/17/2013		5.0	1009	85.5	0.1	192	0.0
217	11/18/2013		6.0	1001	76.6	0.1	191	0.0
218	11/19/2013		5.7	1000	84.8	0.2	163	0.0
219	11/20/2013		5.2	992	71.0	0.2	185	0.9
220	11/21/2013		4.4	999	78.6	0.8	198	0.9
221	11/22/2013		5.7	1007	80.5	0.2	188	0.0
222	11/23/2013		5.2	1013	84.3	0.2	168	0.9
223	11/24/2013		5.2	1020	82.8	0.2	165	0.9
224	11/25/2013		1.1	1026	88.1	0.1	186	1.2
225	11/26/2013		1.7	1027	88.4	0.0	197	0.3
226	11/27/2013		4.5	1025	86.9	0.0	186	2.1
227	11/28/2013		7.6	1021	82.4	0.2	177	0.3
228	11/29/2013		6.2	1009	84.2	0.6	171	1.2
229	11/30/2013		4.2	1024	78.9	0.0	191	0.0
230	12/1/2013		no weather data available					
231	12/2/2013							
232	12/3/2013		2.6	1020	82.9	0.0	183	0.0
234	12/4/2013		4.9	1020	86.4	0.1	189	1.8
234	12/5/2013		4.8	1009	76.3	2.3	176	6.8
235	12/6/2013		3.0	1017	80.9	1.1	171	5.1
236	12/7/2013		6.2	1018	85.8	0.1	194	2.1
237	12/8/2013		8.7	1019	77.2	0.9	201	0.0
238	12/9/2013		8.2	1025	78.9	0.3	197	0.0
239	12/10/2013		5.9	1027	87.1	0.1	206	0.0
240	12/11/2013		5.6	1025	87.7	0.6	201	0.0

Annex 6 **Ambient conditions at the field test sites** **Page 9 of 10**

No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
241	1/13/2014	Cologne, Winter	6.8	1002	82.5	0.0	210	0.0
242	1/14/2014		6.3	1001	77.9	0.3	203	0.0
243	1/15/2014		5.3	998	86.2	0.3	205	3.9
244	1/16/2014		7.8	993	80.2	0.2	220	0.0
245	1/17/2014		8.2	994	72.4	0.3	209	0.3
246	1/18/2014		6.5	992	75.3	0.7	202	0.0
247	1/19/2014		5.7	994	80.7	0.2	202	0.0
248	1/20/2014		3.8	1000	83.9	0.3	135	0.0
249	1/21/2014		4.0	1005	87.1	0.0	186	0.0
250	1/22/2014		2.7	1006	84.8	0.1	203	0.0
251	1/23/2014		3.8	1004	87.2	0.2	193	8.0
252	1/24/2014		4.1	1010	86.2	0.0	188	0.3
253	1/25/2014		5.0	1004	79.5	1.1	208	6.5
254	1/26/2014		5.1	991	79.6	0.8	207	18.9
255	1/27/2014		4.9	990	75.6	0.8	214	0.3
256	1/28/2014		3.8	992	73.6	0.6	204	0.0
257	1/29/2014		2.6	996	71.0	1.1	198	0.0
258	1/30/2014		2.5	1000	72.6	0.2	194	0.0
259	1/31/2014		5.7	996	70.7	0.6	204	0.3
260	2/1/2014		5.5	997	81.6	0.5	214	3.6
261	2/2/2014		4.2	1008	76.5	0.5	207	0.0
262	2/3/2014		4.9	1001	77.9	0.7	203	0.0
263	2/4/2014		5.9	998	75.1	0.3	204	0.0
264	2/5/2014		7.4	992	73.8	1.2	209	0.0
265	2/6/2014		10.2	989	66.1	1.6	210	5.1
266	2/7/2014		7.6	991	72.7	2.4	216	7.7
267	2/8/2014		7.7	984	70.0	1.9	219	0.6
268	2/9/2014		5.9	989	67.2	1.7	221	0.0
269	2/10/2014		5.5	990	75.2	0.3	205	1.8
270	2/11/2014		6.7	997	70.1	1.1	217	2.4

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No.	Date	Test site	Ambient temperature (AVG) [°C]	Ambient pressure [hPa]	Rel. air humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
271	2/12/2014	Cologne, Winter	7.1	994	68.5	1.7	224	0.3
272	2/13/2014		5.2	992	80.2	0.5	201	8.0
273	2/14/2014		8.6	992	74.6	1.4	217	9.5
274	2/15/2014		10.0	995	65.2	3.0	210	1.5
275	2/16/2014		7.4	1004	71.7	0.8	220	0.6
276	2/17/2014		4.2	1008	82.8	0.0	212	0.0
277	2/18/2014		7.4	1005	76.0	0.1	214	1.8
278	2/19/2014		8.3	1006	77.5	0.3	208	0.0
279	2/20/2014		9.7	999	78.3	0.9	209	5.4
280	2/21/2014		5.8	1002	77.2	0.6	207	0.9
281	2/22/2014		5.5	1010	76.2	0.7	211	1.8
282	2/23/2014		7.3	1011	70.4	0.5	206	0.0
283	2/24/2014		12.9	1005	53.2	0.5	203	0.0
284	2/25/2014							
285	2/26/2014		no weather data available					
286	2/27/2014							
287	2/28/2014		6.6	994	75.3	0.3	199	0.0
288	3/1/2014		5.8	995	78.1	0.1	223	0.6
289	3/2/2014		6.1	990	69.9	0.7	199	0.0
290	3/3/2014		6.2	988	71.5	0.6	187	0.0
291	3/4/2014		7.9	1002	70.6	0.1	199	0.0
292	3/5/2014		4.6	1018	81.8	0.2	146	0.0
293	3/6/2014		7.6	1020	67.2	0.2	191	0.0
294	3/7/2014		11.1	1021	63.3	0.1	178	0.0
295	3/8/2014		12.4	1022	56.2	0.5	202	0.0
296	3/9/2014		13.1	1020	46.8	0.3	164	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 45). 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 46 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.

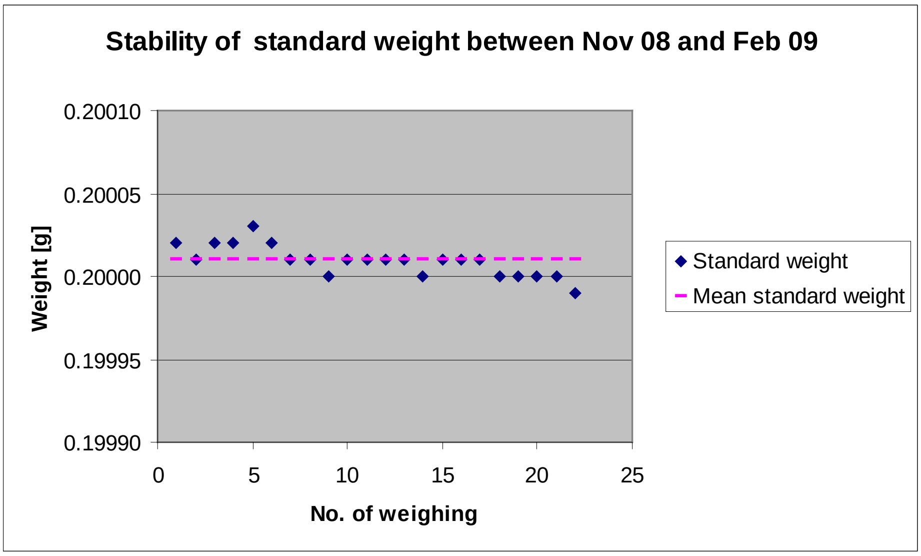

Figure 45: Stability calibration weight

Table 22: 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

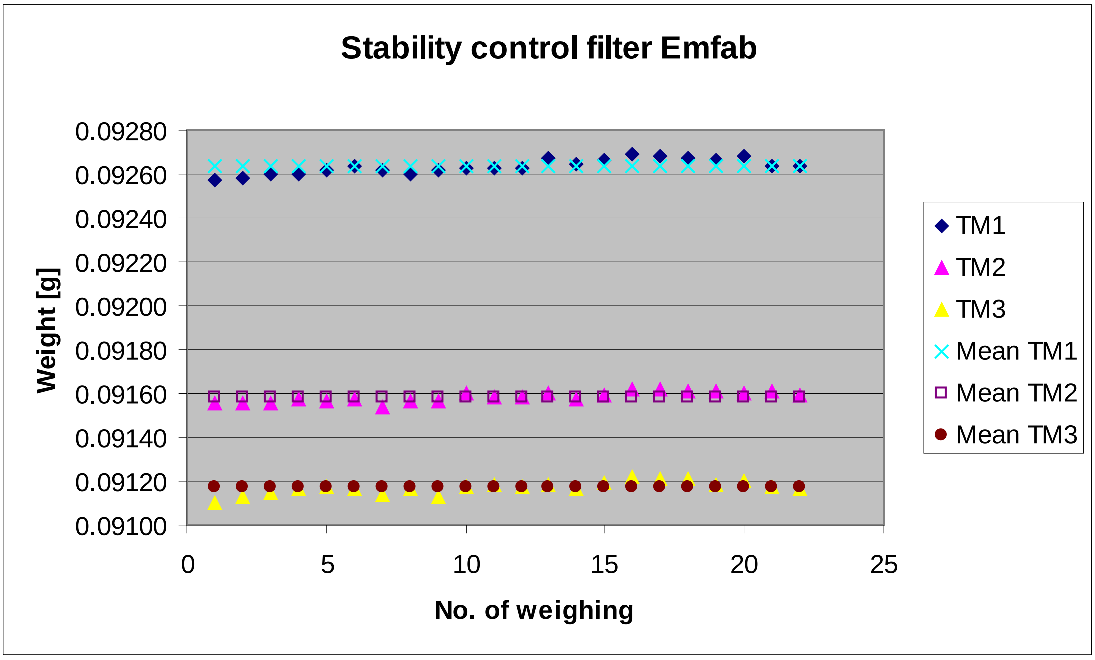

Figure 46: Stability of the control filter

Table 23: 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
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